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ORDINATION AND CLASSIFICATION OF IMMATURE FOREST ECOSYSTEMS IN THE COWICHAN LAKE AREA, VANCOUVER ISLAND

by

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B.Sc.F., University Of New Brunswick, 1978

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

(FACULTY OF FORESTRY)

We accept this thesis as conforming

to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

June 1984

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Date: June 15, 1984

Abstract

The objectives of this study included: 1) classification of immature forest ecosystems surrounding Cowichan Lake on Vancouver Island, 2) investigation of relationships between floristic composition, selected site and soil properties, and ecosystem productivity as estimated by site index (m/100 years) of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), and 3) evaluation of the usefulness of several multivariate analysis techniques for deriving the classification and investigating relationships. Methods employed included: 1) standard methods used in the biogeoclimatic ecosystem classification system as applied by the B.C. Ministry of Forests, and 2) multivariate analysis techniques, including ordinations (polar,reciprocal averaging, and detrended correspondence analysis) and cluster analysis of the vegetation data, and stepwise discriminant analysis of edatopic indicator species groups (EISG's), and site and soil properties.

The classification was finalized after consideration of the environment data and results of multivariate analyses (particularly reciprocal averaging and detrended correspondence analysis) applied to the vegetation data. Three orders, five alliances, and six biogeocoenotic associations (BA's) were established. An objective, repeatable procedure for extracting characteristic combinations of species from summary vegetation tables was developed and applied. A comparison of the summary vegetation tables of three of the immature Cowichan Lake associations to the summary vegetation tables of three

(climatically and edaphically) similar mature associations revealed strong similarities in understory species abundance and composition. This suggested that understory plant communities of the immature forest ecosystems had sufficiently stabilized to permit successful identification of probable climax associations.

Estimated hygrotope and trophotope values of each plot suggested that axis 1 of the floristic data ordinations corresponded to a complex environmental gradient related to increasing availability of soil moisture and nutrients. This suggestion was supported by the results of indicator plant analysis, and by trends in a limited number of quantitatively assessed site morphological and soil physical and chemical properties.

Discriminant analysis of EISG's and several site and soil properties selected linear combinations of variables which best characterized differences between the BA's. Soil properties proved more successful than site properties for this purpose. In addition, classification functions were produced which could be used to classify plots not used in the original analysis.

Variation in site index values suggested an increase in productivity from BA's 2 to 4 but no differences between BA's 4 and 5. An investigation of relationships between axis 1 scores of detrended correspondence analysis of the floristic data, canonical variable 1 from the discriminant analysis of soil properties, and site index of Douglas-fir suggested that (for the forty-one intermediate plots in BA's 2 to 5): 1) 83% of the

variation in understory vegetation was related to differences in the selected soil properties, 2) 78% of the variation in site index was related to changes in understory species abundance and composition, and 3) 71% of the variation in site index was related to changes in the selected soil properties.

Mineral soil mineralizable N and exchangeable Ca values were highest, and C:N ratios lowest on the most productive sites. In addition, most of these sites had a mull humus form. This suggested that increases in site productivity were at least partially due to higher N availability. The higher levels of soil Ca on the most productive sites suggested more rapid nitrification rates and more nitrate, a form of N often found to be associated with the best growth of Douglas-fir.

It was concluded that multivariate analysis techniques (particularly reciprocal averaging, detrended correspondence analysis, and discriminant analysis) were useful not only for classification purposes, but also for the investigation of trends in environmental properties and site productivity. These techniques provide a rapid, computer-assisted approach to data synthesis, and a more objective basis for interpretations. It was recommended that proponents of the biogeoclimatic system make greater use of these techniques in future studies.

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Acknowledgement

I would especially like to thank my advisor, Dr. K. Klinka, for his guidance, encouragement and support throughout the study, and my committee members, Dr. J.P. Kimmins and Dr. G.F. Weetman, for their advice.

I would also like to thank Mr. I. Carlsson, Director of the B.C. Ministry of Forests Cowichan Lake Research Station, for providing lodging and laboratory facilities during the sampling stage, and P. Courtin, R. Green, R. Laird, and G. Shishkov of the B.C. Ministry of Forests Research Branch for their help during the sampling and data analysis stages.

Special thanks are also extended to Dr. V.J. Krajina and F. Boas who helped with plant identification; to J. Emanuel and B. Wong for advice regarding computer analysis; to W. Hamby who performed the mineralizable N determination; and to Dr. L.M. Lavkulich, Chairman of the Soil Science Department, who gave the author access to the laboratory facilities required to perform the soil chemical analyses.

Finally, I am grateful for the financial support provided by the Natural Sciences and Engineering Research Council of Canada, and the Faculties of Forestry and Graduate studies at the University of British Columbia.

I. INTRODUCTION

1.1 RESEARCH NEEDS

Several approaches for classifying forest land have been applied in British Columbia. These approaches have been discussed in Drew and Kimmins (1977), Jones (1978), Kimmins (1979), and Beese (1981). Of these, the system of biogeoclimatic ecosystem classification developed by Dr. V.J. Krajina and his students at the University of British Columbia has received the widest use in B.C.. In addition to B.C., this system has also been applied in other parts of the world, including the Hawaiian Islands (Krajina, 1963), Hokkaido Island, Japan (Kojima, 1979), and the province of Alberta (Kojima and Krumlik, 1979; Kojima, 1980).

Since 1975, the British Columbia Ministry of Forests (MOF) has applied this system to gain a comprehensive understanding of forest ecosystems in a systematic fashion (Annas, 1977; Schmidt, 1977; Klinka et al., 1980a,1980b). To date, the biogeoclimatic system has provided the ecological framework for a wide variety of applications, including the development of practical guides for tree species selection and prescribed burning (Klinka 1977a, 1977b,1977c; Utzig and MacDonald, 1977; Nuszdorfer and Klinka, 1982), park management (Inselberg et al., 1982), and integrated resource management (Klinka et al., 1980a,1980b). The most current update of work being done by the MOF to refine and apply the biogeoclimatic system is found in the publication "Forest Research Review" compiled annually by the MOF's Research Branch.

In the Vancouver Forest Region, recent work by the MOF has concentrated on refinement of the taxonomic classification of ecosystems at the regional (biogeoclimatic) level. Detailed biogeoclimatic maps which cover the southwestern corner of the B.C. mainland and most of Vancouver Island are now available (Klinka et al., 1979; Courtin et al., 1984). Now that the regional framework is fairly well established, there is a need to more fully determine the range and properties of ecosystems (biogeocoenoses) occurring within climatically uniform areas (i.e. biogeoclimatic subzones and variants). Thus, there is a need to concentrate research efforts on the more detailed (biogeocoenotic) level.

Many studies at the biogeocoenotic level have already been conducted in the Vancouver Forest Region, but most of these have investigated the properties of mature, old-growth forests. Since forest managers will be increasingly dealing with second-growth forest ecosystems, there is a need to study these second-growth forest ecosystems and, more specifically, determine their properties and classification status.

Klinka et al. (1979) noted that in the southeastern part of Vancouver Island, there is a close relationship between the climate of the East Vancouver Island variant of the Drier Maritime Coastal Western Hemlock subzone (CWHa2) and the Nanaimo and Georgia variant of the Wetter Maritime Coastal Douglas-fir subzone (CDFb1). They also noted that, in addition to this lack of distinctly different climates, the presence of rich parent materials, and extensive disturbance of the forest cover makes the classification and mapping of low elevation ecosystems difficult. Consequently, there is a particular need to increase the present sampling base on southeast Vancouver Island and determine the classification status of immature forest ecosystems in this area.

Jones (1978) criticized the techniques used for data analysis and synthesis in the biogeoclimatic system. He stated that they are not always consistent or repeatable. There is indeed an almost complete reliance on a relatively subjective (environment and vegetation) table rearrangement process for recognition of syntaxa at the biogeocoenotic level. The application of more objective, computer-assisted methods in data synthesis and taxa formation is needed to increase the reproducibility of results and also to handle increasingly larger data sets. Thus, in addition to the need to classify second-growth forest ecosystems and determine their properties, there is also a need to further develop classification methods and, in particular, to make these methods more objective.

One property of particular concern to forest managers is the productivity of different tree species in second-growth forest ecosystems. Nuszdorfer and Klinka (1982) noted that this information is required for the refinement of tree species selection guides. Thus, there is a need to determine the productivity of different tree species in these second-growth forest ecosystems.

Within uniform climatic regions, the supply of available soil water and nutrients strongly influences the nature and distribution of ecosystems (Krajina *et al*., 1982), and ecosystem productivity (Ralston, 1964; Carmean, 1975; Pritchett, 1979; and Spurr and Barnes, 1980). Proponents of the biogeoclimatic system have recognized this fact and have developed the concepts of <u>soil moisture regime</u> (SMR) or hygrotope, and <u>soil nutrient regime</u> (SNR) or trophotope from ideas originally proposed by Pogrebnyak (1930). Krajina *et al*. (1982) defined SMR as "available soil water over a long period of time", and SNR as "available soil nutrients over a long period of time". In the biogeoclimatic system, eight qualitative hygrotope classes (0-7) are used to characterize the SMR, and five qualitative trophotope classes (A-E) are used to characterize the SNR of forest ecosystems. The hygrotope and trophotope class of a particular ecosystem is currently estimated on the basis of a number of field-assessed site and soil properties (Nuszdorfer and Klinka, 1982). Despite the proven usefulness of these concepts for an approximate, management-oriented characterization of SMR and SNR, Kimmins (1984) noted that the lack of absolute quantitative values has been criticized by several authors. Nuszdorfer and Klinka (1982) recognized that these hygrotope and trophotope classes must be more precisely defined. But, before this can occur, those soil properties which control and/or affect SMR and SNR must be more precisely quantified. Thus, <u>there is a need to more precisely quantify those soil properties which control and/or affect SMR and SNR</u>.

1.2 COWICHAN LAKE STUDY

During the summer of 1981, a study was initiated in immature forest ecosystems surrounding Cowichan Lake on Vancouver Island, within the limits of the CWHa2. The purpose of this study was to classify these ecosystems and investigate relationships among several important ecosystem attributes, i.e. floristic composition, site properties, soil physical and chemical properties, and ecosystem productivity.

The main objective of this study was to develop a classification of these forest ecosystems which could provide a basis for ecosystem mapping and more site-specific forest management. This classification was to follow the approach used in the biogeoclimatic ecosystem classification system as applied by the MOF. Another objective was to evaluate the usefulness of several multivariate analysis techniques as aids for developing the classification, and for investigating the complex relationships which characterize these forest ecosystems.

Specific objectives of this study included:

1. Apply reciprocal averaging, detrended correspondence analysis, polar ordination, and cluster analysis as means for providing a more objective basis for data synthesis and syntaxa formation.
2. Classify the immature forest ecosystems to the level of biogeocoenotic association (BA).
3. Develop an objective, repeatable procedure for extracting from summary vegetation tables the Characteristic Combinations of Species (CCS) for orders, alliances, and

associations.

4. Determine the degree of floristic similarity between the immature Cowichan Lake associations and, climatically and edaphically similar, mature associations.
5. Using indicator plant analysis, determine whether the established syntaxa differ in terms of edatopic indicator species groups (EISG).
6. Quantify (in terms of $kg \bullet ha^{-1}$) a number of soil properties which affect the SMR and SNR, and determine whether the established syntaxa differ in terms of these measured soil properties.
7. Apply discriminant analysis to environmental attributes of the ecosystems to determine which are of greatest importance for differentiating between the BA's.
8. Using the results of multivariate analyses, investigate the possibility of corresponding trends in floristic composition and soil properties.
9. Determine site index (SI) of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) in these immature forest ecosystems and use this estimate of site productivity to investigate differences in productivity between the established syntaxa.
10. Using the results of floristic data ordinations, investigate possible relationships between changes in SI and understory species composition.
11. Using the results of discriminant analysis of soil properties, investigate possible relationships between

changes in SI and the soil properties which are most useful for characterizing differences between the BA's.

12. Investigate relationships between SI of Douglas-fir, several indices of soil N (total N, mineralizable N, and C:N ratios) and Ca (exchangeable Ca) status, and site humus form.

This report will begin with a general overview of forest land classification. This will be followed by a description of the study area, and a description of the methods used for data analysis and synthesis. The results will then be presented and discussed. Finally, the report will end with a brief summary and conclusions.

II. FOREST LAND CLASSIFICATION

2.1 THE NEED FOR FOREST LAND CLASSIFICATION

Long-term projections indicate an increased demand for forest products (Kimmins, 1977a). This increased demand will be accompanied by continuing losses of the forest land base to other uses (eg. agriculture, parks, urban and industrial expansion, etc.). Thus, the challenge facing forest managers is to intensify forest management in order to maximize production on an ever-shrinking forest land base.

An important consideration must be addressed before intensive management practices can be implemented. Different portions of the forest landscape possess different properties. Because of this, they often show different responses to a given management practice. Certain management practices which have been applied ubiquitously, without regard to differences in site properties, have often produced undesirable results (Jones, 1978). These results have included degradation of forest land and subsequent impairment of its production potential, a situation which is no longer tolerable in view of the need to maximize productivity. Forest managers must therefore have the ability to predict the outcome of various management practices on a site-specific basis. The only way to do this is to study the properties of the full range of sites occurring in a given area. This information must then be organized according to some framework which allows it to be utilized and communicated efficiently. Such a framework is provided by forest land classification (Kimmins, 1977b; Klinka et al., 1979).

2.2 THE NEED FOR AN ECOSYSTEM APPROACH

Rowe (1971) and Kimmins (1977b) stressed that there is no single forest land classification system that is "best" or "correct" under all circumstances. The correct system for any given purpose is that which achieves the required objectives in the most direct and inexpensive manner.

If the purpose of the system is simply to stratify the forest landscape into units which are similar in their ability to produce timber crops, then a simple method which stratifies on the basis of one or a few selected properties may be entirely adequate. Several methods have been developed for this purpose. These include direct determination of tree volume increment, and indirect approaches based on tree height growth (site index), presence and abundance of diagnostic understory plants, a consideration of factors of the physical environment such as climate, soils and topography, and finally various combinations of these methods. The application of these methods has been discussed by several authors (Ralston, 1964; Jones, 1969; Husch, et al., 1972; Carmean, 1975,1977; Daubenmire, 1976; Damman, 1977,1979; Daniel et al., 1979; Kreutzer, 1979; Pritchett, 1979; Havel, 1980a,1980b; Spurr and Barnes, 1980; Hagglund, 1981; Kilian, 1981; McRae and Burnham, 1981; Tesch, 1981; Zonneveld, 1981; Jahn, 1982; Kimmins, 1984). Papers dealing specifically with Canada include those by Burger (1972) and Grandtner and

Vaucamps (1982).

If, as is most often the case today, the purpose of the forest land classification system is to rate sites in terms of their "potential for withstanding recreational impacts, importance as wildlife habitats, yield of high quality water, hazards in road or engineering structures, and other uses as well as their suitability for timber production" (Pritchett, 1979), then a more complex, holistic approach is needed (Rowe, 1971). Admittedly, most forest managers are primarily concerned with understanding and reliably predicting plant growth (Klinka et al., 1979). But, they must also be concerned with these other aspects of forest management. Because of the complexity inherent in this objective, the forest manager must consider a large number of factors and their interactions (Kimmins, 1977b). As Kimmins (1977b) noted, the more factors we study and understand, the greater will be our ability to make accurate predictions about the outcome of various management strategies. The forest manager must therefore direct his (her) attention to the only true "level-of-integration" above that of the individual organism, the forest ecosystem (Rowe, 1961). It is necessary to adopt an approach to forest land classification which considers the full range of ecological factors affecting forest ecosystems, in other words, it is necessary to adopt an ecosystem approach (Kimmins, 1977b; Bailey, 1981).

Several recent symposia have stressed the need for an ecosystem approach to forest land classification (Thie and Ironside, 1976; Drew and Kimmins, 1977; Lund et al., 1978;

Rubec, 1979; and Laban, 1981), and several ecosystem classification systems have been developed. These are reviewed in Gimbarzevsky (1978) and Bailey (1981). Wiken (1980) presents a summary of ecological classification studies done in Canada.

2.3 CONCEPTUAL BASIS

The philosophy, objectives, and principles of classification have been discussed by several authors (Cline, 1949; Gilmour, 1951; Sokal, 1974; Bailey et al., 1978; Whittaker, 1978; Zonneveld, 1981; and Gauch, 1982). Classification is a prerequisite for all conceptual thought. Its primary function is to construct classes (taxa) about which we can make generalizations (Gilmour, 1951). Classification involves the ordering or arrangement of a relatively large number of "objects" into a smaller number of classes on the basis of their similarity in selected properties (Cline, 1949). This process creates order out of factual chaos and reduces to a workably small number the total number of things we must deal with and remember (Bailey et al., 1978).

Properties used to differentiate between classes are called differentiating characteristics (Cline, 1949), the product of the classification process is a classification system, and the subsequent assignment of unclassified "objects" to the established classes is called identification (Sokal, 1974). Since classification is an abstract process, any classification system is more or less imposed and not entirely natural. Miles

(1979) stated that a classification system is only a working hypothesis, an "ad hoc fiction", but that such systems are necessary for the advancement of scientific understanding.

2.4 THE CONTINUOUS NATURE OF ECOSYSTEMS

Rowe (1960) suggested that the ease with which a classification system can be developed depends on the nature of the "objects" to be classified. He stated that these "objects" may be "self-evident entities" (eg. individual plants or animals) which may be classified relatively easily, or they may be "blending, coalescent, patterned phenomena" (eg. climates or soils) which are more difficult to classify. In ecosystem classification, the objects which are studied and classified (forest ecosystems) belong to the latter group.

The term "ecosystem" was introduced by Tansley (1935). He defined an ecosystem as the basic unit of nature, composed of living organisms and inorganic "factors", and characterized by constant interactions between these components. Tansley's definition does not consider the question of scale. According to his view, an ecosystem can include any sized system from a small pond (or even smaller entities) to the entire earth system (Kojima, 1981).

Because of the open nature of the ecosystem concept, Malcolm (1981) noted that, in theory, it is difficult to delineate an individual ecosystem either physically or in a classification. But, he also noted that, "in practice, it is usually possible to demarcate ecological units which are sufficiently discrete for separate description and mapping". To do this requires a narrower definition of a forest ecosystem which will permit forest managers to put limits on its areal extent. Such a definition, which considers forest ecosystems as concrete, three-dimensional bodies at a scale useful for forest management, has been provided by Sukachev (Sukachev, 1944,1960; Sukachev and Dylis, 1964a,1964b). Sukachev proposed the term forest biogeocoenose for such an entity, and defined it as "that part of the forest uniform over a certain area in the composition, structure, and properties of its components, and in the interrelationships among them; that is, uniform in the plants, animals, and microorganisms inhabiting it, in the parent material, in its hydrological, microclimatic (atmospheric), and soil environments and the interactions among them; and in the kind of matter and energy exchange between these components and other natural phenomena in nature" (translation in Klinka *et al*. (1979) of definition in Sukachev and Dylis (1964a)). In summary then, a forest biogeocoenose is a concrete entity, a plot on the earth's surface having a uniform biocoenose (vegetation, animals, and microorganisms), and ecotope (climate and soil). The terms "forest ecosystem" and "forest biogeocoenose" will both be used in this report. Unless stated otherwise, their use will always imply the narrower definition of the latter.

Lateral boundaries between adjacent forest biogeocoenoses can be either distinct or gradual. This depends on the abruptness of the differences in the structure and properties of ecosystems (Klinka et al., 1979; Inselberg et al., 1982). This problem of intergrading types has been addressed by several authors, including Cline (1949), Whittaker (1956), Rowe (1960), Maarel (1975), and Miles (1979). Rowe (1960) stated that, no matter how they are defined, on systematic examination forest ecosystems are found to be intergrading rather than discrete entities. He stated that information about forest ecosystems is not "self-ordering". He suggested that forest ecosystems can be considered in terms of gradient patterns, that these gradients can be divided, and the segments grouped into classes in the same way that discrete objects are organized. He also stated that, for forest management purposes, the classification of forest ecosystems into "types" has useful aspects and that this is sufficient justification for doing it.

Whittaker (1956), Maarel (1975), and Miles (1979) discussed the problems of typology as it relates to vegetation classification. However, their observations apply equally well to forest ecosystem classification. Miles (1979) stated that, in order to study any biological phenomena, it is necessary to identify small units which it is possible to study but, since vegetation shows endless variation in composition in both time and space, different units will inevitably intergrade. Whittaker (1956) noted that "because of environmental interruptions and some relative discontinuities inherent in vegetation itself", vegetation patterns may be considered "a complex mixture of continuity and relative discontinuity".

However, Maarel (1975) noted that a typological concept does not necessarily imply a recognition of discontinuity. He referred to the ideas of Tuxen (1955) when he stated that types are "ideal concepts" which are recognized in an empirical way from "correlation concentrates" (groups of correlated characters). Maarel (1975) also stated that "that which is evident of a type is always its nucleus, not its periphery; types are not pigeonholes but foci in a field of variation". This concept of a "nucleus" is similar to the "modal individual" concept used in soil classification (Cline, 1949). As Cline (1949) noted, every class is typified by its modal individual, and class membership is determined on the basis of relative similarity to the modal individual. Pierpoint (1981) has recently discussed the application of the modal individual concept in ecosystem classification.

In summary then, it is recognized that forest ecosystems intergrade in a more or less continuous fashion. However, for practical management purposes, it is necessary to divide the forest landscape into small units so that we may study their properties and classify them. The units so formed may be natural, i.e. where obvious discontinuities exist between forest ecosystems (a relatively uncommon occurrence). If no obvious discontinuities are apparent, it may be necessary to impose divisions between intergrading types. This process is entirely justifiable for practical purposes. However, if it is to be repeatable by other workers, so that they arrive at similar units, it is necessary to precisely define what criteria were used to subdivide the gradients.

2.5 THE APPLICATION OF ECOSYSTEM CLASSIFICATION

The application of ecosystem classification in forest management requires two distinct steps. The first step involves a taxonomic (natural, objective) classification of ecosystems, and the second step involves an interpretive (subjective, technical, use) classification (Klinka *et al*., 1979; Wiken, 1980). This distinction is similar to that used in soil classification (Cline, 1949; Lavkulich, 1972).

The taxonomic classification is preceded by "an independent scientific description of the ecosystem complex" (Kilian, 1981). The properties of the full range of ecosystems occurring in the area of interest are determined by observation and measurement. Classes are then formed by grouping ecosystems which are similar in selected properties. The ecosystem classes (types) are then named, defined, and organized to produce the basic taxonomic classification system. Since factors which control the properties and distribution of ecosystems vary with the scale of observation (Damman, 1977,1979; Bailey, 1981; Kilian, 1981; Malcolm, 1981), the basic taxonomic classification should have a hierarchical structure which emphasizes different ecosystem properties at different levels. Malcolm (1981) stated that the essential features of any classification of forest ecosystems have to be based on the recognition of two main environmental gradients, i.e. climate, expressed in terms of site heat and water balances, and the rootable volume of soil which affects soil moisture and nutrient status. Damman (1977,1979) stated that both these gradients are reflected in properties of the vegetation such as physiognomy and floristic composition. Kilian (1981) stated that a two level system is needed, and that such a system should stratify climate (as indicated by regional plant communities) at the higher (regional) level, and soil, landform, and vegetation types at the lower (local) level. The biogeoclimatic system used in British Columbia recognizes this need for a hierarchical structure which emphasizes different properties at different levels. The actual properties used will be discussed in the following section.

The taxonomic classification groups ecosystems without regard to practical application, and often results in a relatively complex system with numerous taxa. Many of these taxa may show a similar response to a given management regime and thus, for management purposes, may be grouped into a smaller number of management units (Klinka et al., 1979; Klinka et al., 1980a,1980b). This second step, the production of the interpretive classification, involves a determination of the suitability of the ecological units for different kinds of land use (land evaluation), and includes not only environmental, but also technical, economic, and social considerations (Kilian, 1981). Several different interpretive classification systems can be developed once the basic taxonomic system has been established. If the basic system is truly ecological in nature, it should be useful for any possible combination of forest management objectives.

For practical management purposes, it is often useful to delineate on maps, the units established in the classification. This mapping procedure may involve the delineation of the basic ecosystems or the delineation of management units. Since any mapping project is time-consuming and expensive, it may seem desirable to only produce a management unit map to meet immediate needs. However, it must be noted that maps which show the basic ecosystem units can subsequently be used to produce different management unit maps to meet a variety of management objectives, and are thus of lasting value (Daubenmire, 1980).

In summary then, the application of ecosystem classification in forest management usually involves the following steps (modified from Kilian, 1981):

1. a study of the properties of ecosystems as they occur in the field,
2. development of the basic taxonomic ecosystem classification system (grouping ecosystems into several classes based on similarity in observed and measured properties),
3. development of an interpretive classification (grouping into management units those classes of ecosystems which are known (or expected) to show a similar response to a given management regime), and
4. mapping of the ecosystems and/or mapping of the management units.

2.6 THE SYSTEM OF BIOGEOCLIMATIC ECOSYSTEM CLASSIFICATION

2.6.1 Historical Development

The historical development of the biogeoclimatic ecosystem classification system has been discussed by Krajina (1972,1977). The basic framework of the system evolved from a large number of studies done throughout British Columbia during the 1950's and 1960's by Dr. V.J. Krajina and his graduate students. The results of this early work were synthesized and presented in the publication "Ecology of forest trees in British Columbia" (Krajina, 1969).

The biogeoclimatic system has undergone numerous changes during its development. Explanations of the system at various stages of development are found in several publications, including Krajina (1965,1969,1972,1977), Mueller-Dombois and Ellenberg (1974), Kojima and Krajina (1975), Beil et al. (1976), Klinka (1976), Daniel et al. (1979), Klinka et al. (1979), and Pojar (1983). Even today, the system is continually being refined as new and better information is aquired. Most of the recent work in British Columbia has been carried out by staff of the Research Branch of the B.C. MOF (Klinka et al., 1979,1980a, 1980b; Inselberg et al., 1982; and Courtin et al., 1984).

2.6.2 Synecological Integration Levels

In the biogeoclimatic system, information about forest ecosystems is organized in several different ways referred to as "synecological integration levels" (Krajina, 1969,1972,1977). The five basic integration levels include: three taxonomic (biogeoclimatic, biogeocoenotic, and phytocoenotic), one functional, and one interpretive level. The properties used to assess differences and similarities between ecosystems differ with the integration level under consideration.

The three taxonomic levels organize knowledge of the natural properties of forest ecosystems as they occur in the field. It was stated earlier that a forest biogeocoenose is a portion of the earth's surface which is uniform in climate, soils, vegetation (phytocoenose), animals, and microorganisms. In reality, the biogeoclimatic system only considers climate, vegetation, and soils directly. The biogeoclimatic level stratifies the landscape according to differences in macroclimate, the biogeocoenotic level stratifies according to differences in vegetation and soil (Klinka et al., 1979; Kojima, 1981), and the phytocoenotic level organizes knowledge of plant communities according to the hierarchical system of Braun-Blanquet (1928,1932). The phytocoenotic level is useful for communication and comparison of information about plant communities according to a vegetation classification system that is used worldwide, particularly in Europe (Maarel, 1975; Westhoff and Maarel, 1978).

The other two synecological levels are derived once the taxonomic classification has been established. The functional level considers the relationships between biogeocoenotic taxa and ecosystem processes such as productivity and succession. The interpretive level considers the potential response of ecosystems to different management regimes.

2.6.3 Biogeoclimatic Level

Regional climate plays a major role in influencing the nature and distribution of ecosystems (Krajina *et al*., 1982), and is also important in determining ecosystem productivity (Gholz, 1982). Thus, in order to study and compare local ecosystems (forest biogeocoenoses), it is necessary to have a framework which stratifies the landscape into areas which have a relatively uniform climate. By doing so, we can eliminate the contribution that climate has in explaining differences between the local ecosystems. In the biogeoclimatic system, climatic stratification is done at the biogeoclimatic level. Klinka *et al*. (1979), Kojima (1981), and Kimmins (1984) have recently discussed the concepts and methods used at this level. The following discussion is a synthesis of their observations.

To deal with climatic variability, Krajina (1965,1969) proposed a hierarchical system of four biogeoclimatic categories. These categories are, in order of increasingly specific definition of macroclimate, the formation, the region, the zone, and the subzone. Klinka *et al*. (1979) further refined the system by adding an even more specific category, the biogeoclimatic variant, which is a subdivision of a subzone. The number of taxa at each level has varied at different stages during the system's development. In its present form, the system includes five formations, seven regions, and twelve zones (Krajina et al., 1982).

Stratifying the landscape into climatically uniform areas solely on the basis of climatic data would be a difficult and expensive task. The only way to do this accurately would be to collect climatic data over a long period of time, from a large number of climatic stations scattered uniformly throughout the landscape. Since such data are not available, and since it is not even clear which combination of climatic parameters should be used to delineate ecologically meaningful units, the delineation of these climatically uniform areas is usually based on an indirect approach (Damman, 1979; Kilian, 1981). Kilian (1981) suggested using regional climax forest plant communities. Damman (1979) also suggested using properties of the vegetation. A similar indirect approach is used in the biogeoclimatic system. The geographical extent of biogeoclimatic taxa is determined on the basis of the properties and distribution of a particular type of ecosystem, the zonal ecosystem.

Even within a climatically uniform area, there is a mosaic of different forest ecosystems reflecting different combinations of soil moisture regime (SMR) and soil nutrient regime (SNR). If the assessment of differences and similarities in regional climate is to be made on the basis of the properties of a particular ecosystem, then the one in which the effects of climate are most strongly expressed should be selected. It is considered that zonal ecosystems satisfy such criteria. A zonal ecosystem is that forest biogeocoenose which occurs on sites which have an intermediate SMR and SNR (i.e. mesic/mesotrophic (4/C) sites). On other sites, which are wetter, drier, richer or poorer, the influence of climate is not so clearly expressed. Each combination of SMR and SNR will result in a different successional pattern. Ecosystems which are not zonal will reach "edaphic" climaxes, but the zonal ecosystem will reach a "climatic" climax which reflects the "development potential of the regional climate" (Klinka et al., 1979). The relatively stable, self-perpetuating vegetation of a zonal ecosystem which has reached climatic climax is referred to as the "zonal vegetation", and the soil which underlies such an ecosystem is referred to as the "zonal soil". The zonal ecosystem is similar to the "normal site" of Hills (1954), the "reference site" of Damman (1979), and the "ecologically medium site" of Genssler (1982).

In the biogeoclimatic system, differentiating characteristics of biogeoclimatic taxa include not only climatic variables, but also soil and vegetation properties. Differentiating characteristics of biogeoclimatic taxa recognized in British Columbia have been presented in several publications. Characteristics of taxa at the level of formation, region, zone, and subzone are found in Krajina (1965,1969,1972,1976,1980), Beil et al. (1976), Jones and Annas (1978), Kojima (1981), Kimmins (1983), Krajina et al. (1982), and Pojar (1983). Maps showing the distribution of biogeoclimatic zones are found in Krajina (1965,1969,1973), MacMillan Bloedel (1974), Taylor and MacBryde (1977), Jones and Annas (1978), Farley (1979), Kimmins (1983), Krajina *et al*. (1982) and Pojar (1983). To date, only the southwestern portion of the B.C. mainland and most of Vancouver Island have been classified to the level of biogeoclimatic variant. Descriptions of the taxa established and maps showing their distribution are found in Klinka *et al*. (1979) and Courtin *et al*. (1984).

2.6.4 Biogeocoenotic Level

The methodology applied at the biogeocoenotic level has recently been discussed by Klinka *et al*. (1979) and Inselberg *et al*. (1982). At this level, the similarity between ecosystems is assessed on the basis of plants and soil because these two ecosystem properties are readily observed and characterized, and because it is assumed that they integrate and reflect the combined influences of climate, parent material, relief, organisms, and time (Jenny, 1941,1961; Major, 1951).

Biogeocoenotic syntaxa are abstracted through synthesis of releves done on sample plots of a range of forest biogeocoenoses occurring in a climatically uniform area (i.e. a biogeoclimatic subzone or variant). The two main biogeocoenotic categories are: 1) *biogeocoenotic associations* (BA's), which are differentiated mainly on the basis of floristic structure and composition, and 2) biogeocoenotic types (BT's), which are subdivisions of the BA's which have certain environmental (mainly soil) properties in common. It must be stressed that forest biogeocoenoses are the only "real" entities existing in the field, whereas a given BA or BT is but an abstract class formed by grouping biogeocoenoses similar in selected properties.

No two patches of vegetation are ever exactly the same in the combinations and proportions of the different plant species present (Miles, 1979). Despite this fact, Miles (1979) noted that patches of vegetation growing under similar environmental conditions and with similar histories are often so alike in composition that clearly definable "types" may be recognized. This concept has been used in the biogeoclimatic system to define the central unit at the biogeocoenotic level. This central unit is the biogeocoenotic association which is essentially identical to the plant association as defined by Krajina (1960a,1960b): "A plant (forest) association is a definite uniform (homogeneous) phytocoenosis that is in dynamic equilibrium with a certain complex of environmental factors (ecotope); its floristic structure.... lies within limits governed not only by the ecotope.... but also by historical factors....". This definition is more ecosystematic than the definition proposed by Braun-Blanquet (1928,1932) because it explicitly recognizes the importance of the ecotope.

The main criterion for the abstraction of a BA (i.e. similarity of samples in floristic structure and composition) is determined on the basis of a characteristic combination of species (CCS). Inselberg *et al*. (1982) defined a CCS as "a group of plant species common to a particular group of samples but absent in other groups to which it is compared". It is assumed that the plant species included in the CCS (diagnostic species) are precise indicators of the integrated effect of biotic and environmental factors affecting the development of the biogeocoenoses. Daubenmire (1980) supported this view when he stated that the ecological amplitude of a specific plant association is narrower than the amplitude of any of its component species. He also stated that "wherever we find the same combination of species growing together, the same narrow range of plant-growth conditions occurs".

Rowe (1960) argued that it would be unwise to base the identification of equivalent ecosystems solely on the basis of their phytocoenose. He stressed that the concurrent evaluation of ecotope properties is also required. Proponents of the biogeoclimatic system have recognized this need. Soil properties of the biogeocoenoses within a BA may vary, but it is assumed that the overall effect of these differences results in similar quantities of available moisture and nutrients (which is reflected by the similar phytocoenose). Thus, the differentiating characteristics for a BA include not only the CCS but also the estimated values of SMR and SNR (Klinka *et al*., 1979). It is also assumed that, because ecosystems within a BA are influenced by similar environmental conditions, they will undergo a similar secondary succession following disturbance, and should culminate in similar (but not identical) climax ecosystems (Klinka _et_ _al_., 1979; Inselberg _et_ _al_., 1982). As Miles (1979) noted, the pattern and final stage of succession will not be identical, even on similar sites, because any given succession is the result of a large number of probabilities including differences between individual species in their dispersal efficiency, their ability to persist as seeds, and their ability to establish, grow, compete, and reproduce.

Inselberg _et_ _al_. (1982) discussed how BA's may be grouped to form higher levels of generalization (categories) or subdivided to form lower levels. They stated that BA's related on the basis of floristic composition, successional trends, and broad environment-vegetation relationships may be grouped at the phytocoenotic level into the higher synsystematic units of classes, orders, and alliances (Braun-Blanquet, 1928,1932). BA's may also be subdivided into BT's on the basis of similarity in those soil properties which influence SMR and SNR. Properties most frequently used include: texture, coarse fragment content, slope gradient, rooting depth, horizon sequence, humus form, and parent materials. There may also be minor floristic differences in the vegetation of BT's within a BA. As Klinka _et_ _al_. (1979) noted, these BT's are identical to the "type of biogeocoenosis" as defined by Sukachev (1944), and Sukachev and Dylis (1964a,1964b). They are also similar to the "site types" of Hills (1954), and the "land types" of Lacate (1969) which are, according to Damman (1979), areas uniform with respect to soil conditions and characterized by a particular chronosequence of plant communities.

2.6.5 Functional Level

In the biogeoclimatic system, the functional or edatopic level of integration involves the use of edatopic grids (Krajina, 1977). "Edatope" or "edaphotope" refers to a particular combination of hygrotope and trophotope, and an "edatopic" or "edaphic" grid is a two-dimensional representation of these parameters. A total of forty edatopes (eight hygrotope classes (0-7) x five trophotope classes (A-E)) are usually considered when classifying ecosystems. As Klinka (1977b) noted, the edatopic grid was first proposed by Pogrebnyak (1930) and later modified by Krajina (1969). In addition to British Columbia, similar grids have been used elsewhere in North America (Bakuzis and Hansen, 1962,1965; and Pierpoint, 1981).

Edatopic grids are a type of two-dimensional ordination. They provide a visual summary of the distribution of biogeocoenotic taxa (e.g. BA's) occurring within a particular biogeoclimatic subzone or variant. They are useful for demonstrating relationships between taxa. As with any ordination, points (in this case biogeocoenotic taxa) which are closer together on the grids are more similar than points which are further apart.

Edatopic grids have been prepared by Krajina (1969) for each major tree species in each subzone. On these grids, growth class (a range of site index values) and shade tolerance of tree species are indicated for each grid cell (edatope). By comparing the edatopic grids for all tree species growing in a particular subzone, it is possible to predict which species might be the most productive on a given site (i.e. the ones with the highest growth class), and which species could form a part of the climax stand (i.e. the shade-tolerant species). A more complete discussion of the functional level of integration is found in Krajina (1969,1972,1977), Klinka (1977b), Nuszdorfer and Klinka (1982), and Kimmins (1984).

2.6.6 Interpretive Level

As mentioned previously, the application of ecosystem classification involves two steps: 1) establishment of the basic taxonomic classification of ecosystems, and 2) development of an interpretive classification, whereby classes of ecosystems which are expected to show a similar response to a given management regime are grouped into a smaller number of management units. In the biogeoclimatic system, biogeocoenotic taxa are grouped into interpretive classes called treatment units. In British Columbia, very little work has been done to date at this most advanced and applied level of integration. Examples include the work by Klinka (1977b, 1977c) who developed an ecosystem-specific guide for tree species selection and prescribed burning for the Vancouver Forest Region, and the work by Klinka *et al.* (1980a,1980b) who developed an integrated resource management plan for the Koprino River watershed.

III. STUDY AREA

3.1 LOCATION

Sample plots were located on the B.C. Ministry of Forests Cowichan Lake Research Station and at low elevations (below 400 m) surrounding Cowichan Lake. The study area was thus confined to the East Vancouver Island Drier Maritime variant of the Coastal Western Hemlock zone (CWHa2). Surrounding Cowichan Lake, the CWHa2 may extend to an elevation of 700 m (Klinka *et al.*, 1979).

Cowichan Lake is situated in the centre of southern Vancouver Island (Figure 1). It extends from about longitude 124° 02' W to 124° 28' W and latitude 48° 49' N to 48° 55' N.

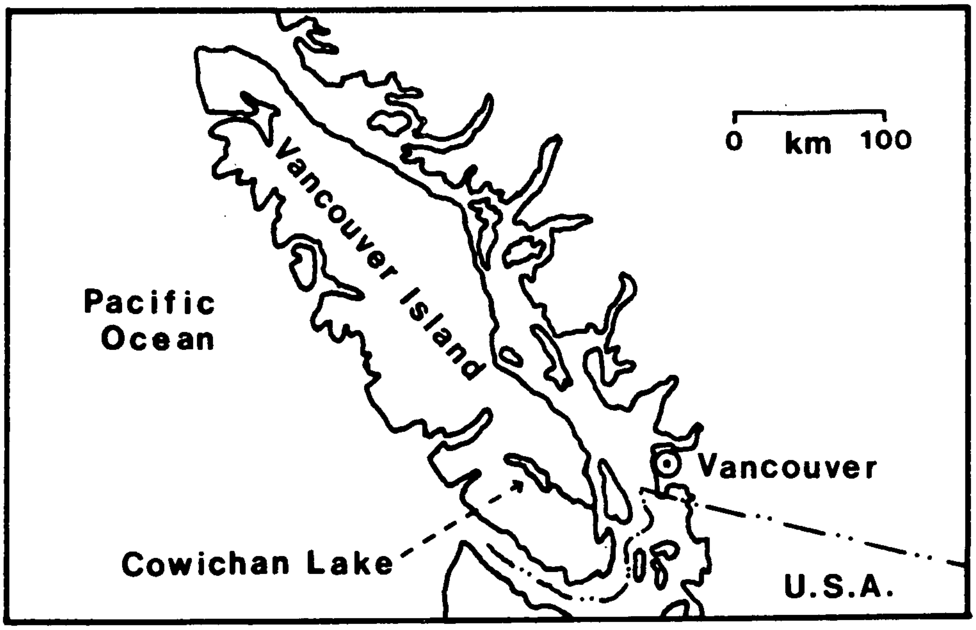

Figure 1 - Location of the study area.

It is covered by National Topographic Series map sheets 92-C/16 East and 92-C/16 West (scale 1:50,000). According to these maps, lake level is at an elevation of about 161 m (527 feet). The Lake is located between two mountain ranges, the Kennedy Range on the north side and the Seymour Range on the south side. The Kennedy Range includes Heather Mountain (1345 m), Mount Landalt (1537 m), and Mount Holmes (1158 m). The Seymour Range includes Mount Vernon (988 m), Towincut Mountain (1249 m) and Mount Sutton (1170 m). Numerous small and large creeks and rivers drain these mountains and empty into the Lake. These include: on the north side, Shaw Creek, Cottonwood Creek, and Meade Creek, and on the south side, Nixon Creek, Sutton Creek, and the Robertson River. The Lake is drained at its eastern end by the Cowichan River.

Cowichan Lake is about 32 km long and 3 km wide at its longest and widest points, and is the largest body of fresh water on southern Vancouver Island. The Lake is surrounded by a number of communities including Lake Cowichan, Mesachie Lake, Honeymoon Bay, Caycuse, Nitinat and Youbou. The forest industry forms the economic base of all of these communities. The British Columbia Ministry of Forests maintains a research station at the eastern end of the Lake. This station includes two separate properties. The main property, which has the station headquarters, is located on a peninsula in the southeast corner of the Lake near the village of Mesachie Lake. The other property, called the North Arm Forest, is located about 5 km from the village of Lake Cowichan between Meade Creek and the head of the North Arm of Lake Cowichan. The Cowichan Lake area is also part of the Cowichan Valley Demonstration Forest.

Access to and around the Lake is excellent. The village of Lake Cowichan, at the eastern end of the Lake, can be reached by travelling west along Highway 18 about 27 km from the town of Duncan. Paved roads extend to the village of Youbou on the north side of the Lake and a few kilometers past the village of Honeymoon Bay on the south side. Beyond these points, good gravel roads surround the Lake. In addition, a number of secondary roads (some with controlled access) extend into the mountains on both sides of the Lake.

3.2 BEDROCK GEOLOGY

In southwestern British Columbia, the main physiographic subdivisions include the Pacific Ranges on the B.C. mainland, the Georgia and Namaimo Lowlands, and the Vancouver Island Mountains (Holland, 1976). The bedrock geology of the Pacific Ranges differs considerably from that of the Vancouver Island Mountains. Whereas the former are primarily composed of intrusive igneous rocks (granitic batholiths), the latter are primarily formed of folded and faulted volcanic and sedimentary rocks with some igneous intrusions (Holland, 1976; Muller, 1977; Farley, 1979; and Northcote, 1981).

The geological structure of Vancouver Island is almost entirely dominated by steep faults (Muller, 1977). The Cowichan Valley is a curving fault-controlled lineament (alignment of topographic features) with a northwesterly trend and a length of 64 km (Holland, 1976). This valley, which is occupied by Cowichan River and Lake, and by Nitinat River tributaries, is part of a depression which extends from Clo-oose on the west coast of Vancouver Island to Duncan on the east coast.

Geological maps of Vancouver Island have been presented by Muller (1977) and Northcote (1981). A discussion of the bedrock geology of the Cowichan Lake area is found in Korelus and Lewis (1976,1978). In summary, the bedrock in the Cowichan Lake area is mainly of volcanic origin. The north side of the Lake is underlain by rocks of the Paleozoic Sicker Group which includes both metamorphosed volcanic (mainly basaltic to rhyolitic lava flows, tuff and agglomerate), and (volcanic derived) metamorphosed sedimentary (mainly metagreywacke and argillite) deposits. The eastern end of the Lake is underlain by volcanic (mainly massive flow basalts and marine pillow basalts) deposits of the Triassic Vancouver Group (Karmutsen Formation). The southern side and western end of the Lake are underlain by volcanic (mainly andesites, basalts and rhyolites) deposits of the Jurassic Bonanza Group. There are also a few small (relative to the volcanic bedrock types) igneous intrusions (Island Intrusions) and limestone deposits (Vancouver Group, Quatsino Formation) in the Cowichan Lake area.

On the basis of their susceptiblity to glacial erosion and other weathering processes, Korelus and Lewis (1976,1978) grouped the volcanic bedrock types into two groups: the "hard" volcanics, and the more easily weathered "soft" volcanics. They included the Sicker volcanics and the Vancouver volcanics (Karmutsen Formation) in the "hard" group, and the Bonanza volcanics in the "soft" group. They also suggested that the metamorphosed sedimentary deposits of the Sicker Group would be similar in weatherability to the "soft" volcanics.

3.3 GLACIATION

Holland (1976), Ryder (1978), and Farley (1979) summarized the Pleistocene events which drastically altered the British Columbia landscape. The Pleistocene Epoch, which began about two million years ago, was characterized by a number of glaciation and interglaciation periods of varying duration. The most recent glaciation, referred to as the Fraser glaciation, began about 25,000 years B.P. (before present), and was characterized by formation of the massive Cordilleran Ice Sheet. At its maximum extent, about 15,000 years B.P., the Cordilleran Ice Sheet covered the whole province, including the Queen Charlotte Islands and Vancouver Island, and even extended into northern Washington State (Ryder, 1978).

The glaciation history of Vancouver Island and the Cowichan Valley has been discussed by Halstead (1968) and Alley (1981). From their observations and the observations of others, they suggested the following scenario. The Cowichan Valley was not free of ice at any time during the Fraser glaciation. The three main episodes which characterized the Fraser glaciation included the earliest Evans Creek Stade, the main Vashon Stade, and the final Sumas Stade. During the Evans Creek Stade, a valley glacier developed in the Cowichan Valley. This glacier, referred to as the "Cowichan Ice Tongue" (Halstead, 1968), was confined to the valley by the surrounding topography, and moved in an easterly direction eroding the valley walls. The Cowichan Ice Tongue reached its maximum extent, the Saanich Peninsula, about 18,000 years B.P.. It had started to recede when it was overriden by the main Cordilleran Ice Sheet (Vashon Stade). On southern Vancouver Island, this continental glacier moved in a south-southwest direction and probably exceeded 1460 m in thickness at its maximum development. About 14,000 years B.P., a rapid and pronounced climatic warming led to in situ melting and retreat of the continental ice masses. Remnant ice still occupied the Cowichan Valley about 11,500 B.P. when further climatic changes led to a temporary rejuvenation of the Cowichan Valley glacier (Sumas Stade). This "brief" episode was followed by gradual melting of the glacier and evidence suggests that the Cowichan Lake area has been free of ice since about 10,200 years B.P..

3.4 SURFICIAL MATERIALS

The surficial materials that form the parent material of most B.C. soils were deposited during and since the Fraser glaciation. Till, "a compact, non-sorted and non-stratified sediment which contains a heterogeneous mixture of particle sizes", is probably the most extensive of all surficial materials in B.C. (Ryder, 1978). The Cowichan Valley is no exception. Halstead (1968) noted that when the glacial ice finally did melt in this valley, it left a thick blanket of till. Till (specifically basal or lodgement till deposited directly by moving ice) is indeed the most widespread surficial material in the Cowichan Lake area (Korelus and Lewis, 1976,1978). To a lesser extent, colluvial and fluvial (alluvial) materials are also important. Maps showing the distribution and type of surficial materials in the Cowichan Lake area have been produced by the E.L.U.C. Secretariat (1975) and Korelus and Lewis (1976,1978).

Korelus and Lewis (1976,1978) discussed the distribution and nature of surficial materials in this area. They stated that deep till often occurs on gentle and moderate slopes but can also occur on steep slopes. Where deep till occurs on steep slopes, it has often been extensively modified by gullying since deglaciation. Where the till is shallow (less than 1 or 2 m thick), it is generally interrupted by rock outcrops, and a complex mosaic of bare rock, shallow till, and deep till results. Under old-growth forests, only the steepest rock faces are bare and long-term accumulation and decomposition of forest litter often results in small pockets of shallow organic soils which are easily destroyed by fire (Korelus and Lewis, 1976, 1978).

Korelus and Lewis (1976,1978) also noted that soil texture and coarse fragment content depend somewhat on the type of bedrock from which the till was derived: the coarsest tills (very stony, gravelly, loamy sands) were derived from the igneous intrusions (Island Intrusions), intermediate textured tills (stony, sandy loams) were derived from the "hard" volcanics (Sicker Group and Karmutsen Formation), and the finest textured tills (sandy loam to loam, low stone and gravel content) were derived from the "soft" volcanics (Bonanza Group).

On steep slopes, both deep and shallow tills are often modified by colluvial processes. The till is often covered with varying depths of colluvial materials which are loose, often gravelly, sandy-textured and contain a high proportion of coarse fragments (cobble to boulder size). The coarse fragments are usually concentrated on the surface and the proportion of fines increases with depth (Korelus and Lewis, 1978)

Numerous small and large streams empty into Lake Cowichan and, as a result, much of the till on lower slopes immediately adjacent to the Lake has been covered with varying thickness of post-glacial fluvial (alluvial) deposits. The fluvial fans have a highly variable texture but usually grade from bouldery to gravelly at the apex to sandy, stone-free material at the base. Floodplains and terraces are also found along some of the major streams (eg. Meade Creek, Robertson River). On the terraces, fine to medium loamy sands usually overlie gravels and cobbles (Korelus and Lewis, 1976,1978).

Till, colluvial and fluvial materials are the most widespread materials on lower slopes (below 700 m) adjacent to Cowichan Lake but there are also minor glaciofluvial, lacustrine and organic deposits. The glaciofluvial (outwash) materials are well-sorted and well-stratified sands and gravels which were deposited by glacial meltwater streams. They are most abundant near the Shaw Creek, Meade Creek and Robertson River areas and the villages of Nitinat and Lake Cowichan. A small silty lacustrine deposit is also located near the village of Lake Cowichan. Organic deposits occur where rates of accumulation of organic materials exceed decomposition rates. These deposits often occur on gentle terrain where compacted till or bedrock depressions lead to a perched water table (Korelus and Lewis, 1976,1978).

3.5 HISTORY

Saywell (1967) discussed the history of human impact in the Cowichan Lake area. He noted that the first official records of Europeans reaching the Lake are the expeditions of Pemberton in 1857 and Brown in 1864. The purpose of these expeditions was to make a rough survey of the area's natural resources. Upon their return from the Lake, they reported that the Cowichan Valley was covered with magnificient forests of Douglas-fir, western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and western redcedar (*Thuja plicata* Donn *ex* D. Don *in* Lamb.). The subsequent development of the Cowichan Lake area has been almost entirely focused on efforts to extract this high-quality timber.

The first timber lease of which there is an authentic record was granted in 1879. A number of other small land grants had been given out by 1886. In that year, the Esquimalt and

Nanaimo (E&N) Railway received a huge land grant on southern Vancouver Island in partial payment for the construction of a railway system. This grant included all of the lands around Cowichan Lake which had not already been committed.

The first logging operations didn't really begin until the late 1880's. At first, these operations concentrated on sites close to the Lake's edge. Logs were held in booms in the Lake and, at high water, were floated down the Cowichan River to mills near Duncan. These river drives occurred from 1891 to 1909 but proved to be very risky undertakings as many valuable logs were usually broken or lost in the woods on their way down the Cowichan River. Because of the great financial risks involved in getting the logs to market, very little of the forests in the Cowichan Lake area had been logged by 1910.

Intensive logging of the Cowichan Lake forests didn't really begin until the arrival of the railway. The main line of the E&N Railway which went from Victoria to Nanaimo had been completed in 1887 but it wasn't until 1912 that a branch of this line reached the present village of Lake Cowichan at the eastern end of the Lake. From that time on, the exploitation of Cowichan Lake forests proceeded rapidly.

In addition to the extensive logging activities, many of the forests in the Cowichan Lake area have been destroyed by fires since the arrival of white settlers. Of particular note are the major fires which burnt out the Gordon Bay area, the Bear Lake area, and parts of the Robertson River Valley in 1908, and the fire which started in the mountains above Youbou in 1945 and spread east and west (Saywell, 1967).

The history of the B.C. Ministry of Forests Research Station has been discussed in B.C. Forest Service (1974). Before the Research Station became a Provincial Forest Reserve in 1929, most of the original forests had been cleared by logging activities. Logging of the North Arm Forest was completed in 1893. The Mesachie Lake property was logged between 1904 and 1909. The major fire which occurred in 1908 (mentioned above) also burnt through the Mesachie Lake property.

In summary then, the original old-growth stands of Douglas-fir, western hemlock, and western redcedar have been removed by fire and logging since the mid-1880's. Intensive exploitation didn't really begin until 1912 with the arrival of the railway. As a consequence of these activities, most of the forests at lower elevations near the Lake are now composed of second-growth stands of Douglas-fir. The oldest second-growth stands are usually located near the Lake's edge on the more accessible sites which were logged first and the youngest stands are usually found at greater distances from the Lake.

3.6 DRIER MARITIME CWH SUBZONE

3.6.1 Climate

On southern Vancouver Island (i.e. west of the Alberni Inlet), there is a strong east-west climatic gradient. There is also a strong climatic gradient from low to high elevations. These gradients are reflected by often pronounced differences in soil and vegetation development, and by the distribution of regional ecosystems (Table 1).

Southern Vancouver Island has a cool, maritime climate with a wet winter, and a relatively dry summer. This type of climate is characteristic of the Pacific Coast of North America, from northern California to southern Alaska (Shumway, 1981). The rather distinct climate of this area is produced by the interaction of several major factors, including the effects of several major mountain barriers, the prevailing westerly winds, and proximity to the immense heat and moisture reservoir of the Pacific Ocean (Franklin and Dyrness, 1973; Schaefer, 1978,1980; Farley, 1979; Hare and Thomas, 1979; and Shumway, 1981).

On southern Vancouver Island, the strong east-west and altitudinal climatic gradients are reflected in the distribution of biogeoclimatic zones. The Coastal Western Hemlock zone (CWH) occurs at low and middle elevations in the wetter, western and central parts of the southern Island. This zone is replaced at colder, high elevations by the Mountain Hemlock zone (MH), and on the drier, east side of the Island by the Coastal Douglas-fir zone (CDF). Klinka et al. (1979) stated that the climates of the CWH, CDF, and MH zones are classified according to the system of Koppen/Trewartha (Trewartha, 1968) as Cfb, Csb, and Dfc, respectively. Maps showing the geographical extent of these zones on southern Vancouver Island are found in Jones and Annas (1978), Farley (1979), Klinka et al. (1979), Krajina et al. (1982), Pojar (1983), and Courtin et al. (1984), and climatic characteristics used to distinguish between these zones

Table 1 - Climate, soil and vegetation characteristics along a low elevation (<600 m) transect across southern Vancouver Island (Krajina, 1976; Valentine *et al.*, 1978; Klinka *et al.*, 1979; and Courtin *et al.*, 1984).

LOCATION	West (Nitinat Valley)	Central (Cowichan Lake)	East (Cowichan R. Valley)	East Coastal (Duncan)
BIOGEOCLIMATIC SUBZONE	Wetter Maritime CWH (CWHb)	Drier Maritime CWH (CWHa)	Wetter Maritime CDF (CDFb)	Drier Maritime CDF (CDFa)
BIOGEOCLIMATIC VARIANT	West Vancouver Island Submontane	East Vancouver Island	Nanaimo and Georgia	Nanaimo and Georgia
CLIMATE	wetter Cfb	drier Cfb	wetter Csb	drier Csb
PRECIPITATION (mm/yr)	6500-2800	2800-1524	1524-1016	1016-657
SOIL SUBGROUP[1]	Ferro-Humic Podzol	Humo-Ferric Podzol	Dystric Brunisol	Dystric Brunisol
BIOGEOCOENOTIC ASSOCIATION[1]	RL-VA-AA-TH	HS-RL-PM-TH	MN-GS-PM	GS-MN-PM

[1] on zonal ecosystem

where AA = *Abies amabilis*
GS = *Gaultheria shallon*
HS = *Hylocomium splendens*
MN = *Mahonia nervosa*
PM = *Pseudotsuga menziesii*
RL = *Rhytidiadelphus loreus*
TH = *Tsuga heterophylla*
VA = *Vaccinium alaskaense*

are found in Krajina (1969,1976), Klinka et al. (1979), Krajina et al. (1982), and Pojar (1983).

Both the CWH and CDF zones are subdivided into wetter and drier subzones. The climate according to the Koppen/Trewartha system (Trewartha, 1968), and mean annual precipitation of these four subzones is shown in Table 1. The study area, which is located at low elevations (below 700 m) surrounding Cowichan Lake, has a climate which is classified as the East Vancouver Island variant of the Drier Maritime CWH (CWHa2). At higher elevations surrounding Cowichan Lake (above 700 m), the climate is wetter and the CWHa2 is replaced by the East Vancouver Island Montane Wetter Maritime CWH (CWHb5). The climate also becomes wetter at low elevations to the west of the Lake, and the CWHa2 is replaced by the West Vancouver Island Submontane Wetter Maritime CWH (CWHb2). At low elevations to the east of the Lake, the climate becomes drier and the CWHa2 is replaced by the Nanaimo and Georgia Wetter Maritime CDF (CDFb1) (Klinka et al., 1979; Courtin et al., 1984). Table 1 presents a synopsis of biogeoclimatic subzones and their associated, low-elevation variants across southern Vancouver Island.

Selected climatic data (Klinka et al., 1979) for the three low elevation biogeoclimatic variants mentioned above are presented in Table 2. Also included in this table are precipitation data (Korelus and Lewis, 1978) from the Nitinat weather station, which is in the CWHb2, and the Cowichan Lake Forest Research Station at Mesachie Lake, which is in the CWHa2. This data reflects the east-west precipitation and temperature

Table 2 - Comparison of climatic data for 3 low elevation biogeoclimatic variants on southern Vancouver Island (data from Klinka et al., 1979) and 2 weather stations near Cowichan Lake (data from Korelus and Lewis, 1978).

CLIMATIC VARIABLE	CWHb2	A	CWHa2	B	CDFb1
Mean annual precip. (mm)	3819	3224	2060	2122	1217
Mean precip. April-Sept. (mm)	876	734	404	390	260
Mean precip. driest month (mm)	91	16	36	32	27
Mean precip. wettest month (mm)	541	548	347	372	207
Mean annual temp. (°C)	7.1	---	8.7	---	8.8
Mean temp. warmest month (°C)	12.4	---	16.8	---	16.7
Mean temp. coldest month (°C)	2.1	---	0.9	---	1.5
Months with mean temp. > 10°C	3.8	---	5.0	---	4.8
Months with mean temp. < 10°C	0.1	---	0.0	---	0.0
Index of continentality	2	---	15	---	14

where CWHb2 = West Van. Island Submontane Wetter Maritime CWH
A = weather station at Nitinat in the CWHb2
CWHa2 = East Van. Island Drier Maritime CWH
B = weather station at Mesachie Lake in the CWHa2
CDFb1 = Nanaimo and Georgia Wetter Maritime CDF

gradients discussed above.

Klinka et al. (1979) stated that the CWHa2 is a drier variation of the CWHa, and is similar in climate to the CDFb. This statement is supported by data presented in Table 2. In this table, both the precipitation and temperature regimes of the CWHa2 are more similar to those of the CDFb1 than those of the CWHb2. These regimes affect the duration and severity of annual water deficits, and potential plant growth. Whereas the

CWHb2 never experiences a summer water deficit, the CWHa2 experiences an average 2.2 month water deficit of 133 mm. The CDFb1 experiences an even greater water deficit of 3.8 months and 192 mm. As a result, the ratio of actual to potential evapotranspiration (an index of potential heat available for plant growth) decreases in an easterly direction being 100%, 76%, and 67% for the CWHb2, the CWHa2, and the CDFb1 variants respectively (Klinka et al., 1979). Data provided by Klinka et al. (1979) suggests that actual evapotranspiration in the CWHa2 and the CDFb1 is considerably reduced during the "growing season", especially during the two warmest months (July and August). This suggests a soil moisture deficit during this period, a deficit which reduces potential plant growth (Klinka et al., 1979).

3.6.2 Soil

Properties of B.C. soils have been discussed in Valentine et al. (1978). Maps showing the distribution of soil Great Groups in B.C. are found in Cotic et al. (1978), Valentine et al. (1978), and Farley (1979). A description of the properties of these Great Groups is found in the Canada Soil Survey Committee's (C.S.S.C.) most recent approximation of the Canadian System of Soil Classification (C.S.S.C., 1978). In this section, the Cowichan Valley soils will be discussed in terms of Jenny's (1941,1961) five soil-forming factors (climate, parent materials, topography, organisms, and time). A consideration of these factors is important because they control the rate of soil processes (Simonson, 1959; Lavkulich and Valentine, 1978a), and determine the type of soil that will develop in a particular area.

On southern Vancouver Island, the strong east-west aerial climatic gradient discussed in the previous section, is reflected by a gradient in soil climates, which in turn is reflected by the distribution of soil Great Groups (Table 1). From the cool boreal, humid (very slight water deficit) soil climates of the west coast to the mild mesic, semiarid (moderately severe water deficit) soil climates of the east coast (Clayton et al., 1977; Lavkulich and Valentine, 1978b), the soils grade from Ferro-Humic Podzols (FHP) to Humo-Ferric Podzols (HFP), to Dystric Brunisols (DYB). Lewis (1976), and Korelus and Lewis (1976,1978) suggested an explanation for this observed gradient. They suggested that the decrease in annual precipitation is accompanied by a decrease in the rate of mineral soil weathering and a parallel increase in the rate of organic matter decomposition. As a result, the FHP soils of the west coast have the highest concentrations of Fe, Al, and organic matter in the B horizon while the DYB soils of the east coast have the lowest concentrations; the HFP soils of the Cowichan Valley being intermediate between these two extremes.

The importance of parent materials in determining soil properties in the Cowichan Lake area has been discussed by Korelus and Lewis (1976,1978). They noted that the texture and coarse fragment content of soils derived from morainal deposits depended on the bedrock type from which the original deposits were derived. Very stony, gravelly, loamy sand is associated with intrusive tills; stony, gravelly, sandy loam is associated with "hard" volcanic tills; sandy loam to loam is associated with "soft" volcanic tills; and silt loam to loam is associated with metamorphic tills. Soil water holding capacity should therefore increase in the order of intrusive tills, "hard" volcanic tills, "soft" volcanic tills, and metamorphic tills. Korelus and Lewis (1976,1978) also noted that bedrock type affects the chemical and nutritional character of till and till-derived soils. Intrusive tills, characterized by the intimate mixing of a wide range of rock types, do not allow the development of especially rich (basic) or poor (acidic) soils. Also, their coarse-textured nature promotes slow rates of weathering and nutrient release. Volcanic tills tend to be more rich in the basic nutrients (especially Ca and Mg) than the intrusive tills. Tills derived from the "hard" volcanics weather more slowly than tills derived from the "soft" volcanics. The silty, metamorphic tills weather rapidly but are usually low in Ca. Finally, they noted that soils associated with the "soft" volcanics probably represent the "most ideal combination of nutrient content and weathering rate".

Topography is a passive soil forming factor which includes a consideration of slope gradient, surface shape, slope position, and slope aspect. Topography affects the redistribution of water and insolation (Korelus and Lewis, 1976,1978) and thus has an important influence on many ecosystem processes. For example, steep upper slopes are characterized by rapid drainage, and xeric moisture conditions, while gently sloping, lower slopes usually have slower drainage, receive water (seepage) from upslope sites and thus have more hygric moisture conditions. Also, seepage water carries plant nutrients and is thus linked to tree nutrition.

The soils map of the Cowichan Lake area (E.L.U.C., 1978) was examined to determine which soil associations occur in the study area. The approximate abundance of each soil association on a given parent material is shown in Table 3. Additional information includes the most common texture (C.S.S.C., 1978), the most common drainage class (Canada Department of Agriculture, 1974), and the most common soil Subgroup (C.S.S.C., 1978) of each soil association. In summary, Duric Humo-Ferric Podzols (DU.HFP) are found on morainal and coarse fluvial (mainly glaciofluvial) deposits while Orthic Dystric Brunisols (O.DYB) are found on medium-textured fluvial deposits, and Orthic Humo-Ferric Podzols (O.HFP), shallow lithic phase (shli), are found on colluvial materials. In addition to these soil Subgroups, other soil Subgroups of the Gleysolic Order, the Organic Order, and the Regosolic Order occur in the study area. However, soils belonging to these other Subgroups only occur in small patches associated with specific edaphic conditions (Jungen and Lewis, 1978). In fact, in the study by Day *et al*. (1959), organic soils of the Arrowsmith series (Peat type) were recognized in the Cowichan Lake area. In the study by Klinka *et al*. (1981a), which included three plots on fluvial

Table 3 - Approximate abundance of soil associations occurring on different parent materials at low elevations (< 700 m) in the Cowichan Lake area. Abundance estimated from soils map produced by E.L.U.C. (1978).

ASSOCIATION	ABUNDANCE	TEX[1]	DR[2]	SUBGROUP[3]	Comments
MORAINE					
Quimper (QP)	70%	gsl	w	DU.HFP	strongly cemented pan
Reegan (RN)	30%	gl	m	DU.HFP	moderately cemented pan
FLUVIAL					
Honeymoon (HM)	90%	vgls	r	DU.HFP	generally level landscape position
Effingham (EH)	9%	l	w	O.DYB	stonefree floodplain soils
Errington (EA)	1%	gls	r	O.DYB	gravelly floodplain soils
COLLUVIUM					
Rossiter (RT)	85%	gsl	r	O.HFP (shli)	stony soils on steep slopes
Strata (ST)	10%	gls	r	O.HFP (shli)	soils of the Island Intrusions
Cullite (CT)	4%	gsl	w	O.HFP	stony soils on steep slopes
Robertson (RB)	1%	gsl	w	O.HFP (shli)	stony soils on steep slopes
BEDROCK					
Rock Outcrop (RO)	100%	---	-	-----	bedrock within 10 cm of surface

[1] most common texture (C.S.S.C., 1978),
where g = gravelly (20-50% gravel by volume)
vg = very gravelly (50-90% gravel by volume)
l = loam, ls = loamy sand, sl = sandy loam

[2] most common drainage class (C.D.A., 1974),
where r = rapidly drained
mw = moderately well drained
w = well drained

[3] most common soil Subgroup (C.S.S.C., 1978),
where O = Orthic, DU = Duric
HFP = Humo-Ferric Podzol
DYB = Dystric Brunisol
shli = shallow lithic phase

materials in the Cowichan Lake area, soils of the Sombric HFP, Orthic HFP (Sombric Phase) and Cumulic Regosol Subgroups were recognized.

The characteristics of Vancouver Island Podzols have been discussed by several authors (Lewis, 1976; Jungen and Lewis, 1978; Valentine and Lavkulich, 1978). These podzols are usually well to moderately well drained, have dark reddish brown colours, textures which are predominantly coarse to medium, low pH values (4.0-5.0), moderate to high Fe and Al contents, and a low base saturation. The soil profile typically has the following sequence of horizons: a relatively thick ectorganic surface layer (LFH), possibly an incipient eluvial Ae horizon (usually absent), a thick Bf horizon, and a compact, cemented Bc or BCc horizon (Jungen and Lewis, 1978).

An explanation for the frequent absence of an Ae horizon (characteristic of the classical Ae/B Podzol model) in Vancouver Island Podzols has been suggested by Lewis (1976), and Valentine and Lavkulich (1978). The warm, moist climate of southern Vancouver Island favors rapid <u>in situ</u> weathering which results in large losses of the bases and silica and the subsequent residual enrichment of sesquioxides. Ae horizons do not form because weathering of relatively Fe-rich parent materials leads to the "rapid overloading and insolubilization of metallo-organic complexes, thereby precluding any significant downward translocation" (Lewis, 1976). Valentine and Lavkulich (1978) further added that, despite the heavy leaching, the addition of organic matter to, and the weathering of Fe and Al in, the upper mineral horizon is so great that there is no net depletion to form an Ae. They also noted that in other areas, the organic matter simply masks the Ae horizon under moist field conditions.

McKeague and Sprout (1975), C.S.S.C. (1978), and Jungen and Lewis (1978) discussed the properties of cemented, duric horizons which commonly occur in southwestern B.C. Podzols. These duric horizons are usually found at a depth of 40 to 80 cm from the mineral surface. They usually have an abrupt upper boundary to an overlying Bf, and a diffuse lower boundary at least 50 cm below. Cementation is usually strongest near the upper boundary and decreases with depth. The structure of these horizons is usually massive or very coarse platy, and the color usually differs little from that of the parent material. Air-dry clods do not slake in water (C.S.S.C., 1978). McKeague and Sprout (1975) suggested that the cementing material may be secondary amorphous to weakly crystalline products containing varying proportions of Fe, Al, and Si. McKeague and Sprout (1975) also noted that these duric horizons are relatively impermeable to water. Korelus and Lewis (1976,1978) stated that this prevents rapid downward flow and permits slower lateral flow of water. McKeague and Sprout (1975) also noted that these duric horizons are impermeable to roots. As a result, root mats commonly occur on top of the upper boundary of these duric horizons, a situation which may limit the volume of soil potentially exploitable by tree roots, and consequently tree nutrition.

McKeague and Sprout (1975) noted that a cemented duric horizon occurs most commonly in soils derived from moderately coarse-textured basal till. They also noted that it occurs in some fluvial deposits, but is not known to occur in fine-textured materials. Jungen and Lewis (1978) noted that it is common in morainal and gravelly, fluvial materials, but does not occur in colluvial deposits. Similar trends were observed on the E.L.U.C. soils map of the Cowichan Lake area (E.L.U.C., 1978). The Quimper and Reegan associations which develop on gravelly, morainal deposits, and the Honeymoon association which develops on very gravelly, fluvial deposits have a duric horizon, whereas the Effingham association which develops on stonefree, loamy fluvial deposits, and the four associations which develop on gravelly, colluvial materials do not (Table 3).

Korelus and Lewis (1976,1978) suggested that the presence or absence of a duric horizon might depend on soil age. They suggested that sufficient time has passed since deglaciation for the development of a duric horizon on the older, morainal and gravelly, fluvial (mainly glaciofluvial) deposits, whereas insufficient time has passed for them to develop on the more recent colluvial and fluvial deposits. They suggested that the occurrence of Brunisols instead of Podzols on the recent fluvial deposits was also related to soil age, i.e. these more recently deposited materials are as yet little changed by soil processes and the Bf horizon has not yet had time to develop.

3.6.3 Vegetation

The CWH is the largest biogeoclimatic zone in the Vancouver Forest Region and covers much of Vancouver Island and the Coast Mountains (Klinka *et al.*, 1979). This zone is analogous to the *Tsuga heterophylla* zone (TH) which covers a large part of western Washington and Oregon (Franklin and Dyrness, 1973). The CWH includes most of Rowe's (1972) Coast Forest Region which has the largest trees, the highest mean annual increments per hectare, and the highest yields in Canada (Bickerstaff *et al.*, 1981). A large number of studies done partly or entirely in the CWH have contributed to current knowledge of vegetation in this zone. The results of these studies have been presented in Spilsbury and Smith (1947), Becking (1954), Krajina (1965,1969), Mueller-Dombois (1959,1965), Orloci (1961,1964,1965), Eis (1962), Kojima (1971), Franklin and Dyrness (1973), Kojima and Krajina (1975), Klinka (1976), Klinka *et al.* (1979,1980a,1981a), Inselberg *et al.* (1982), Kimmins (1983) and Pojar (1983).

Most mature forest ecosystems in the CWHa are dominated by various combinations of western hemlock, Douglas-fir, and western redcedar. Western hemlock is usually abundant in almost all layers of forest stands. In this subzone, western hemlock is shade-tolerant, produces abundant regeneration, and usually forms a major component of climax stands on zonal (i.e. mesic and mesotrophic) ecosystems. On drier or richer sites, it regenerates where there is an abundance of decaying wood, or a thick mor humus layer. Douglas-fir is a shade-intolerant "pioneer" on the majority of sites in the CWHa. However, on very dry sites, it is shade-tolerant and can form part of climax stands. Western redcedar is also abundant, especially on richer, moister sites where it often forms a part of climax stands. Other less common conifer species in the CWHa include western white pine (Pinus monticola Dougl. ex D. Don in Lamb.), lodgepole pine (Pinus contorta Dougl. ex Loud.), grand fir (Abies grandis (Dougl. ex D. Don) Lindl.), and the occasional Sitka spruce (Picea sitchensis (Bong.) Carr.). Pacific silver fir (Abies amabilis (Dougl. ex Loud.) Forbes) and Alaska yellow-cedar (Chamaecyparis nootkatensis (D. Don) Spach) which are common in the CWHb, only rarely occur in the CWHa. Compared to other subzones, Douglas-fir, grand fir, western white pine, and western redcedar have their highest potential productivity in the CWHa. Red alder (Alnus rubra Bong.) is common on disturbed or very wet sites. Other hardwood species include black cottonwood (Populus trichocarpa Torr. & Gray ex Hook.), bigleaf maple (Acer macrophyllum Pursh), Pacific madrone (Arbutus menziesii Pursh), western flowering dogwood (Cornus nuttallii Audub. ex Torr. & Gray), cascara sagrada (Rhamnus purshianus DC.), vine maple (Acer circinatum Pursh), and willows (Salix spp.) (Krajina, 1969; Klinka et al., 1979; Eyre, 1980; Krajina et al., 1982; and Pojar, 1983).

As mentioned previously, the climate of the CWHa2 is very similar to that of the CDFb (Table 2). As in the rest of the CWHa, western hemlock in the CWHa2 produces abundant regeneration on zonal sites and has the potential to become the climatic climax species. However, due to the relatively dry climate and rich parent materials in this variant, the vigor of western hemlock on zonal sites is only fair to poor. In contrast, under the same conditions, good growth is shown by Douglas-fir (Klinka et al., 1979).

Characteristic floristic features of zonal ecosystems in the CWH include: the abundance of western hemlock, the relative paucity of herbs, and the predominance of several moss species. Biogeocoenotic associations which characterize zonal ecosystems in the CWHb and CWHa are presented in Table 1. Characteristic plant species on zonal ecosystems in the CWHa2 differ slightly from those listed in Table 1 for the modal CWHa. In this variant, Kindbergia oregana ((Sull.) Ochyra) replaces Rhytidiadelphus loreus ((Hedw.) Warnst.) as a dominant moss species on zonal sites. Characteristic species on zonal sites thus include Kindbergia oregana, Hylocomium splendens ((Hedw.) B.S.G.), Douglas-fir and western hemlock. Another distinguishing feature of this variant is the relative abundance of several species more characteristic of the CDFb, including common Saskatoon (Amelanchier alnifolia (Nutt.) Nutt.), salal (Gaultheria shallon Pursh), baldhip rose (Rosa gymnocarpa Nutt. in Torr. & Gray), Vancouver groundcone (Boschniakia hookeri Walp.), common western pipsissewa (Chimaphila umbellata (L.) Barton), and the moss Homalothecium megaptilum ((Sull.) Robins.) (Klinka et al., 1979).

Mature forests in the CWHa are characterized by the following sequence of plant communities (Krajina, 1969; Kojima and Krajina, 1975; Klinka, 1977b; Kimmins, 1983). The driest sites, located on rock outcrops and very shallow soils, are occupied by non-forested ecosystems which are characterized by the abundance of Rhacomitrium mosses and several lichen species. With increasing soil depth and soil moisture-holding capacity, forested ecosystems supporting lodgepole pine, Pacific madrone, and stunted Douglas-fir become more prevalent. These stands are characterized by an abundance of lichens on tree trunks and on the ground. Particularly common are lichens of the Peltigera and Cladonia genera. As soil depth increases and SMR approaches subxeric conditions, the overstory becomes dominated by Douglas-fir and the understory by salal. The absolute dominance of salal in these ecosystems does not usually allow the development of a herb or moss layer of any consequence. On these subxeric sites, western hemlock only grows on decaying wood. Floristic characteristics of zonal ecosystems (intermediate SMR and SNR) have already been discussed. These include the abundance of hemlock in both the main canopy and understory, a carpet of mosses, and the absence of well-developed herb or shrub layers. Douglas-fir is also common on zonal ecosystems, particularly in younger stands, and particularly in the CWHa2. On richer sites with an intermediate moisture regime, western redcedar replaces western hemlock as an associate of Douglas-fir in the overstory. Mosses are still common but the abundance of herbs increases, particularly that of american vanilla leaf (Achlys triphylla (Sm.) DC.) and western sword fern (Polystichum munitum (Kaulf.) Presl). On rich sites with a subhygric to hygric SMR, the forest canopy is occupied by Douglas-fir, western redcedar, and grand fir, and herbs dominate the understory. On these sites, sword fern and trifoliate-leaved foamflower (*Tiarella trifoliata* L.) achieve their maximum development. Douglas-fir does not grow on sites with a very shallow water table and a subhydric SMR. On nutrient-rich, subhydric sites, the overstory is characterized by the presence of red alder, western redcedar, and Sitka spruce. The understory is characterized by the presence of a dense herb layer and the usual dominance of skunk cabbage (*Lysichitum americanum* Hult. & St. John). In contrast, nutrient-poor, subhydric sites are characterized by non-forested ecosystems dominated by *Sphagnum* mosses, *Spirea* species, and the occasional stunted lodgepole pine or western white pine. A similar sequence of plant communities also occurs in mature forests of the TH zone in Washington and Oregon (Franklin and Dyrness, 1973; Franklin, 1981).

The original forest vegetation of the CWHa in British Columbia and the analogous TH in the U.S. has been extensively modified by fire and logging. Douglas-fir, a "pioneer" species on the majority of sites, now dominates the canopy of vast expanses of forest in the Pacific Northwest (Eyre, 1980; Franklin, 1981). Franklin and Dyrness (1973) presented a review of studies which examined secondary succession in these Douglas-fir / western hemlock forests. They noted that much of the research has been limited to the first five to eight years after complete tree removal, and that detailed successional patterns for the entire period of forest reestablishment have not been entirely worked out. A summary of the results of some of these studies will be presented later.

IV. METHODS

4.1 APPROACH

In the Cowichan Lake study, the general approach used to produce the classification of forest ecosystems was similar to that employed by Brooke et al. (1970), Kojima and Krajina (1975), Klinka (1976), and Inselberg et al. (1982). This approach involves two main elements: ecosystem analysis followed by ecosystem synthesis.

Ecosystem analysis proceeds in three stages: reconnaissance, entitation and sampling. During the reconnaissance stage, the study area is investigated to determine the variety and qualitative nature of ecosystems present, and possible environmental factors related to their distribution. The second stage, entitation , involves the preparation of a tentative list of ecosystem classes (entities). The preparation of this list is based on information acquired during the reconnaissance stage and a review of the relevant literature. The final, sampling stage involves collection of the required vegetation and environment data from several examples of each of the entities. Mueller-Dombois and Ellenberg (1974), Gauch (1982), and Kimmins (1983,1984) present more detailed descriptions of ecosystem analysis methods.

During the subsequent ecosystem synthesis, the objective is to group the relatively large number of samples into a smaller number of classes on the basis of similarity in selected properties. Once the final classes have been established, their properties are described, and they are named and organized into a hierarchy in order to show relationships between the classes. During ecosystem synthesis, the preliminary, tentative list of ecosystem classes may be drastically revised or, on the other hand, may not be changed at all. The extent of revisions depends on how well the preliminary list of classes agrees with new insights provided by data acquired during the sampling stage.

In the biogeoclimatic system, ecosystem synthesis involves a table rearrangement procedure which is based on traditional methods used in the Braun-Blanquet school of phytosociology (Maarel, 1975; Westhoff and Maarel, 1978). The Braun-Blanquet method involves the preparation of a "raw" vegetation table which is a matrix with species as rows and sample plots as columns. Matrix entries are the abundance of a particular species in a particular plot. The order of samples and plots in the matrix is changed so that species which typify a given group of samples are grouped together and samples typified by a given group of species are grouped together (Gauch, 1982). The objective is to produce a "synthesis" table which shows the vegetation data matrix in a well-organized form so that: 1) important trends of species distribution among the sample plots are immediately recognized, 2) similarities and differences between plots are emphasized, and 3) the identification of recurring patterns is facilitated (Mueller-Dombois and Ellenberg, 1974). Gauch (1982) noted that Braun-Blanquet tablework is the most frequently used method for analyzing plant community data. Complete details of the table rearrangement process have been outlined in Shimwell (1972) and Mueller-Dombois and Ellenberg (1974).

In the biogeoclimatic system, the establishment of ecosystem classes includes the Braun-Blanquet vegetation table rearrangement process described above. However, in addition to vegetation tables, there is a simultaneous consideration of environment data in parallel environment tables. Thus, there is an attempt to optimize the arrangement of samples in terms of both vegetation and environment properties thereby making the approach more ecosystematic. As Inselberg et al. (1982) noted, the vegetation and environment data for each plot are compared using tabular methods in order to determine "similarities and differences, consistency of groups, and conformity to patterns of relationship", and subsequently, "various units at different levels of generalization are recognized or identified using both floristic and environmental variables as the differentiating characteristics".

In the Cowichan Lake study, ecosystem synthesis differed from the traditional approach described above. Multivariate analysis techniques were employed in order to provide a more objective basis for grouping the plots into ecosystem classes. Gauch (1982) discussed the application of multivariate analysis techniques in hierarchical classification. He noted that there are three main groups of techniques:

1) monothetic divisive (eg. association-analysis),
2) polythetic divisive (eg. ordination space partitioning), and

3) polythetic agglomerative (eg. cluster analysis). Monothetic techniques subdivide the set of sample plots on the basis of presence or absence of a single plant species, while polythetic techniques consider the entire species composition of sample plots. Divisive techniques begin with all plots in a single cluster (group), and successively partition this cluster into a hierarchy of smaller and smaller clusters until each cluster contains only one, or some specified small number of sample plots. Agglomerative techniques begin with each cluster comprised of a single sample plot, and agglomerates these into a hierarchy of larger and larger clusters until a single cluster contains all plots. These and other properties of classification techniques have been discussed by Williams (1971), Sneath and Sokal (1973), Orloci (1978), and Gauch (1982). Gauch (1982) reviewed the application and relative merits of the three groups of techniques mentioned above. The following is a summary of his major points.

Monothetic techniques have generally been characterized by a high misclassification rate because of their reliance on a single attribute (i.e. the presence or absence of a single species). As Gauch (1982) noted, community data are often quite "noisy". For various reasons, a sample plot may lack the differentiating species which would group it with otherwise very similar plots or, conversely, may possess a differentiating species ordinarily absent (given the others present). For this reason, monothetic techniques are now generally considered to be only of historical interest, and polythetic techniques are preferred.

The simplest polythetic divisive classification technique is ordination space partitioning. Gauch (1982) stated that the purpose of ordination is to summarize plant community data by producing a low-dimensional ordination space in which similar entities (eg. sample plots) are close together and dissimilar entities far apart. He noted that "some degree of fidelity to the data structure must be frequently sacrificed in the projection into only one to a few dimensions" but that the advantage of this low-dimensionality is "workability for contemplation and communication". He also noted that ordination produces "an economical understanding of the data in terms of a few gradients in community composition (which may be interpretable environmentally)". Ordination space partitioning usually involves the subjective drawing of boundary lines between clusters of points (which represent sample plots) on an ordination graph. If desired, this partitioning procedure can be made automatic and objective. Gauch (1982) noted that subjective partitioning can be very useful when:

1) Divisions through sparse regions of the cloud of points are desired. These sparse regions may indicate relative discontinuities which may have environmentally interpretable reasons or, on the other hand, may simply reflect the fact that intermediate communities were (either consciously or unconsciously) not sampled.

2) The investigator wishes to incorporate into the analysis his/her prior understanding of the data structure but cannot

specify this information precisely or supply it to the computer. This understanding of the data may be based on field experience and/or previous analyses.

3) Subjective clustering is adequate for the purposes of the study.

Cluster analysis is a polythetic agglomerative technique. In this method, plant community data and the relationship between sample plots is summarized in a dendrogram. Similar sample plots are joined into clusters by connecting branches. Sample plots which are more similar are joined by branches of the dendrogram at a lower level than sample plots which are less similar. Examination of the dendrogram suggests which sample plots should (could) be grouped together to form a class (i.e. all plots linked to a particular branch). Since the number of clusters varies at different levels in the dendrogram, the number of classes considered can also be varied.

In the Cowichan Lake study, ordination space partitioning (a polythetic divisive technique), and cluster analysis (a polythetic agglomerative technique) were applied to the vegetation data. The results of these analyses and the environment tables were then used to determine which plots should be grouped together to form an ecosystem class. It was felt that the use of these techniques would provide a more objective, repeatable basis for development of the classification. Finally, it should be noted that a similar approach has been applied in other studies for the abstraction of forest "types" and the investigation of environmental patterns (Coffman and Willis, 1977; Bell, 1978; Betters and Rubingh, 1978; Watanabe and Miyai, 1978; Becker, 1979; Golden, 1979; Picard, 1979; Pfister and Arno, 1980; Amiro and Courtin, 1981; Beese, 1981; Jones and Pierpoint, 1982; and Jones *et al.*, 1983).

4.2 ECOSYSTEM ANALYSIS

4.2.1 Provisional Ecosystem Classes

Since the objective of the Cowichan Lake study was to study and classify immature forest ecosystems, the study area was investigated to determine the location and nature of forest stands ranging in age from about 41 to 80 years. According to Inselberg *et al.* (1982), this range includes immature (41-60 years) and late-immature (61-80 years) coniferous stand age classes. Following a reconnaissance of these stands and a literature review (previous section), it was decided that the following entities, hereinafter referred to as provisional ecosystem classes (PEC) would be sampled:

1) the lichen unit,
2) the salal unit,
3) the moss unit,
4) the moss-sword fern unit,
5) the foamflower-sword fern unit, and
6) the skunk cabbage unit.

This sequence of provisional ecosystem classes occurs along a topographic sequence from very dry ridge crests to very wet depressions, and corresponds to SMR conditions ranging from very xeric (hygrotope 0) to subhydric (hygrotope 7) respectively. With the exception of the lichen and skunk cabbage units, most of the forest canopies of these second-growth stands were dominated by Douglas-fir. Because of this, the units were named for characteristic understory species.

Sample plots were established so that each represented a sample of an individual ecosystem (biogeocoenose). Plots were placed in those parts of forest stands which were relatively homogeneous in external environment and vegetation structure and composition. Particular attention was taken to avoid heterogeneous and/or disturbed sites (Kojima and Krajina, 1975). This method of sample plot selection, referred to as "preferential sampling", is the method most frequently used by plant ecologists (Gauch, 1982).

During May and June 1981, a complete releve was obtained for forty-three sample plots. The releve included site description, vegetation description, mensuration, soil description and humus form description. To ensure data consistency with other ecological investigations in British Columbia, standard field data forms and standard approaches and definitions for ecological data collection (Walmsley et al., 1980) were utilized. In addition to these forty-three sample plots, similar information was obtained for eight plots on the Cowichan Lake Forest Research Station bringing the total number of plots used in the analysis to fifty-one. These eight additional plots had been surveyed by Ministry of Forests (MOF) staff during the summers of 1979 and 1980. These plots were the same eight plots studied by Giles (1983) in his investigation of growing season soil moisture deficits.

4.2.2 Vegetation Analysis

On each sample plot, the vegetation was analyzed by both phytosociological and mensurational techniques. For the phytosociological analysis, 400 m^2 plots were established. In most cases, a 20 m by 20 m square plot was used. This is consistent with the minimal plot area of 200 to 500 m^2 recommended by Mueller-Dombois and Ellenberg (1974) for temperate-zone forests.

For each sample plot, all vascular plants, bryophytes, and lichens growing on the forest floor were listed. Species growing exclusively as epiphytes, on decaying wood and/or on rocks were not included in this list. Plant specimens of uncertain identity were collected. These were later identified by Dr. V.J. Krajina, Dr. K. Klinka, and Mr. F. Boas. Nomenclature of vascular plants (with some exceptions) followed that of Taylor and MacBryde (1977), while Ireland *et al*. (1980) was followed for mosses (two exceptions), Stotler and Crandall-Stotler (1977) for hepatics, and Hale and Culberson (1970) for lichens. Exceptions followed Krajina *et al*. (1984) and Ochyra (1982).

For sampling purposes, the vegetation was stratified into seven layers (Table 4). The system used for this stratification was that of Walmsley *et al*. (1980). As Walmsley *et al*. (1980)

Table 4 - Vegetation strata (Walmsley et al., 1980).

CODE[1]	LAYER		DESCRIPTION
1	A1	-	Dominant trees
2	A2	-	Main tree canopy (codominant and intermediate trees)
3	A3	-	Suppressed trees over 10 m tall
4	B1	-	Tall shrubs (woody plants between 2 m and 10 m tall)
5	B2	-	Low shrubs (woody plants less than 2 m tall)
6	C	-	Herbaceous species, species of doubtful lifeform, and some low shrubs
7	D	-	Bryophytes, lichens, and seedlings

[1] Klinka and Phelps (1979)

suggested, several low woody species and several species of doubtful lifeform were assigned to the herb (C) layer (Appendix A). An estimate of species significance (Table 5) and vigor (Table 6) was obtained for each species for each layer in which it occurred. Species significance ratings were based on the Domin-Krajina scale which combines estimates of species abundance and dominance (Krajina, 1933). Cover values used for significance ratings were those suggested by Klinka and Phelps (1979). Vigor was determined according to the 5-point scale developed by Peterson (1964).

On each sample plot, the age of five trees was determined by counting the growth rings on cores extracted with an increment borer, and the height of two to four trees was determined with a clinometer. Only dominant and co-dominant trees were used for these determinations. Stand age and stand height were calculated by averaging these values. Site index

Table 5 - Species significance scale (Klinka and Phelps, 1979).

CODE	MEAN COVER VALUE (%)	RANGE OF COVER VALUES (%)
+	0.2	0.1 - 0.3
1	0.7	0.3 - 1.0
2	1.5	1.0 - 2.2
3	3.5	2.2 - 5.0
4	7.5	5.0 - 10.0
5	17.5	10.0 - 25.0
6	29.0	25.0 - 33.0
7	41.5	33.0 - 50.0
8	62.5	50.0 - 75.0
9	87.5	75.0 - 100.0

Table 6 - Vigor rating scale (Peterson, 1964).

CODE	DESCRIPTION
0	dead
+	vigor poor
1	vigor fair
2	vigor good
3	vigor excellent

(m/100 years) and growth class (a range of site index values) of Douglas-fir were determined for all plots except those in the lichen and skunk cabbage PEC's. On plots belonging to these provisional ecosystem classes, growth of Douglas-fir is severely limited by edaphic conditions. Site index (SI) of Douglas-fir was calculated using the equation provided by Hegyi et al. (1979) and growth class (GC) of Douglas-fir was determined using the ranges of site index values suggested by Lowe and Klinka (1981). These ranges are shown in Table 7.

Table 7 - Growth class (GC) and corresponding range of site index (SI) values (m/100 years) for coastal Douglas-fir (*Pseudotsuga menziesii*) (Lowe and Klinka, 1981).

	GC	SI (m/100 years)
Good	1	> 57.0
	2	51.1 - 57.0
Medium	3	45.1 - 51.0
	4	39.1 - 45.0
	5	33.1 - 39.0
Poor	6	27.1 - 33.0
	7	21.1 - 27.0
Low	8	15.1 - 21.0
	9	< 15.1

In addition to the above, two prism plots were established in each sample plot. In these prism plots, diameter breast height (d.b.h.) was measured, crown class and species was determined, and total height estimated (by comparing to measured trees) for all trees greater than 7.5 cm d.b.h.. This data was used to calculate gross volume (m^3/ha), the number of stems per hectare, mean annual increment (m^3/ha/year), average d.b.h. (cm), and stand basal area (m^2/ha).

4.2.3 Soil Analysis

On each sample plot, general site features were described and a single soil pit was excavated. During excavation, material removed from the pit was passed through a sieve to remove all large (> 2 cm diameter) coarse fragments. The weight of these large coarse fragments (Mcl) was determined in the field. Soil pits were excavated in the shape of a rectangular or square box so that their dimensions could be readily determined. These dimensions were used to calculate soil pit volume (Vp). Subsequently, the percent volume of these large coarse fragments in the soil pit (VCL) was determined (Appendix B).

The humus form and mineral soil profile were described. The humus form description included, for each horizon, measurement of horizon depth and thickness, and a description of colour, fabric, roots and soil biota. The mineral soil profile description included, for each horizon, measurement of horizon depth and thickness, and a description of coarse fragments, texture, structure, consistency, colour, mottles, roots, and pores (Walmsley *et al.*, 1980). Following these descriptions, separate soil samples were collected for chemical analysis and bulk density determination.

Soil sampling methods differed from usual techniques (i.e. acquisition of samples by genetic horizon) in that samples were consistently collected from four standard soil layers defined by depth from boundary between ectorganic layer and mineral soil. Table 8 describes the soil layers sampled in the

Cowichan Lake study. Layer 0 samples for chemical analysis

Table 8 - Soil layers sampled in the Cowichan Lake study.

LAYER	DEPTH	DESCRIPTION
0	TE[1] - 0 cm	ectorganic layer
1	0 - 30 cm	upper mineral layer
2	30 - 60 cm	middle mineral layer
3	60 - 90 cm	lower mineral layer

[1] TE = thickness of ectorganic layer

consisted of a composite of samples taken at three random locations within the sample plot. No layer 0 sample was collected from plots that had a mull humus form, and no layer 2 sample and/or layer 3 sample was(were) collected from plots where bedrock or compacted material (usually a duric horizon) occurred at shallow depth. In total, one hundred and sixty samples were collected for chemical analysis. One hundred and sixty separate samples were also collected for bulk density and porosity determination.

Samples which were to undergo chemical analysis were prepared in the following manner. Organic samples were air-dried and ground in a Waring blender. Mineral samples were air-dried, crushed with a wooden roller, and sieved to remove coarse (≥ 2 mm diameter) fragments. The following analyses were then performed on the fine (<2 mm diameter) fraction:

1. pH in calcium chloride (PH)

2. exchangeable cations - calcium (CA)
   - magnesium (MG)
   - potassium (K)
   - sodium (NA)
3. cation exchange capacity (CEC)
4. total carbon (TC)
5. total nitrogen (TN)
6. exchangeable nitrogen (EN)
7. mineralizable (plus exchangeable) nitrogen (MEN)

Analyses 1 through 5 were performed according to procedures outlined in Lavkulich (1981). For pH of mineral samples, a 1:2 (m/v), soil:0.01 M calcium chloride solution was used. For organic samples, a 1:5 solution was used. Exchangeable cations and cation exchange capacity were determined by the ammonium acetate method. Total carbon was determined by dry combustion with a Leco analyzer. Total nitrogen was determined by acid digestion followed by colourimetric determination of released ammonium using a Technicon Autoanalyzer. Analyses 6 and 7 followed the procedure used by Waring and Bremner (1964) with some modifications (Appendix C).

Results of the chemical analyses were used to calculate the following derived variables:

8. organic matter content (OM = TC x 1.724)
9. base saturation (BS = (CA+MG+K+NA) / CEC)
10. carbon:nitrogen ratio (CN = TC / TN)
11. mineralizable nitrogen (MN = MEN - EN)

Bulk density samples for each soil layer were collected using the field method for rocky soils described by Lavkulich (1981). Instead of water, glass beads were used for sample volume (Vt) determination. These samples were oven-dried at 105°C for 36 hours. Oven-dried organic and mineral samples were immediately weighed upon removal from the oven. Mineral samples were crushed and sieved to separate fine (<2 mm) and coarse (≥ 2 mm) fractions. The weight of both the fine (Mf) and coarse (Mc) fractions was then determined. Standard (whole soil) bulk density (SBD) was calculated using the formula provided by Brady (1974) and Lavkulich (1981), coarse fragment-free bulk density (CFFBD) was calculated using the formula in Nuszdorfer (1981), and porosity was calculated using the formula provided by Brady (1974) which was modified to account for differences in organic matter content. Details of these calculations are shown in Appendix B.

The results of chemical analyses are usually reported as concentration in the fine (<2 mm) fraction. Units commonly employed include ppm, percent (by weight) or m.e. per 100 g. However, it is often desirable to convert these values to $kg \bullet ha^{-1}$. This conversion permits us to integrate soil chemical data with soil physical data (Lewis, 1976) and obtain a better estimate of the amount of a given nutrient actually present in the soil. Heilman (1979) noted that weight of nutrient on an area basis has the advantage over concentration of nutrient on a soil weight basis because variation in gravel content and bulk density is accounted for. The calculations which perform this conversion for a given nutrient "n" are shown in Appendix D.

This procedure was modified from Lewis (1976).

Lewis (1976) defined "effective soil depth" as the depth from mineral surface to the basal till contact or BCd horizon. In the Cowichan Lake study, soil depth of a given sample plot was defined as depth from the top of the first mineral horizon to K (compacted or cemented material), L (lithic contact), or to rooting depth (depth at which the majority of roots stop), whichever was less. Using this definition of soil depth and the equations for kg of"n"•ha^{-1} shown in Appendix D, the quantity of nutrients was calculated for each soil layer (i.e. layers 0, 1, 2, and 3). Also, the quantity in kg•ha^{-1} of various combinations of layers was calculated. These combinations are shown in Table 9.

Table 9 - Combinations of soil layers for which nutrient content (kg•ha^{-1}) was calculated.

COMBINATION	DESCRIPTION
01	Layer 0 + Layer 1
12	Layer 1 + Layer 2
012	Layer 0 + Layer 1 + Layer 2
123	Layer 1 + Layer 2 + Layer 3
0123	Layer 0 + Layer 1 + Layer 2 + Layer 3

Klinka _et al_. (1981a) noted that samples from more than one soil pit are usually required to accurately determine mean soil properties of a sample plot. The actual number of samples needed to adequately assess mean soil properties of B.C. forest soils has recently been studied by Lewis (1976), Quesnel and Lavkulich (1980), and Courtin et al. (1983). They found that fifteen or more samples were required for most soil properties. However, in the Cowichan Lake study, time and financial constraints limited the number of soil samples which could be collected and analyzed.

4.3 ECOSYSTEM SYNTHESIS

4.3.1 Multivariate Analysis Of Vegetation Data

One hundred and ninety plant species occurred on the fifty-one sample plots (Appendix A). A vegetation data matrix was prepared which considered each species in each stratum (Table 4) as a separate species-stratum-unit (SSU). Two hundred and forty SSU's were derived from the original one hundred and ninety species. It should be noted that this process only affects tree and shrub species which often occur in more than one vegetation stratum.

Gauch (1982) noted that "rare" species are usually deleted from a vegetation data matrix because: 1) their occurrence is usually more a matter of chance than an indication of ecological conditions, 2) most multivariate analyses are affected very little by the deletion of rare species, and 3) the deletion of these species reduces the amount of data storage required. He also noted that "rare" is a relative term but a typical definition includes species occurring in less than about 5% of the plots. This suggestion was followed by deleting from the original (240 SSU's x 51 plots) matrix a total of one hundred and twelve SSU's which occurred on less than three (5.9%) of the plots. This deletion resulted in the production of the final one hundred and twenty-eight SSU's x fifty-one plots data matrix which was subsequently used in the multivariate analyses. The estimated Domin-Krajina species significance values were used throughout the analysis as the quantitative measure of species abundance in each layer. Species significance values of "+" were coded as 0.5, and species significance values of 1 to 9 were coded as 1.0 to 9.0 respectively.

Techniques used for multivariate analysis of the vegetation data included three types of ordination, and cluster analysis. Reciprocal averaging (RA) ordination (Hill, 1973), also known as "analyse factorielle des correspondances" (Benzecri, 1969), correspondence analysis (Hill, 1974), or reciprocal ordering (Orloci, 1978), and polar ordination (PO), also known as Bray-Curtis ordination (Bray and Curtis, 1957), were performed using the ORDIFLEX (Release B) program developed by Gauch (1977) as part of the Cornell Ecology Programs (CEP) series. Detrended correspondence analysis (DCA) ordination (Hill, 1979a; Hill and Gauch, 1980) was performed using the DECORANA program developed by Hill (1979a) as part of the same CEP series. Several different options are available for modifying the DCA performed by DECORANA. For analysis of the Cowichan Lake vegetation data, all default options were used. For polar ordination, percentage dissimilarity (PD) was used as the distance measure between plots and sample totals were standardized to 100. First axis endpoint selection for PO was based on results of the RA and DCA ordinations while automatic endpoint selection was used for the second axis.

Following the ordinations, cluster analysis was performed using the MIDAS (Fox and Guire, 1976) statistical package supported by the U.B.C. Computing Centre. Euclidean Distance (ED) (Orloci, 1978; Pimentel, 1979; Gauch, 1982) was used as the measure of dissimilarity between plots. Seven clustering algorithms are available for cluster analysis in the MIDAS package. These are described by Sneath and Sokal (1973) and Pimentel (1979). For analysis of the Cowichan Lake vegetation data, the AVERAGE clustering algorithm was used.

The ordinations and cluster analysis were performed on four different combinations of plots and vegetation layers. The first combination included all fifty-one plots and all seven vegetation layers. The second combination included all fifty-one plots and the four understory vegetation layers (i.e. layers B1, B2, C and D). The third combination included the forty-one intermediate plots for which SI of Douglas-fir could be determined, and all seven vegetation layers, while the fourth and last combination included the same forty-one intermediate plots and the four understory vegetation layers only. All of these analyses were assigned a code to facilitate future discussion of the results (Table 10).

Table 10 - Analysis codes for the 16 combinations of multivariate analysis, plots, and vegetation layers.

Multivariate Analysis	all plots (51) 7 layers (128 SSU)	all plots (51) 4 layers (115 SSU)	intermediate plots (41) 7 layers (111 SSU)	intermediate plots (41) 4 layers (98 SSU)
Reciprocal Averaging (RA)	RA11	RA12	RA13	RA14
Detrended Correspondence Analysis (DCA)	DCA11	DCA12	DCA13	DCA14
Polar Ordination (PO)	PO11	PO12	PO13	PO14
Cluster Analysis (CA)	CA11	CA12	CA13	CA14

4.3.2 Tabular Methods

Tables of selected environment variables were prepared using the F405:ENV program developed by Klinka and Phelps (1979) at the University of British Columbia. The original sorting instructions were based on the preliminary, tentative assignment of plots to the six PEC's. By comparing ordination graphs and dendrograms of the vegetation data, and tables of environment variables, the original assignment of the fifty-one plots to the six PEC's was revised. In total, four plots were reassigned to a different ecosystem class to which they showed a better "fit".

Once class membership of all plots was finalized, new sorting instructions were prepared. These new instructions were used to prepare the final environment tables for each syntaxon.

The same sorting instructions (in a different format) were used to prepare a long vegetation table for each syntaxon and a summary vegetation table. These vegetation tables were prepared using the F405:VTAB program developed by Emanuel and Wong (1983) also at the University of British Columbia. In addition to species significance and vigor for each species in each plot, the long vegetation tables show: presence (P), mean species significance (MS), and the range of species significance (RS) values for each species in each syntaxon. Presence (P) is simply the percentage of plots in a given syntaxon which have a particular species present in their species list. The other two synthetic values (MS and RS) are self-explanatory. Summary vegetation tables show presence class (also called constancy class) and mean significance (MS) for each species in each syntaxon. Presence class is an expression of the frequency of occurrence of a given species in a given syntaxon and is based on species presence. The relationship between presence and presence class is shown in Table 11. If the number of plots in a group is 5 or less, the presence class is printed in arabic, rather than roman numerals (Emanuel and Wong, 1983).

Once the assignment of plots to syntaxa has been finalized and the summary vegetation tables have been prepared, the units are then organized into a hierarchy of biogeocoenotic associations (BA's), plant alliances, and plant orders. The classes formed at these different categorical levels (ranks) are named according to a system which is largely based on rules established by the Nomenclature Commission of the International

Table 11 - Relationship between presence and presence class (Emanuel and Wong, 1983).

PRESENCE	PRESENCE CLASS
1 - 20%	I
21 - 40%	II
41 - 60%	III
61 - 80%	IV
over 80%	V

Society of Vegetation Science. These rules are outlined in Barkman et al. (1976). This process of providing labels (names) for the various classes is referred to as the syntaxonomical stage.

Plant species names used in a syntaxon (class) label are obtained from a list of species which characterize that particular syntaxon. This list, referred to as the "Characteristic Combination of Species" (CCS), contains:
1) species whose distribution shows varying degrees of concentration in a particular syntaxon (character-species and differential-species), and
2) species which occur in over 80% (i.e. presence class = V) of the plots in a given syntaxon (constant-species). These species may or may not show any distributional concentration in the syntaxon under consideration.
Species which are not included in the CCS of any syntaxon are referred to as accidental-species. Criteria for assigning differentiating values to plant species were modified from Inselberg et al. (1982) and will be discussed later.

During the preparation of the CCS lists, the desirability of an objective, repeatable procedure became apparent. To this end, such a procedure was developed and applied. This procedure will be outlined in a later section.

4.3.3 Indicator Plant Analysis

An edatopic indicator species spectrum was prepared for each biogeocoenotic association using the SPECTRA program developed by Rowat (1984) at the University of British Columbia. These spectra show, for each BA, the relative frequency of occurrence (importance) of plant species belonging to eighteen edatopic indicator species groups (EISG). In this system, three hundred and sixty-two species are grouped into three main classes. The first main class includes species which indicate nutrient-very poor to medium sites, the second main class includes species which indicate nutrient-medium sites, and the third main class includes species which indicate nutrient-medium to very rich sites. These three main classes are further subdivided into eighteen EISG's which indicate different soil moisture conditions. Complete details, including the list of species in each EISG, are found in Klinka et al. (1984). A synopsis of the eighteen groups is found in Table 12.

Discriminant Analysis (DA) was performed on the plots by EISG matrix. This DA was performed using the 7M program which is part of the BMDP data analysis series developed at the University of California (Dixon, 1983). DA was used to find the

Table 12 - Synopsis of edatopic indicator species groups (EISG) (Klinka *et al.*, 1984).

EISG	CHARACTERISTIC SPECIES AND DESCRIPTION
	Indicators of nutrient-very poor to medium sites
1.1 -	Lichen spp. Very dry, nutrient-very poor to poor sites (vdvp)
1.2 -	*Chimaphila umbellata* Very dry to dry, nutrient-very poor to med. sites (dpm)
1.3 -	*Goodyera oblongifolia* Dry to fresh, nutrient-very poor to medium sites (dfpm)
1.4 -	*Hylocomium splendens* Dry to moist, nutrient-very poor to medium sites (dmpm)
1.5 -	*Rhytidiadelphus loreus* Fresh to moist, nutrient-very poor to med. sites (fmpm)
1.6 -	*Blechnum spicant* Moist to wet, nutrient-very poor to medium sites (mwpm)
1.7 -	*Sphagnum* spp. Wet, nutrient-very poor to medium sites (wpm)
	Indicators of nutrient-medium sites
2.1 -	*Arctostaphylos uva-ursi* Very dry to dry, nutrient-poor to medium sites (vdm)
2.2 -	*Amelanchier alnifolia* Dry to fresh, nutrient-medium sites (dfm)
2.3 -	*Pyrola asarifolia* Dry to moist, nutrient-medium sites (dmm)
2.4 -	*Luzula parviflora* Fresh to moist, nutrient-medium sites (fmm)
	Indicators of nutrient-medium to very rich sites
3.1 -	*Juniperus scopulorum* Very dry, nutrient-medium (to rich) sites (vdmr)
3.2 -	*Mahonia aquifolia* Very dry to dry, nutrient med. to very rich sites (dmr)
3.3 -	*Pteridium aquilinum* Dry to fresh, nutrient-medium to very rich sites (dfmr)
3.4 -	*Achlys triphylla* Dry to moist, nutrient-medium to very rich sites (dmmr)
3.5 -	*Tiarella trifoliata* Fresh to moist, nutrient-med. to very rich sites (fmmr)
3.6 -	*Athyrium filix-femina* Moist to wet, nutrient-medium to very rich sites (mwmr)
3.7 -	*Lysichitum americanum* Wet, nutrient-medium to very rich sites (wmr)

classification functions (linear combinations of the EISG's) which best characterize differences between the BA's. These derived functions can subsequently be used to classify new plots. A detailed description of the procedure and output of DA performed by the 7M program can be found in Dixon (1983).

4.3.4 Environmental Patterns

Descriptive statistics for seven site morphological, thirteen soil physical, and fifty-seven soil chemical properties were calculated using the MIDAS statistical package (Fox and Guire, 1976). These statistics included means (MN), sample sizes (n), standard deviations (SD), and 95% confidence intervals (CI) for each property. These statistics were calculated for all fifty-one plots, for the forty-one intermediate plots in BA's 2 to 5, and for all plots in each BA taken separately. In addition, correlation coefficients (r) were calculated in order to investigate the possibility of linear trends in these properties. The seven site morphological, and a subset of fourteen soil physical and chemical properties were selected for further consideration. These properties and their assigned codes are shown in Table 13.

Preliminary analyses indicated considerable variability between BA's in the variance of most soil properties. This heteroscedasticity, or inequality of variances (Zar, 1974), precluded the application of regression analysis. Pimentel (1979) noted that the influence of heteroscedasticity on

Table 13 - Codes used to indicate the site morphological, and the selected soil physical and chemical properties.

CODE		DESCRIPTION
A. Morphological (MORPH)		
1. VCL	-	coarse fragments > 2 cm (%)
2. VCT	-	coarse fragments > 2 mm (%)
3. THECT	-	thickness of ectorganic layer (cm)
4. THAE	-	thickness of Ae horizon (cm)
5. THAH	-	thickness of Ah horizon (cm)
6. RTDPTH	-	rooting depth (cm)
7. SLOPE	-	slope gradient (%)
B. Physical and chemical (P&C)		
1. POR.123	-	porosity of mineral soil (%)
2. PHHF	-	pH of humus form (LFH or Ah)
3. PH.123	-	pH of mineral soil
4. TC.0123	-	total C ($kg \bullet ha^{-1}$)
5. TN.0123	-	total N ($kg \bullet ha^{-1}$)
6. MN.0123	-	mineralizable N ($kg \bullet ha^{-1}$)
7. CNHF	-	C:N of humus form (LFH or Ah)
8. CN.123	-	C:N of mineral soil
9. CA.0123	-	exchangeable Ca ($kg \bullet ha^{-1}$)
10. MG.0123	-	exchangeable Mg ($kg \bullet ha^{-1}$)
11. K.0123	-	exchangeable K ($kg \bullet ha^{-1}$)
12. NA.0123	-	exchangeable Na ($kg \bullet ha^{-1}$)
13. CAT.0123	-	exchangeable cations ($kg \bullet ha^{-1}$)
14. CEC.0123	-	cation exchange capacity ($e. \bullet ha^{-1}$)

N.B. Properties in part B (P&C) are weighted to rooting depth, where rooting depth refers to the depth from the ground surface down to the bottom of the effective rooting zone (the level at which the majority of roots stop).

Properties ending with the depth code "0123" include the ectorganic layer (layer 0), while properties ending with the depth code "123" do not (i.e. mineral soil layers only).

canonical axes is poorly understood, but that studies have shown that reliance can be placed on these axes for morphometric interpretations. With these limitations in mind, discriminant analysis was performed on the selected site and soil properties (Table 13) using the same 7M program (Dixon, 1983) as was discussed earlier.

Four separate analyses were performed using different combinations of plots and properties. The first combination included all fifty-one plots and the seven site morphological properties. The second combination included all fifty-one plots and the fourteen soil physical and chemical properties. The third combination included the forty-one intermediate plots for which site index of Douglas-fir could be determined (i.e. plots in biogeocoenotic associations 2, 3, 4, and 5) and the seven site morphological properties, while the fourth and last combination included the same forty-one intermediate plots and the fourteen soil physical and chemical properties. Each of these analyses was assigned a code to facilitate future discussion of the results (Table 14).

The purposes of this discriminant analysis were to: 1) select combinations of properties which best characterize differences between the BA's, 2) derive functions which could subsequently be used to classify other plots not used in the original analysis, and 3) produce canonical variable plots so that relationships between plots and BA's could be examined. Discriminant analysis has recently been used by other authors for similar purposes. Klinka _et_ _al_. (1979) used it to select

Table 14 - Analysis codes for the 4 combinations of plots and variables used in the discriminant analysis.

	number of plots	
variables	51	41
7 site morphological	DA01	DA03
14 soil physical and chemical	DA02	DA04

the climatic variables which best discriminate between biogeoclimatic zones, subzones, and variants, and Jones *et al*. (1983) used it for selecting those soil properties which best characterized differences between a number of "vegetation types".

The possibility of corresponding trends in soil and vegetation patterns was investigated by plotting detrended correspondence analysis scores with canonical variables from discriminant analysis. Correlation coefficients (r) were calculated to determine the degree of linear relationship between these ordination scores and the canonical variables.

4.3.5 Productivity Relationships

Descriptive statistics for eight mensuration variables were calculated using the MIDAS statistical package (Fox and Guire, 1976). Trends in these properties were investigated, and mean site index (m/100 yrs) values for Douglas-fir in three Cowichan

Lake associations were compared to mean site index values found by other workers studying similar associations in the CWHa.

Relationships between ordination scores, canonical variables, and site index of Douglas-fir were examined. Relationships between several indices of soil N status, two indices of soil Ca status, site humus form and growth class of Douglas-fir were also considered.

V. RESULTS AND DISCUSSION

5.1 CLASSIFICATION

5.1.1 Synopsis Of The Classification

The classification of immature forest ecosystems in the Cowichan Lake area was finalized after consideration of the results of multivariate analyses of the vegetation data, environmental properties of the fifty-one sample plots, and syntaxa recognized by other workers (McMinn, 1957; Krajina, 1969; Kojima, 1971; Kojima and Krajina, 1975; Klinka, 1976; Inselberg *et al*., 1982; and others). In summary, three orders, five alliances, and six biogeocoenotic associations were established. A synopsis of the classification is shown in Table 15.

Names proposed for each syntaxon generally followed nomenclatural rules outlined in Barkman *et al*. (1976). Association names are composed of the name of the tree species dominating the forest canopy, and the name of a characteristic understory species. The dollar sign ($) preceeding each name signifies that these associations were abstracted from analysis of vegetation data from immature forest ecosystems. Table 15 shows the probable climax association for each of the immature associations recognized in the Cowichan Lake study.

In the following text, the terms association and biogeocoenotic association (BA) will be considered synonymous. Number codes will frequently be used in the text, and in figures and tables to indicate the BA to which a particular sample plot

Table 15 - Synopsis of the vegetation classification.

SYNTAXON	NAME
ORDER 1	Gaultherio shallonis-Pseudotsugetalia menziesii (Krajina,1969) Roy,1984
Alliance 1.1	Peltigero aphthosae-Pino-Pseudotsugion all. nov. prov.
Assoc. 1.11	$Pinus-Polytrichum juniperinum Roy,1984 (Peltigero-Pino-Pseudotsugetum (McMinn,1957))* = <u>the $PC-PJ association</u>
Alliance 1.2	Gaultherio-Pseudotsugion Krajina <u>et</u> Klinka <u>in</u> Klinka,1976
Assoc. 1.21	$Pseudotsuga-Gaultheria shallon Roy,1984 (Gaultherio-Pseudotsugetum (McMinn,1957))* = <u>the $PM-GS association</u>
ORDER 2	Rhytidiadelpho lorei-Tsugetalia heterophyllae (Krajina,1969) Roy,1984
Alliance 2.1	Hylocomio-Pseudotsugo-Tsugion (Krajina <u>et</u> Klinka <u>in</u> Klinka,1976) Roy,1984
Assoc. 2.11	$Pseudotsuga-Kindbergia oregana Roy,1984 (Hylocomio-Pseudotsugo-Tsugetum (Kojima,1971))* = <u>the $PM-KO association</u>
ORDER 3	Polysticho muniti-Thujetalia plicatae (Krajina,1969) Inselberg <u>et</u> <u>al</u>.,1982
Alliance 3.1	Tiarello trifoliata-Thujion (Krajina <u>et</u> Klinka <u>in</u> Klinka,1976)
Assoc. 3.11	$Pseudotsuga-Hylocomium splendens** Roy,1984 (Hylocomio-Thujetum ass. nov. prov.)* = <u>the $PM-HS association</u>
Assoc. 3.12	$Pseudotsuga-Plagiomnium insigne Roy,1984 (Tiarello-Thujetum (McMinn,1957))* = <u>the $PM-PI association</u>
Alliance 3.2	Lysichito-Thujion (Krajina <u>in</u> Brooke <u>et</u> <u>al</u>., 1970) Krajina <u>et</u> Klinka <u>in</u> Klinka,1976
Assoc. 3.21	$Alnus-Lysichitum americanum Roy,1984 (Lysichito-Thujetum (McMinn,1957))* = <u>the $AR-LA association</u>

* Probable climax association
** Probable climax alliance for this association is Polysticho-Thujion (Inselberg <u>et</u> <u>al</u>.,1982)

or group of sample plots belong(s). These codes are as follows:

1 = the $PC-PJ association (association 1.11)

2 = the $PM-GS association (association 1.21)

3 = the $PM-KO association (association 2.11)

4 = the $PM-HS association (association 3.11)

5 = the $PM-PI association (association 3.12)

6 = the $AR-LA association (association 3.21)

5.1.2 Multivariate Analysis Of Vegetation Patterns

Gauch (1982) suggested that it is often desirable to apply several multivariate analysis techniques to the same data set and compare results. This approach was adopted for analysis of the Cowichan Lake vegetation data. Ordination space partitioning of graphs produced by RA, DCA, and PO, and the inspection of dendrograms was performed. The results are presented and discussed below.

Sample plot scores for axes 1, 2, and 3 of all RA and DCA ordinations, and plot scores for axes 1 and 2 of all PO ordinations (Table 10) are presented in Appendix E. All scores for the RA and PO ordinations have been automatically scaled into the 0-100 range by the ORDIFLEX program, whereas the DCA scores produced by DECORANA have not. Grouping order and Euclidean Distance between clusters for all four CA analyses (Table 10) are presented in Appendix F.

Ordination graphs for all three combinations of axes (i.e. axes 1 and 2, 1 and 3, and 2 and 3) of all twelve ordinations, and dendrograms for all four cluster analyses were prepared and examined. These graphs were inspected to determine which would be of greatest use for aiding in the classification. It was observed that graphs and dendrograms based on analysis of SSU's from all seven vegetation layers did not differ substantially from graphs and dendrograms based on analysis of SSU's in the four understory vegetation layers only. This was attributed to the fact that the upper vegetation layers (i.e. the forest canopy) of most of these immature forest ecosystems were dominated by Douglas-fir. The inclusion of these layers therefore contributed very little to differentiation of the sample plots in the multivariate analyses. Furthermore, it was assumed that the structure and composition of the overstory in these immature forest ecosystems had not yet had time to stabilize, whereas the structure and composition of the understory vegetation had (discussed later). For these reasons, it was decided that only ordination graphs and cluster analysis dendrograms based on analysis of understory SSU's would be considered further. It was also decided that only ordination graphs for axes 1 and 2 would be considered because these two axes account for the greatest amount of variation in the data set.

After careful examination of the understory ordination graphs and cluster analysis dendrograms, and the environment data for each plot, it was decided that six main classes would be maintained, and that the abstraction of the properties of these classes would define six biogeocoenotic associations (BA).

Ordination graphs of axis 1 and 2 scores for these ordinations are shown in Figures 2 to 7, and dendrograms for the two cluster analyses based on understory SSU's are shown in Figures 8 and 9. The BA to which a given sample plot belongs is plotted at the intersection of axis 1 and 2 scores on the ordination graphs, while both plot numbers and BA's are shown on the dendrograms. The environment data for each plot in each BA is shown in Appendix G. Selected soil chemical data and stand growth characteristics are also shown in this appendix.

Results of all three types of ordinations (RA, DCA, and PO) were very similar. In all three, plots belonging to the two environmentally extreme BA's (i.e. 1 and 6) formed relatively distinct groups of points. Sample plots belonging to BA's 3 and 4 were also clearly separated (disjunct), while plots belonging to BA's 2 and 3 formed separate but very close groups. In preliminary ordinations, there was considerable overlap between plots belonging to BA's 4 and 5. To correct this, and consequently use the information provided by the ordinations, four plots were reassigned to different BA's so that there would be no overlap in ordination space; plots 2 and 15 were reassigned from BA 4 to BA 5, and plots 20 and 22 were reassigned from BA 5 to BA 4. This reassignment produced separate but very close groups of points for BA's 4 and 5.

Gauch (1982) noted that, on one hand, the inclusion of environmentally extreme sample plots in ordinations may be very helpful for interpreting relationships between community gradients and environmental gradients but, on the other hand, if

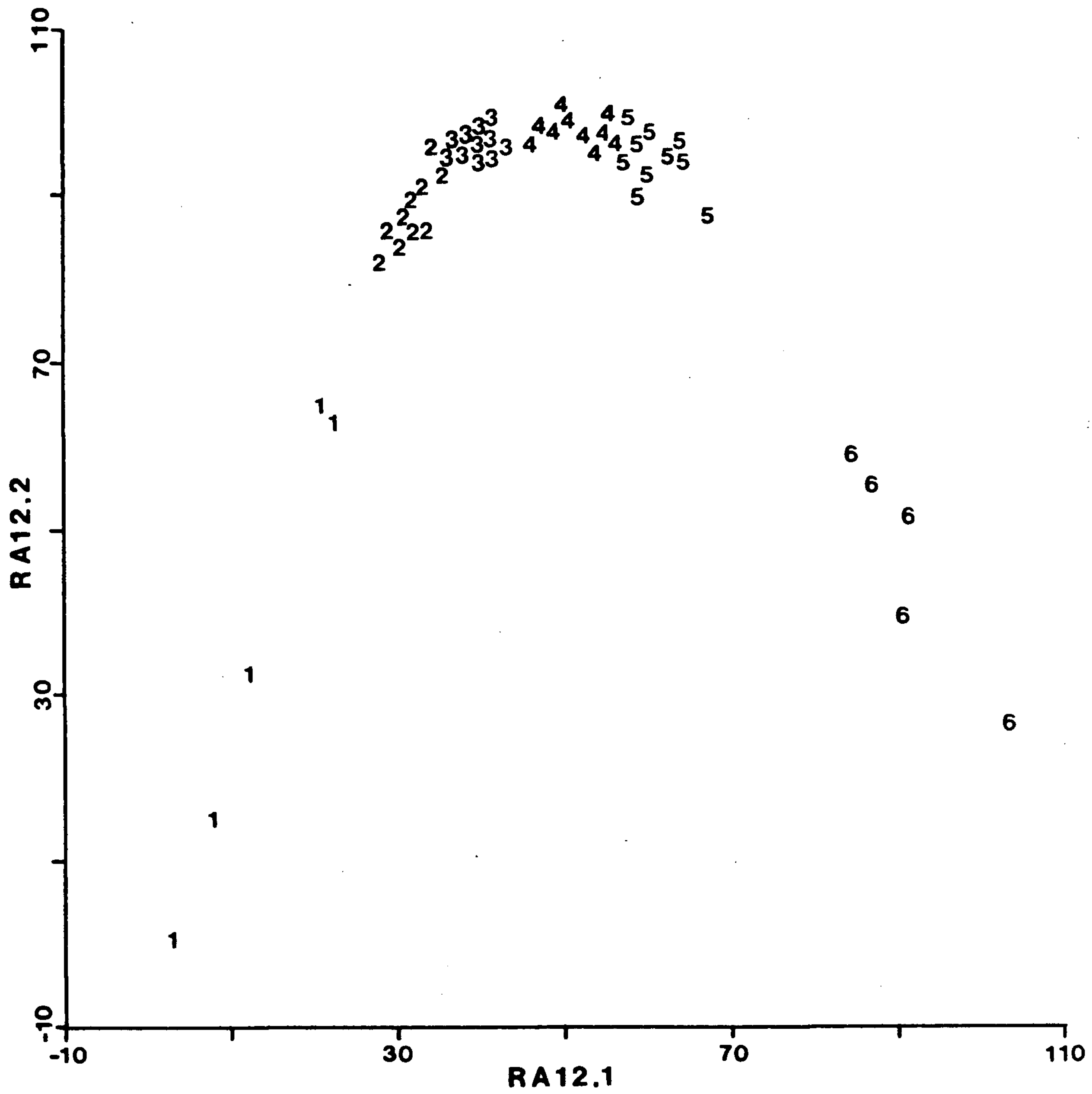

Figure 2 - Ordination graph for axis 1 (RA12.1) and axis 2 (RA12.2) of the RA12 ordination. Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

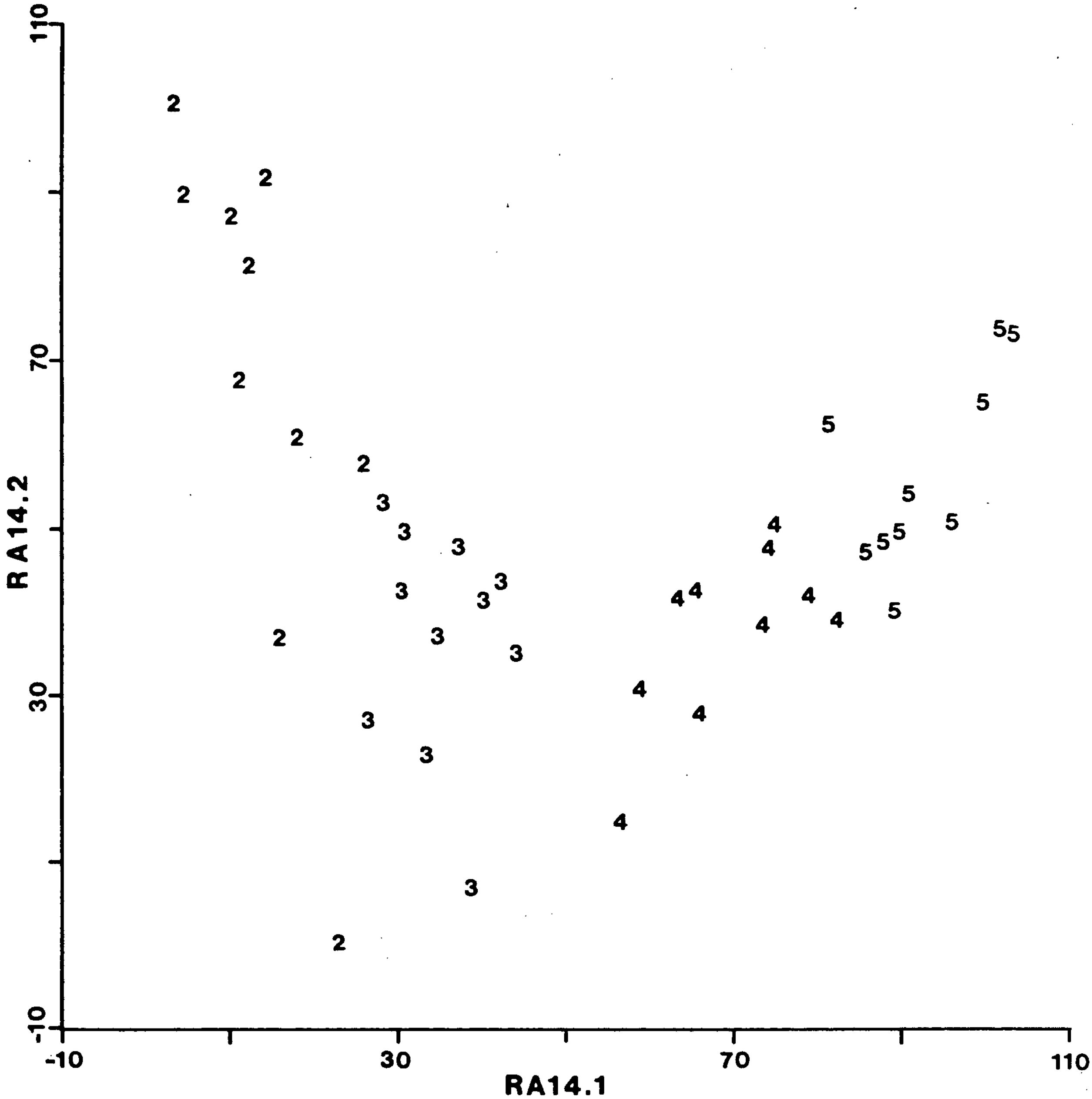

Figure 3 - Ordination graph for axis 1 (RA14.1) and axis 2 (RA14.2) of the RA14 ordination. Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

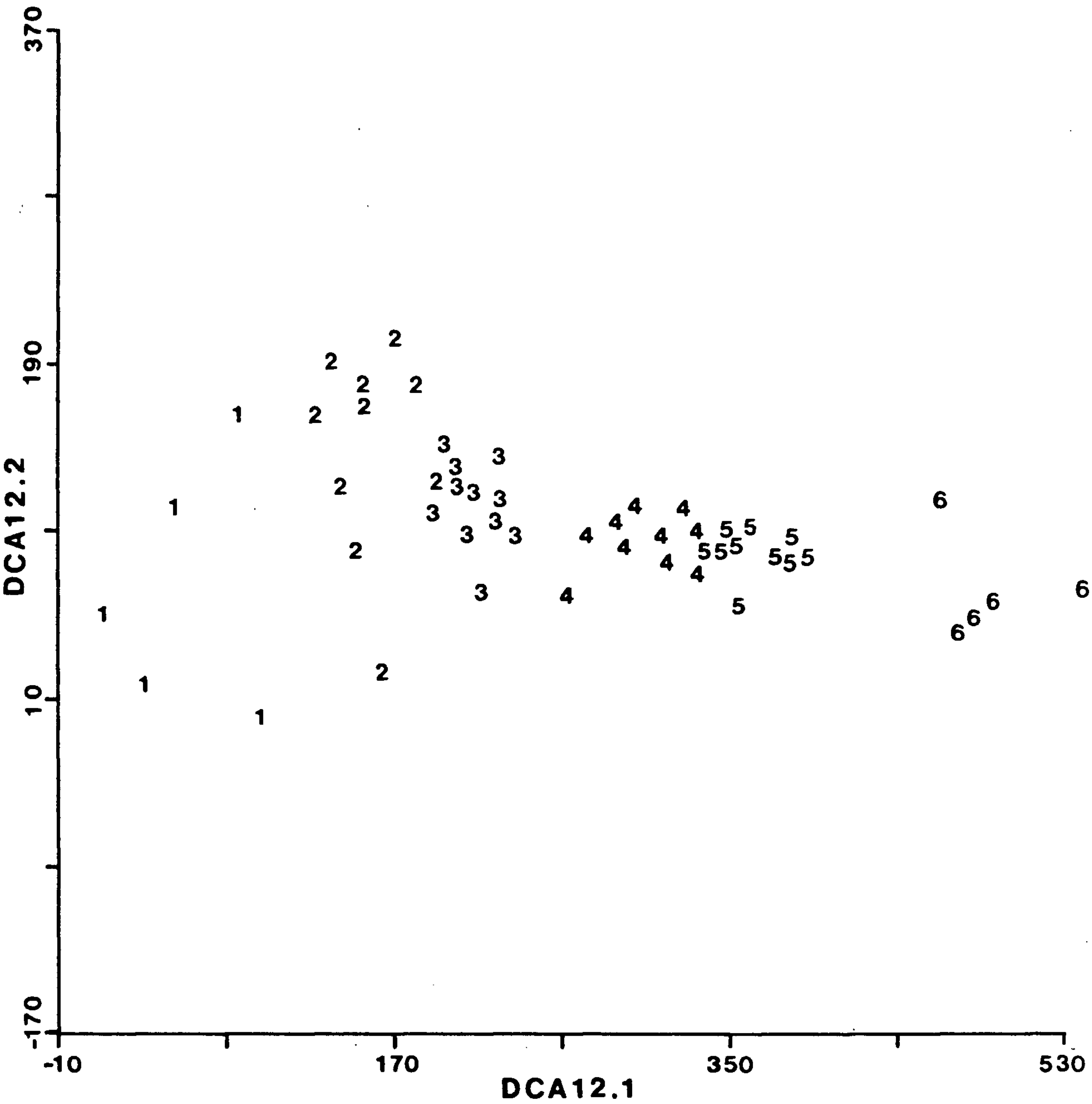

Figure 4 - Ordination graph for axis 1 (DCA12.1) and axis 2 (DCA12.2) of the DCA12 ordination. Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

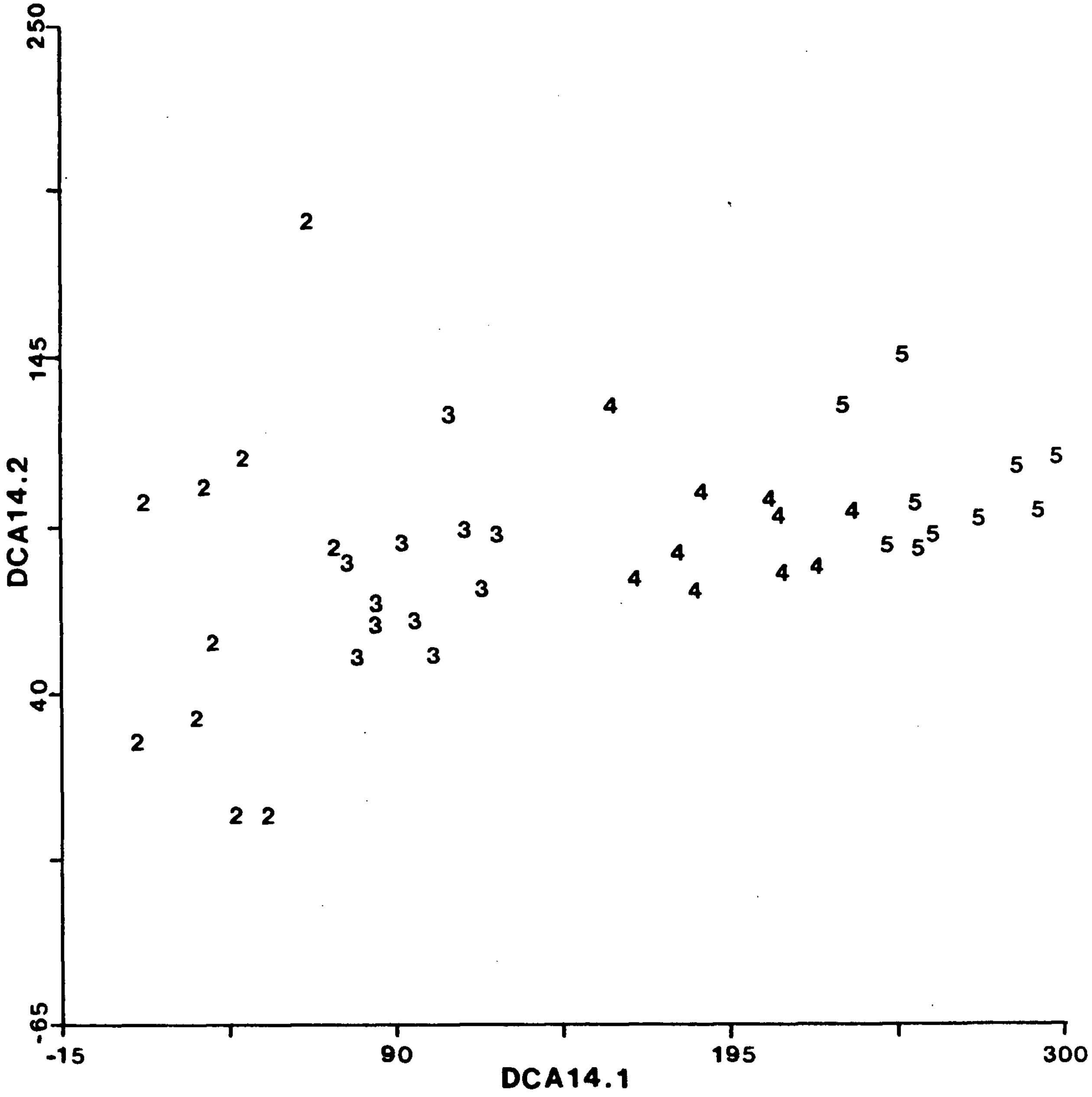

Figure 5 - Ordination graph for axis 1 (DCA14.1) and axis 2 (DCA14.2) of the DCA14 ordination. Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

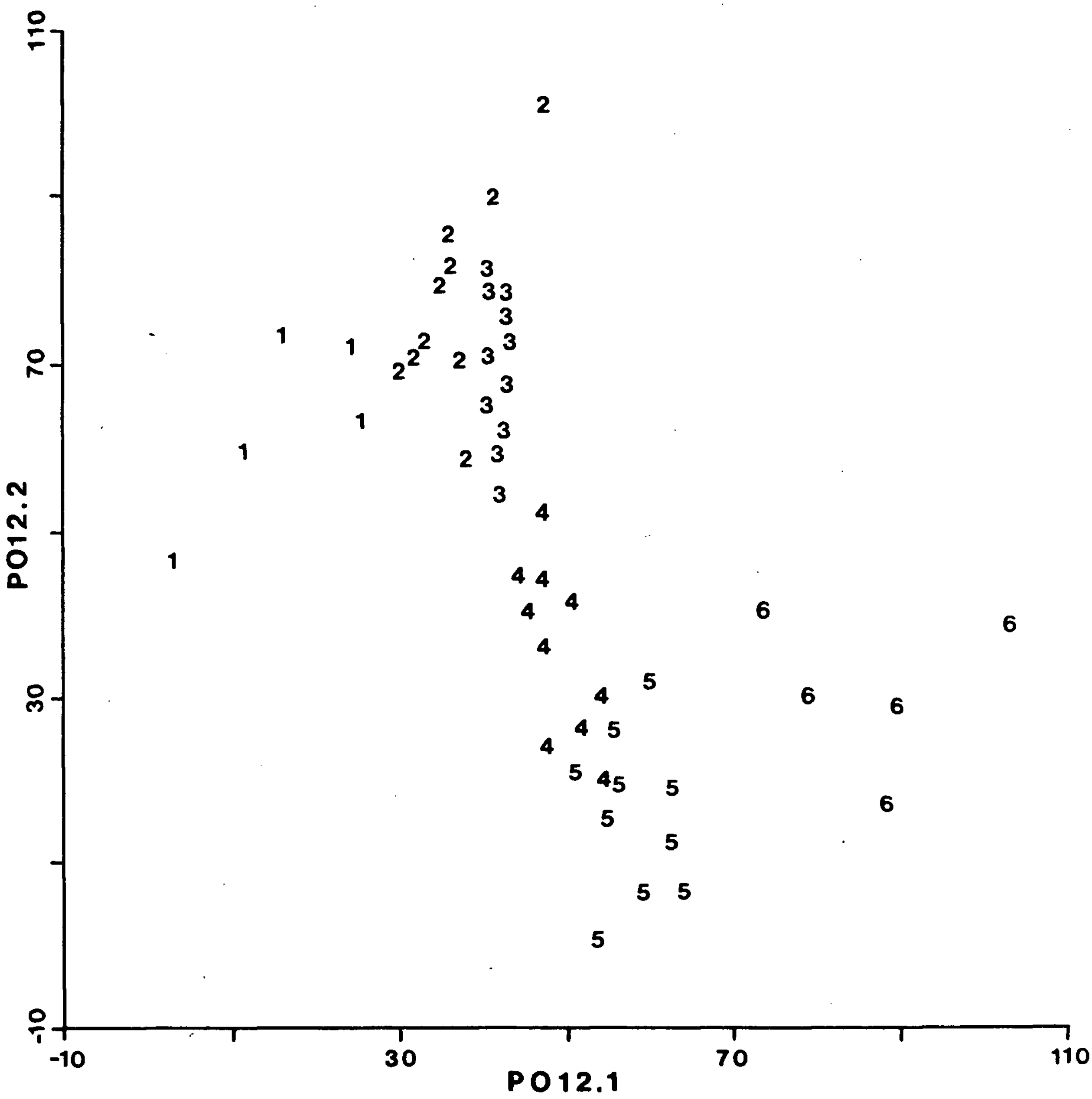

Figure 6 - Ordination graph for axis 1 (PO12.1) and axis 2 (PO12.2) of the PO12 ordination. Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

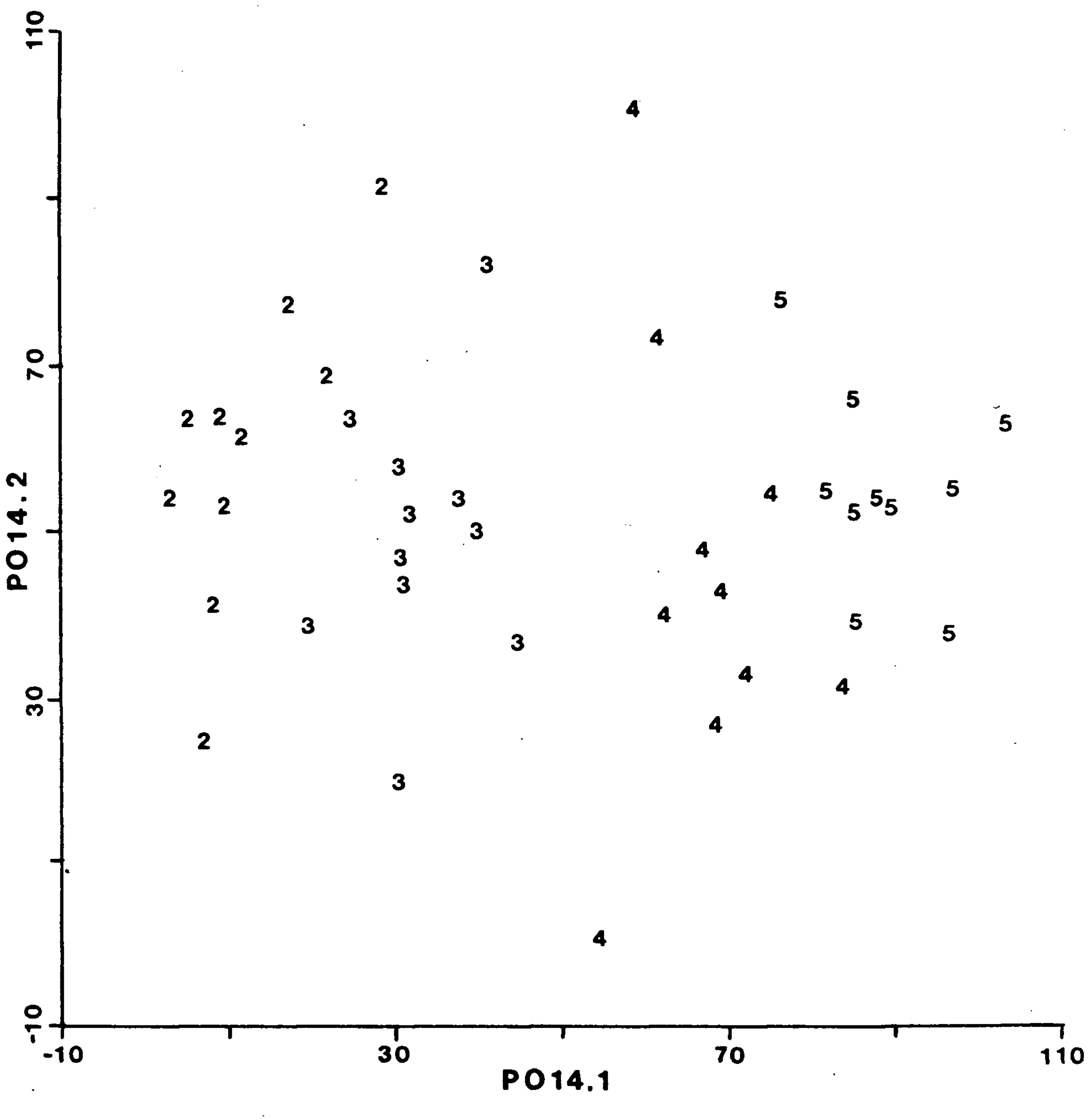

Figure 7 - Ordination graph for axis 1 (PO14.1) and axis 2 (PO14.2) of the PO14 ordination. Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

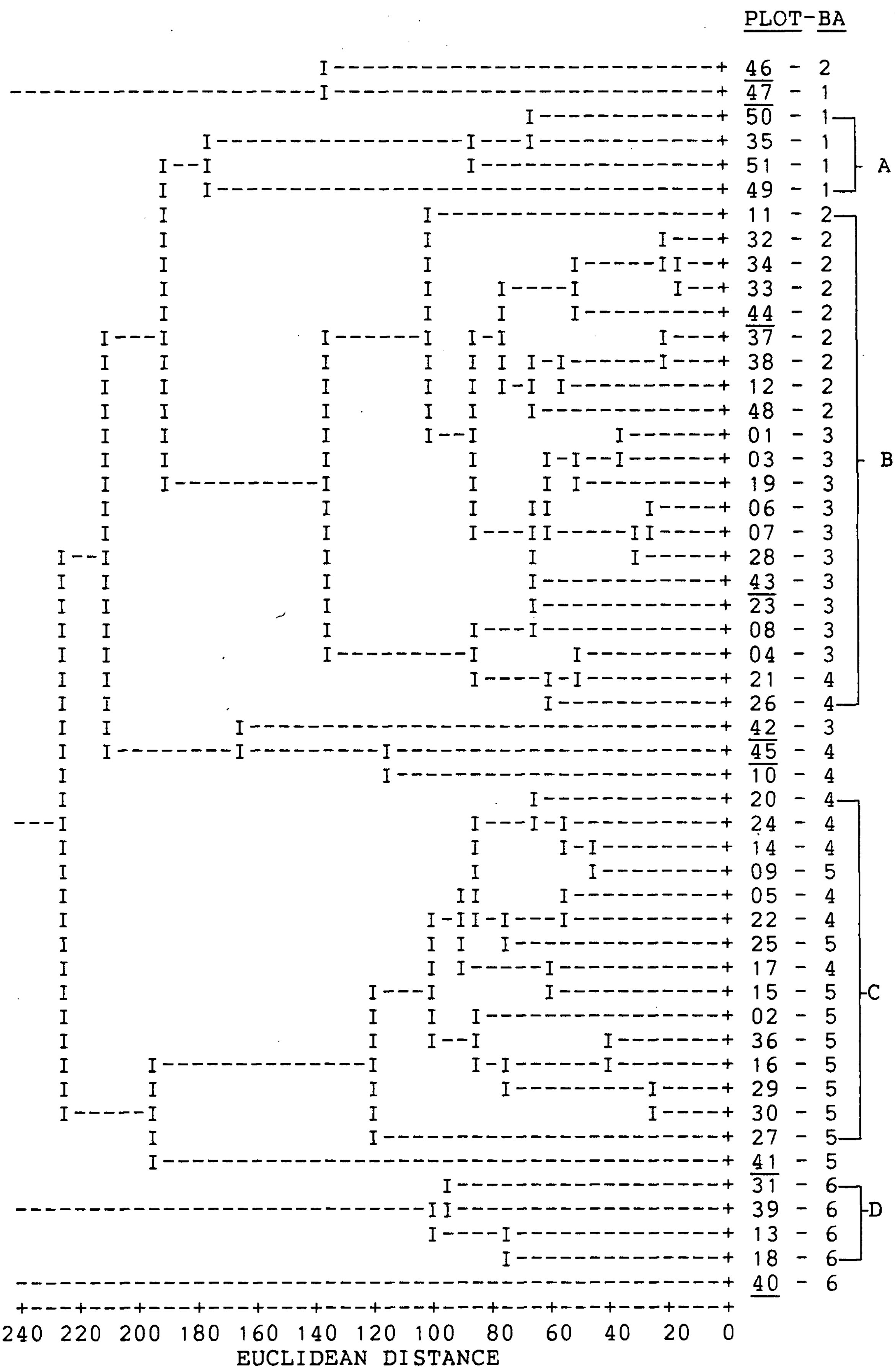

Figure 8 - Dendrogram for the CA12 cluster analysis.

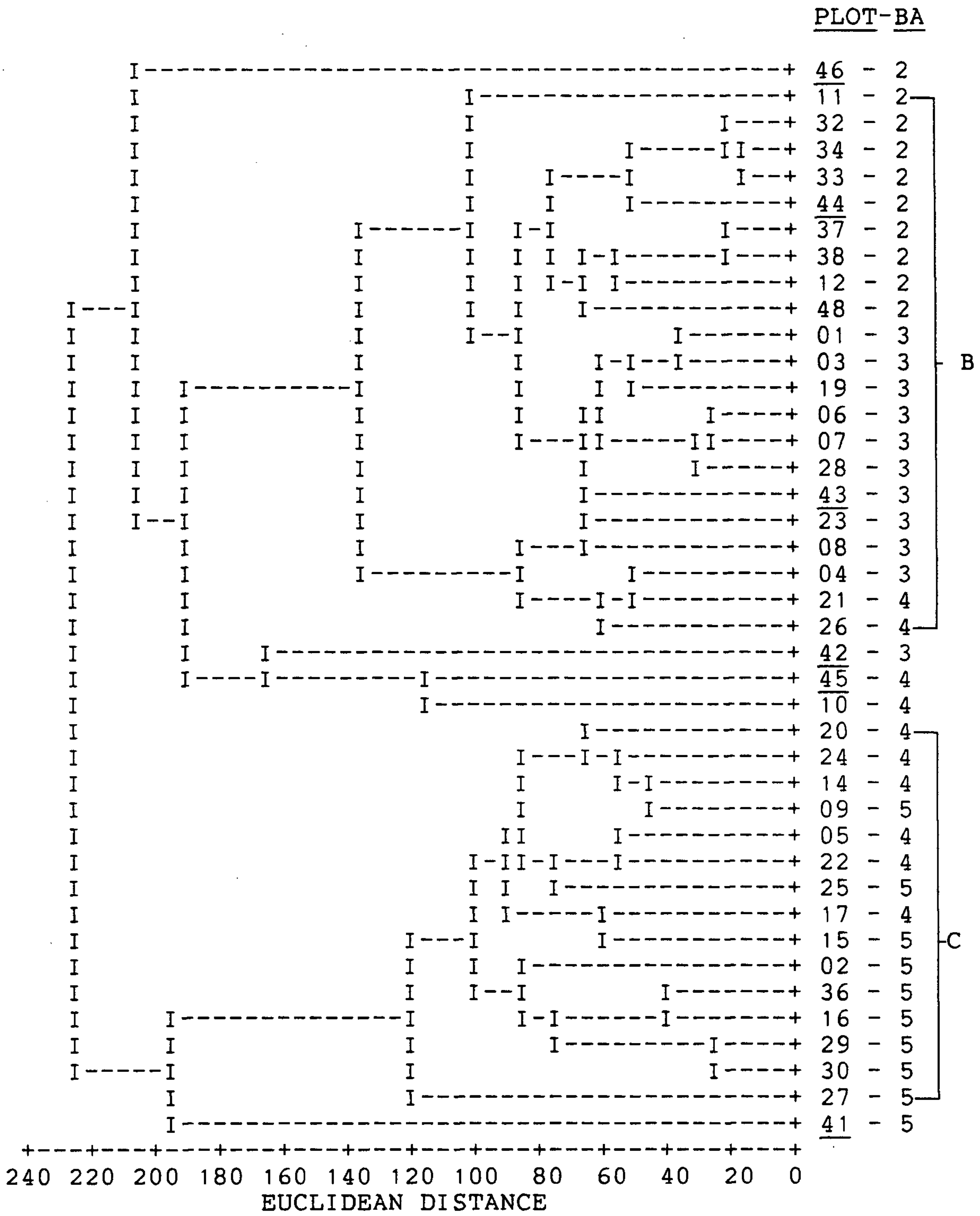

Figure 9 - Dendrogram for the CA14 cluster analysis.

these plots are vegetationally very different from the intermediate plots, they may compress the main body of points on the ordination graph into a very small space. Groups of points belonging to the two environmentally extreme BA's (i.e. 1 and 6) defined the ends of axis 1 in the objective RA12 (Figure 2) and DCA12 (Figure 4) ordinations. From site features (Appendix G), it had been estimated that BA 1 was characterized by low soil moisture (SMR=0) and nutrient (SNR=B-C) availability and BA 6 by considerably higher soil moisture (SMR=7) and nutrient (SNR=E) availability. This suggested that the distribution of sample plots along axis 1 did indeed reflect an important environmental gradient, i.e. a complex gradient related to increasing availability of soil moisture and nutrients. In the first RA ordination shown here (Figure 2), inclusion of plots belonging to the extreme BA's (i.e. 1 and 6) compressed the remaining intermediate plots into a small space. Removal of these extreme plots from the ordination resulted in a much wider distribution of points (Figure 3) but the general trend remained the same. The compression of points characteristic of the RA ordinations was not apparent in the DCA ordinations (Figures 4 and 5).

Both RA ordinations (Figures 2 and 3) showed the "arch" or "horseshoe" effect. This effect is characteristic of RA ordinations and is caused by the frequent quadratic dependency of the second axis on the first (Gauch et al., 1977; Hill, 1979a; Hill and Gauch, 1980; Gauch, 1982). In addition to the arch effect, RA has another fault which is not so obvious, i.e. the ends of the axis are contracted so that points separated by a given real distance are closer together if they lie at the ends of the axis than if they lie in the middle. DCA corrects these two problems and is considered to be the best ordination technique for plant community data (Hill, 1979a; Hill and Gauch, 1980; Gauch, 1982). However, Gauch (1982) noted that the ultimate test of the validity and usefulness of a given ordination technique is the interpretability of results. For analysis of the Cowichan Lake vegetation data, both RA and DCA ordinations proved satisfactory as both produced (very similar) environmentally interpretable results.

In contrast to the two entirely objective ordination methods discussed above (i.e. RA and DCA), PO is computationally much simpler and allows the incorporation of user-specified information. Whereas plots defining endpoints (poles) for axes in RA and DCA are selected entirely on the basis of automatic comparisons of species composition of the plots, endpoint selection for axes in PO may be done by the user. For example, plots known to define extremes of an environmental gradient may be selected as endpoints. PO is thus intermediate between direct gradient analysis methods and indirect methods like RA and DCA (Gauch, 1982). In PO ordination space, plots similar to the plot defining the first endpoint will be located near the first endpoint, plots similar to the plot defining the second endpoint will be located near the second endpoint, and plots dissimilar to both endpoints will be located around the centre of the ordination axis. Plots selected for axis 1 endpoints (i.e. plots 50 and 18) in the PO12 ordination (Figure 6) were from the two environmentally extreme BA's. In addition, these plots defined axis 1 endpoints for both the RA12 and DCA12 ordinations. Plots selected for axis 1 endpoints (i.e. plots 32 and 27) in the PO14 ordination (Figure 7) were from the two environmentally most different of the four intermediate BA's. These plots defined axis 1 endpoints of the RA14 and DCA14 ordinations. Although results of PO (Figures 6 and 7) were similar in general trends to the more objective RA and DCA ordinations, separation of clouds of points representing different BA's was generally not as distinct in the PO ordinations. PO ordinations do not contain the full information provided by the SSU by plots matrix. These ordinations only contain information on the similarity of plots to the endpoint plots, and not to all other plots as in RA and DCA. For this reason, the results of PO did not carry as much weight as RA and DCA for the reassignment of sample plots to different BA's and establishment of the classification.

As mentioned earlier, the AVERAGE clustering algorithm was used to produce the dendrograms shown in Figures 8 and 9. The cophenetic correlation coefficient (CCC) for all seven clustering algorithms available in MIDAS (Fox and Guire, 1976) was calculated for both the CA12 and CA14 cluster analyses. For the CA12 cluster analysis, the CCC using the AVERAGE clustering algorithm was .83 which was higher than that for any of the other six algorithms. For the CA14 cluster analysis, the CCC was .73 using the AVERAGE clustering algorithm. The CCC for this latter analysis was only exceeded when the CENTROID algorithm was used (CCC = .76). The CCC is a measure of the correlation between the distances implied in the dendrograms and those in the original matrix, and its maximization implies a good match between the two (Sneath and Sokal, 1973; Gauch, 1982). Pimentel (1979) stated that, usually, CCC's greater than .75 are considered "good fit" and the algorithm providing the largest coefficient is deemed best. However, he mentions a study by Farris (1977) who stated that this coefficient is not a reliable indicator of the best algorithm. Pimentel (1979) also stated that no method consistently outperforms all others, but "furtherest neighbour" (COMPLETE) and "group average" (AVERAGE) are often accepted as better techniques.

Plot order in the dendrograms shown in Figures 8 and 9 has been changed from that in the original MIDAS output to approximate as closely as possible plot order on axis 1 of the RA and DCA ordinations. This was accomplished by viewing the dendrogram as a hanging mobile, the pendant branches of which can be rotated to a new configuration. By rearranging the dendrogram in this manner, similar clusters are placed in closer proximity and the dendrogram becomes easier to interpret. A similar process is performed automatically by a computer program (TWINSPAN) developed by Hill (1979b).

It was observed that cluster membership and clustering levels of the forty-one intermediate plots in BA's 2, 3, 4, and 5 were virtually identical in the CA12 (Figure 8) and CA14 (Figure 9) cluster analyses. For this reason, the following comments apply to both dendrograms.

In Figures 8 and 9, plot numbers for the plots selected and surveyed by MOF staff (i.e. plots 40-47) are underlined. Six of these (plots 46, 47, 42, 45, 41, and 40) did not "fit" into the main clusters as they were linked at higher clustering levels. It was speculated that this may have been due to the relatively higher species significance estimates of the MOF surveyors compared to the more conservative estimates of species significance on the forty-three plots sampled in 1981. One of the plots sampled in 1981 (plot 10) also did not "fit" well into the main clusters.

Disregarding the seven plots which did not "fit" well, it was observed that the forty-four remaining plots formed four main clusters at a Euclidean Distance of 180. There were two "dry-site" clusters (clusters A and B) and two "wet-site" clusters (clusters C and D). Plots from BA 1 formed a distinct "dry-site" cluster (cluster A), and plots from BA 6 formed a distinct "wet-site" cluster (cluster D). The other "dry-site" cluster (cluster B) contained nine plots from BA 2 (eight of which formed a separate sub-cluster), ten plots from BA 3 (seven of which formed another separate sub-cluster), and two plots from BA 4 which were in a sub-cluster with three plots belonging to BA 3. The other "wet-site" cluster (cluster C) contained six plots from BA 4 and nine plots from BA 5. This "wet-site" cluster had two main sub-clusters: one which contained six BA 4 plots and three BA 5 plots, and one which contained five plots, all of which belonged to BA 5. In summary, the results of cluster analysis agreed somewhat with the results of ordination space partitioning using RA and DCA but considerable differences in suggestions for the number of classes and class membership were noted.

It was decided that less weight would be put on cluster analysis than RA and DCA ordination space partitioning for establishment of the classification because of the two following reasons: the use of Euclidean Distance by cluster analysis in the MIDAS package, and the fact that cluster analysis is an agglomerative technique. Gauch (1982) noted that Euclidean Distance tends to emphasize dominant species when sample plot similarities are calculated. He suggested that PD (such as used by PO) is a better measure of dissimilarity, but PD is not available in MIDAS. He also noted that agglomerative classification techniques begin by examining small distances between similar samples and that, in plant community data, these small distances are more a reflection of "noise" than anything else. For this reason, he indicated a preference for divisive classification techniques such as ordination space partitioning.

5.1.3 Tabular Methods

In the preceeding section, the number of classes and class membership of each plot was finalized after consideration of environment data for each plot (Appendix G), and the results of multivariate analysis (particularly RA and DCA) applied to the floristic data. Following this, floristic and environment information for each class was synthesized using the tabular methods described earlier.

Complete vegetation data for each plot in each BA is presented in long vegetation tables shown in Appendix H. Information on the understory SSU's (which determined the classification much more than overstory SSU's) is summarized in Table 16. This table is an arranged understory SSU by plots matrix which was produced by ORDIFLEX for the RA12 ordination. Plot numbers and the BA to which each plot belongs are printed across the top of the table while SSU codes are printed along the left side. SSU codes are formed from the first three letters of the genus name, the first three letters of the species name, and the vegetation stratum (Table 4) to which an SSU belongs. Table entries are the species significance of each SSU in each plot. The order of SSU's and plots in the matrix has been arranged by ORDIFLEX according to their order on axis 1 in the RA12 ordination.

Gauch (1977,1982) noted that an arranged matrix makes available at a glance both the raw data in its entirety and the overall pattern of species distributions so that the reader can at once gain both detailed (analytic) and general (synthetic) information. He also noted that, if there is one main gradient inherent in the data, the arranged matrix should show a concentration of larger values along the matrix diagonal (banding). Table 16 does show definite banding along the matrix diagonal. The gradient implied by this banding has been mentioned earlier. It was suggested that the change in species composition from BA 1 to BA 6 reflects a complex environmental

Table 16 - Arranged species-stratum-unit (SSU) by plots matrix for the Cowichan Lake vegetation data. SSU codes and plot numbers are arranged according to axis 1 order in the RA12 ordination.

ASSOCIATION	11111222222222223233333333333444444444444555555555566666
PLOT NUMBER	535443311334340400042401204221210212001432123241331
	051977212486341836733289845160475042295165690703198
SSU	
HYPRAD6	1++--
PLAUNA6	+++--
FRAVIR6	121+---
ARCUVA6	431-2--
ACHMIL6	12--1--
DICSCO7	4341---+-+---
PELAPH7	++++---
HOMMEG7	1-41---
POLJUN7	45114---1--
HIEALB6	131+3---+--------------+---------------------------
CLAGRA7	+-+-2--
CLARAN7	+-+-2--
LILCOL6	+---2-+--
FESOCC6	+3+13------2--+----+-----------+-------------------
HOLDIS4	5116-433-12-1--2-----------------------------------
ARBMEN4	--+6--1--+--+--------------------------------------
ANELYA6	----2--+---1---+-----------------------------------
PSEMEN4	-+24--52-32-43--1----------------------------------
HOLDIS5	1-2172122114--++-1-------+-----2-------------------
LONCIL5	-+---++----3---------------------------------------
PSEMEN7	----2---+--2--1-----------+------------------------
ROSGYM5	+11132231223+--2+1--+-31-1--+----+--+--------------
LISCOR6	++1+2-++1++--1++-++1-2+11+--+----------------------
GOODBL6	1+1121-+1-+2--+-+-++-1--++1-++++------+------------
MELSUB6	---14-----+3-----------------------+----1---+------
HEMCON6	-----+-+----+--+--+--------------------------------
GAUSHA5	-13575998978998985546545422--11-1-----1------1-----
RHYTRI7	++-53--21--5--2+---1-31--+2-+-------+--3-----------
SYMALB5	--++22131+1-1----+----+--+------1+--2--------------
CHIUMB6	-------+-----+--+----------------------------------
MAHNER5	+135562362543332544 3+524524-111+-+--3--------1-----
VIOSEM6	----3--+1--2-----+---3--1+--+-+-+------------------
CHIMEN6	-----++-+-------+-+----+-+-------------------------
PELCAN7	-----------1------+--1-----------------------------
PELPOL7	--------++-----------2-----------------------------
PELMEM7	---+---+-------------3-------+---------------------
TSUHET7	----------+2--+----2---+--1--1---------------------
HYPLAN6	-------------------+-+-+---------------------------
RHYLOR7	--+-3--21--5--1++--1-31++31-1+-+-++-1---+-------+--
VIOORB6	---+1-+----1-----+------1-3--+-----------------+---
HYLSPL7	13457+-64++6-1224-248661+657642-2++5-1+513+---+1-+--
CORMER6	----------+---------+-----+-----+------------------
AMEALN5	+------+-++--+-----++-+--+-1-++--++---+-+----------
RUBURS6	+1++11111+121--1111-+-1111+++++1+----+-----+++--+1++--
PLAUND7	--+-2--+++---11---+2-3-++-2+-+--2----+-2-----------
KINORE7	-5+575664457368685886759788657673635425424 1++1-++--
THUPLI5	------1-1--3+--31-+3-311--1-------+--2---+-1-+------
CIRALP6	---2------2-------------1--------------------+--+
PTEAQU6	------1121+-12311323223213 1+11211--1--1++---++--+--
TRILAT6	--+13+++1++2---1+1-+-2+++13-+2++1--+111-+++11+-----
VACPAR4	-------------+--+----2----+---11-------------------
POLGLY6	+---------+---------------------------1+-----------
LINBOR6	---+1---1--2--21-1121431+32-131-1+--------+----+2---
TSUHET5	------1--++2141-11+3+311113115++-11--+-3+-1++----+-
FESSUB6	---------------++-----3---2-----+--+------------+-----
ELYGLA6	-++--------------------------------3---------
VACPAR5	---+-+12-113254+412426-51424522-33-4++-5+1--+16-1--
TSUHET4	------3-132-55233225354452256755265-25-532+4244--1-
THUPLI4	-----2---2-1--42---355----2+5-----43--5-353-3----
ACHTRI6	+----+++++3+-12+12314224241444734354376232573 21+--
RUBPAR5	-------------------------+-----+------------------+-----
ABIGRA5	--------------------4-------5------22-1+--12------
TRIOVA6	--------+--2---++++-+1+++11+111+11-121+211111++-+-
POLMUN6	+---2-+321+31-22253223424658438797986879799983412-
RHIGLA7	-------+-+-+--------+------4+-3++-+311-1-+2------+1-
ACEMAC5	---------------1-----+------1--+---+-11-+--++1-----
ADEBIC6	--------------+-----+----+--1-1++1++--2++-11+111-----
ABIGRA4	---------------------------2-2-----------11------
MONUNI6	------------------------------+------+---+--+-------
DISHOO6	-------------------+-+-++--1112--12+211-2-+-211++---
MAIDIL6	------------------+-----1++--++---2-+1-------++1-+-+-
RHAPUR5	---------------------------------+-+-+----------
BROVUL6	-----+-+-++--------------------1++1-----11-+---+++11---
ACEMAC7	---------------+---------+-+---+-+----22+-+-121------
MYCMUR6	+-----+--++-+-+-+------2--++3-23+33++-114341212222 1-+
TIALAC6	---+-------------------+----2++2++1++1+113112++-1+-+-
CARHEN6	----------------------+----------+-----12+-1++-----
TIATRI6	--------------------+11+-+4+221334152215624223 42-1+
STRAMP6	------------------------+-+-22--2-++++-11++--1--++
MALFUS5	---------+-------------------------------------+-
ACEMAC4	---------------------1---1+-------------1+4-----
GALTRI6	--------------+---------+2-12132+1112231311225+---
GYMDRY6	--------------------------------+1----1-2++----
LUZPAR6	------------------------1------+-----+---1+-----+1----
BROSIT6	--+-------------------+--+--+-----+--+4-----1-+--1
LEUMEN7	-----------2---1------------+-+----2---+51+1+-3-++
VIOGLA6	--+++----
BLESPI6	---------------------------2+-+2++-++-211+-3---51---
ADIPED6	-------------------------------------1----1-----+---
DRYEXP6	---------------------------++-+-1++2-2121-2++12--2-
DICFOR6	--2++----
PLAINS7	----------------------------+-++1++13-3642233551-21
RUBSPE5	--------------------------+-+-1++-+-2+21-++12135111-
OSMCHI6	-----------------------------+-+---1------++1-+-1-
OPLHOR5	----------------------------------+----+---2--+3----
CINLAT6	--------------------------------------2------++
CLASIB6	---------------------------+-++++3--+1114+-21
TRACAR6	--------------------------------2--3----1-++452-6-
STACOO6	--------------------------------------+-2---12+42+11
BRAFRI7	---1---------++
CARDEW6	------------------------------+-----+------+------1--1
ATHFIL6	------------------------------1++1---3112++427+38
RUBSPE4	---------------------+-----------------221-3-53
KINPRA7	-----------------------------------+------+-+63+11
VERVIR6	---+3--2-
CONCON7	--6+--+
RANUNC6	-------------------------------+-------+-----------2---2
MITOVA6	---+-6---2
EQUTEL6	---5+-+3
LYSAME6	---78988
OENSAR6	---6-1-4

gradient related to increasing soil moisture and nutrient availability. The plausibility of this hypothesis will be discussed later when edatopic indicator species groups (EISG) and soil properties are treated in greater detail.

An examination of Table 16 reveals that, to varying degrees, species distributions tend to be concentrated in particular BA's. Thus, it is possible to characterize each BA by a list of the species with a distribution concentrated in that particular BA, i.e. the Characteristic Combination of Species (CCS). A hierarchy may be formed by grouping vegetationally similar BA's into plant alliances, and vegetationally similar plant alliances into plant orders. Syntaxa at all levels of the hierarchy are characterized by their own unique CCS. Different plant orders are characterized by a different CCS. Plant alliances are characterized by the CCS of the plant order to which they belong plus a list of species which differentiate between that alliance and other alliances within the order. Similarly, BA's are characterized by the CCS of the plant alliance to which they belong plus a list of species which differentiate between that BA and other BA's within the alliance.

The procedure used to determine the CCS of each syntaxon has never been outlined in detail in any of the publications relating to the development and application of the biogeoclimatic system. It is unclear whether or not procedures used, and results obtained by different authors using the biogeoclimatic system are strictly comparable. To help alleviate this problem, an objective, repeatable procedure was developed and proposed for use in future studies.

First, criteria for assigning differentiating values to plant species were developed (Table 17). These criteria were modified from Inselberg et al. (1982). Subsequently, an objective, repeatable procedure for extracting from summary vegetation tables the characteristic combination of species for orders, alliances, and associations was developed. This procedure is outlined below:

A. Prepare separate summary vegetation tables for orders, alliances, and associations.

B. Examine the summary vegetation table for orders. For each species:

   1. Assign a tentative constant (c) or constant-dominant (cd) value where applicable. Underline presence class (PC) and mean species significance (MS) and enter appropriate symbol on right side of MS in summary table.

   2. By comparing to all other syntaxa of the same rank, assign a tentative exclusive (e), selective (s), preferential (p), or companion (co) value where applicable. Underline PC and MS (if not already underlined) and enter appropriate character-species symbol on right side of MS in summary table. If a c or cd symbol is present, put character-species symbol above it.

   3. By comparing to all other syntaxa of the same rank and circumscription (i.e. all syntaxa which belong to the same syntaxon at the next higher categorical rank), assign a

Table 17 - Criteria for assigning differentiating values to plant species (modified from Inselberg *et al.*, 1982).

NAME(symbol)	DESCRIPTION
CHARACTER-SPECIES	
EXCLUSIVE (e)	displays a distribution exclusively, or almost exclusively, restricted to a particular syntaxon; PC[1] ≥ IV, MS[2] variable; may be rarely associated with other syntaxa within the same rank, but only when these other syntaxa are geographically adjacent, and PC in these other syntaxa is I
SELECTIVE (s)	displays a distribution which is strongly associated with a particular syntaxon; PC ≥ IV, MS variable; may be infrequently associated with other syntaxa within the same rank, but only when these other syntaxa are geographically adjacent and PC in these other syntaxa is II
PREFERENTIAL (p)	displays a distribution which is definitely associated with a particular syntaxon; PC ≥ IV, MS variable; may be associated with other syntaxa within the same rank, but only when these other syntaxa are geographically adjacent and PC in these other syntaxa is III
COMPANION (co)	displays a distribution which shows an association to a particular syntaxon; PC ≥ II, and at least one presence class higher than in all other (geographically adjacent) syntaxa of the same rank, MS variable
DIFFERENTIAL-SPECIES	
DIFFERENTIAL (d)	displays a distribution which shows an association to a particular syntaxon; PC ≥ III, and at least two PC higher than in all other syntaxa within the same rank and circumscription, MS variable
CONSTANT-SPECIES	
CONSTANT-DOMINANT (cd)	a species with PC = V and MS ≥ 5.0 in a particular syntaxon
CONSTANT (c)	a species with PC = V and MS < 5.0 in a particular syntaxon
ACCIDENTAL-SPECIES	
ACCIDENTAL (a)	displays a distribution which does not meet with any of the above criteria; such species do not appear to be allied to any particular syntaxon and should not be used in a Characteristic Combination of Species (CCS)

[1] Presence Class [2] Mean Species Significance

tentative differential (d) value(s) where applicable. Underline PC and MS (if not already underlined) and enter the differential species symbol (d) on left side of PC in summary table.

C. Examine the summary vegetation table for alliances. For each species, repeat steps 1-3 in B above.

D. Examine the summary vegetation table for associations. For each species, repeat steps 1-3 in B above.

E. For each species, examine the tentative assignments made in all three summary vegetation tables (orders, alliances, and associations) in steps B-D above. Follow the rules listed below to make the final assignments:

1. For each species and each order, assign the final constant-species value to the syntaxon at the highest categorical rank that includes only lower syntaxa with a PC of ≥ IV for that particular species. Circle the symbol. Within each order, if a cd value has been assigned to a syntaxon at higher categorical rank, disregard all other c or cd assignments at lower rank. However, if a c value has been assigned at higher rank, a cd value may be assigned to one or more subordinate syntaxa.

2. For each species, assign the highest character-species value at whatever rank it occurs. Circle the symbol and disregard all other character-species assignments (N.B. a particular species can only have a character-species value for one syntaxon). If it has been assigned the same

character-species value for more than one syntaxon, assign it to the syntaxon at the highest rank that includes the species in all lower syntaxa.

3. For each species, assign the final differential-species (d) value(s) to all syntaxa which have not been assigned a character-species value for that particular species. Circle the symbol(s).

F. Reexamine the summary vegetation table for orders. For each order, prepare a list of species which have at least one circled symbol in the summary table. On this list, add all circled symbols in brackets after the species' name. These lists constitute the Characteristic Combinations of Species (CCS) for the orders.

G. Reexamine the summary vegetation table for alliances. For each alliance, prepare a list of species which have at least one circled symbol in the summary table. On this list, add all circled symbols in brackets after the species' name. These lists constitute the CCS for the alliances.

H. Reexamine the summary vegetation table for associations. For each association, prepare a list of species which have at least one circled symbol in the summary table. On this list, add all circled symbols in brackets after the species' name. These lists constitute the CCS for the associations.

I. From a full species list, delete all those species which occur in the CCS of one or more syntaxa(on). The remaining species constitute a list of the accidental (a) species.

The procedure outlined above was applied in the Cowichan

Lake study to derive the CCS for all syntaxa. Table 18 shows the CCS for all three plant orders, all five plant alliances, and all six BA's, while Table 19 shows the list of accidental species. In Table 18, species names are followed by (in brackets) the differentiating value (Table 17) for that species in that syntaxon. Tables 18 and 19 are based on the summary vegetation table for BA's produced by F405:VTAB, and table entries are presence class (PC) and mean species significance (MS) for each species in each BA.

5.2 COMPARISON WITH MATURE FOREST ECOSYSTEMS

Several studies done in immature, second-growth Douglas-fir stands (Spilsbury and Smith, 1947; Becking, 1954; Mueller-Dombois, 1959,1965; British Columbia Forest Service, 1974) have recognized a sequence of understory plant communities similar to that described earlier for mature forests (i.e. dominance of Gaultheria shallon on dry sites, minor Gaultheria shallon and Polystichum munitum, and abundant mosses on mesic sites, and dominance of Polystichum munitum on moist sites). Kellman (1969), working in the CWHa in B.C., found that understory species present before logging maintained themselves in logged areas, although with reduced abundance, and gradually increased in importance as secondary succession progressed. Daubenmire (1976) noted that understory communities present beneath seral Douglas-fir stands closely approximate those which will be present when western hemlock replaces the Douglas-fir. He

Table 18 - Characteristic Combinations of Species for orders, alliances and associations.

PLANT ORDER	1		2	3		
PLANT ALLIANCE	1.1	1.2	2.1	3.1		3.2
BIOGEOCOENOTIC ASSOCIATION (number of sample plots)	1.11 (5)	1.21 (10)	2.11 (11)	3.11 (10)	3.12 (10)	3.21 (5)
Order 1						
Anemone lyallii (co)	1 1.0	II +.0				
Arbutus menziesii (e)	5 5.0	III 2.8				
Gaultheria shallon (cd)	4 5.1	V 8.8	V 5.8	II 1.0	I +.0	1 +.1
Holodiscus discolor (s,c)	5 5.5	V 3.4	II +.0	I +.3		
Hylocomium splendens (c)	5 5.2	IV 4.3	V 5.3	V 5.1	IV 3.0	2 +.3
Kindbergia oregana (cd)	4 5.3	V 5.7	V 7.9	V 6.3	V 3.8	2 +.0
Lonicera ciliosa (co)	1 +.0	II 1.1				
Mahonia nervosa (c)	5 4.5	V 4.9	V 4.5	III 1.9	I 1.1	
Melica subulata (co)	2 2.5	I 1.1			II +.0	
Pinus contorta (d)	5 8.3	II 3.8				
Pseudotsuga menziesii (cd)	4 5.8	V 9.5	V 9.1	V 8.7	V 8.5	
Rosa gymnocarpa (p,c)	5 2.1	V 2.5	III 1.3	I +.0	I +.0	
Rubus ursinus (co,c)	5 1.1	V 1.4	IV 1.1	IV +.5	II +.0	3 +.5
Salix sitchensis (co)	2 1.6	I +.1				
Symphoricarpos albus (s)	3 1.1	IV 1.7	II +.0	I +.0	I +.3	
Viola orbiculata (co)	2 +.3	I +.0	I +.0	I 1.1	I +.0	
Alliance 1.1, Association 1.11						
Achillea millefolium (co)	3 1.4					
Arbutus menziesii (d,cd)	5 5.0	III 2.8				
Arctostaphylos uva-ursi (e)	4 3.1					
Cladina rangiferina (co)	3 1.1					
Cladonia furcata (co)	2 1.1					
Cladonia gracilis (co)	3 1.1					
Collomia heterophylla (co)	2 +.0					
Dicranum scoparium (e)	4 3.6	I +.0				
Elymus glaucus (co)	2 +.0				I 1.0	
Festuca occidentalis (p,c)	5 2.5	I +.3	I +.0	I +.0		
Fragaria virginiana (e)	4 1.4					
Goodyera oblongifolia (co,c)	5 1.6	III 1.0	IV +.3	III +.2	I +.0	
Hieracium albiflorum (s,c)	5 2.6	I +.0	I +.0			
Holodiscus discolor (cd)	5 5.5	V 3.4	II +.0	I +.3		
Homalothecium megaptilum (co)	3 2.6					
Hylocomium splendens (cd)	5 5.2	IV 4.3	V 5.3	V 5.1	IV 3.0	2 +.3
Hypochoeris radicata (co)	3 +.5					
Lilium columbianum (co)	2 1.1	I +.0				
Listera cordata (c)	5 1.4	IV +.6	V 1.1	I +.0		
Montia parvifolia (co)	2 +.3					
Peltigera aphthosa (e)	4 +.3					
Pinus contorta (s,cd)	5 8.3	II 3.8				
Platanthera unalascensis (co)	3 +.1					
Polytrichum commune (co)	2 +.8					
Polytrichum juniperinum (e,c)	5 4.3	I +.0				
Prunella vulgaris (co)	2 +.0					
Rhytidiadelphus triquetrus (co)	4 3.7	II 2.8	III 1.4	I +.4	I 1.1	
Selaginella wallacei (co)	2 +.3					
Viola adunca (co)	2 +.3					
Alliance 1.2, Association 1.21						
Achlys triphylla (d,c)	1 +.0	V 1.5	V 3.1	V 5.0	V 5.3	3 1.2
Hemitomes congestum (co)		II +.0	I +.0			
Polystichum munitum (d)	2 1.1	IV 2.1	V 4.4	V 7.8	V 8.7	4 3.1
Pteridium aquilinum (d)		IV 1.5	V 3.0	IV 1.3	III +.5	1 +.0
Thuja plicata (co)		IV 3.2	III 4.1	III 3.3	III 4.2	3 4.4
Tsuga heterophylla (d)		IV 4.8	V 6.0	V 7.5	V 5.1	2 3.3
Vaccinium parvifolium (d,c)	1 +.0	V 3.1	V 4.5	IV 3.8	IV 2.8	2 4.1
Order 2, Alliance 2.1, Association 2.11						
Achlys triphylla (c)	1 +.0	V 1.5	V 3.1	V 5.0	V 5.3	3 1.2
Amelanchier alnifolia (co)	1 +.0	II +.0	III +.4	II +.0	I +.0	
Chimaphila menziesii (co)		II +.0	II +.0			
Gaultheria shallon (cd)	4 5.1	V 8.8	V 5.8	II 1.0	I +.0	1 +.1
Hylocomium splendens (cd)	5 5.2	IV 4.3	V 5.3	V 5.1	IV 3.0	2 +.3
Hypopithys lanuginosa (co)			II +.0			
Kindbergia oregana (cd)	4 5.3	V 5.7	V 7.9	V 6.3	V 3.8	2 +.0
Linnaea borealis (s,c)	2 +.3	II +.9	V 2.7	III 1.6	I +.0	1 1.0
Listera cordata (co,c)	5 1.4	IV +.6	V 1.1	I +.0		
Mahonia nervosa (c)	5 4.5	V 4.9	V 4.5	III 1.9	I 1.1	
Plagiothecium undulatum (co)	2 1.1	II +.1	III 1.4	II 1.1	I +.4	
Polystichum munitum (c)	2 1.1	IV 2.1	V 4.4	V 7.8	V 8.7	4 3.1
Pseudotsuga menziesii (cd)	4 5.8	V 9.5	V 9.1	V 8.7	V 8.5	
Pteridium aquilinum (p,c)		IV 1.5	V 3.0	IV 1.3	III +.5	1 +.0
Rhytidiadelphus loreus (s)	2 1.6	II 2.8	IV 1.4	IV 1.3	I +.0	1 +.0
Trillium ovatum (c)		II +.5	V +.7	V 1.2	V 1.7	3 +.1
Tsuga heterophylla (cd)		IV 4.8	V 6.0	V 7.5	V 5.1	2 3.3
Vaccinium parvifolium (c)	1 +.0	V 3.1	V 4.5	IV 3.8	IV 2.8	2 4.1

Table 18 - (cont.)

PLANT ORDER	1		2	3		
PLANT ALLIANCE	1.1	1.2	2.1	3.1		3.2
BIOGEOCOENOTIC ASSOCIATION (number of sample plots)	1.11 (5)	1.21 (10)	2.11 (11)	3.11 (10)	3.12 (10)	3.21 (5)
Order 3						
Athyrium filix-femina (e)				II +.3	IV 2.3	5 5.7
Blechnum spicant (d)				IV 1.2	III 1.5	2 3.5
Bromus sitchensis (co)	1 +.0		I +.0	I +.0	II 1.8	2 +.3
Bromus vulgaris (co)		II +.0		II +.3	III +.5	2 +.8
Claytonia sibirica (e)				II +.0	IV 1.4	4 2.8
Disporum hookeri (s)			II +.0	IV 1.6	IV 1.4	2 +.0
Dryopteris expansa (e)				IV 1.0	IV 1.6	2 1.5
Galium triflorum (e)			I +.0	V 2.1	V 2.5	2 3.4
Leucolepis menziesii (co)		I +.6		I +.0	IV 2.9	3 1.7
Luzula parviflora (co)				I +.0	II +.1	1 +.1
Mycelis muralis (p,c)	1 +.0	II +.0	II +.5	IV 2.5	V 3.1	4 1.7
Osmorhiza chilensis (co)				I +.0	II +.3	2 +.3
Plagiomnium insigne (e)				IV +.6	V 4.4	4 3.6
Polystichum munitum (cd)	2 1.1	IV 2.1	V 4.4	V 7.8	V 8.7	4 3.1
Rhizomnium glabrescens (d)		II +.0	I +.0	IV 2.5	II 1.0	2 +.3
Rubus spectabilis (e)			I +.0	III 1.0	V 2.2	5 4.7
Streptopus amplexifolius (co)			I +.0	III 1.3	IV +.6	3 +.5
Tiarella laciniata (e)	1 +.0		I +.0	V 1.4	V 1.7	3 +.5
Tiarella trifoliata (p,c)			III +.3	V 3.8	V 4.3	4 2.8
Trautvetteria caroliniensis (co)				I +.3	III 2.1	3 4.9
Alliance 3.1						
Abies grandis (co)			I 2.0	II 3.0	III 4.1	
Acer macrophyllum (s)			II +.2	III 2.1	IV 5.3	1 +.0
Achlys triphylla (d,cd)	1 +.0	V 1.5	V 3.1	V 5.0	V 5.3	3 1.2
Adenocaulon bicolor (s)			II +.0	IV +.8	V 1.3	
Blechnum spicant (s)				IV 1.2	III 1.5	2 3.5
Carex hendersonii (co)			I +.0	I +.0	III 1.0	
Disporum hookeri (d)			II +.0	IV 1.6	IV 1.4	2 +.0
Dryopteris expansa (d)				IV 1.0	IV 1.6	2 1.5
Galium triflorum (d,c)			I +.0	V 2.1	V 2.5	2 3.4
Gymnocarpium dryopteris (co)				I +.0	III 1.0	
Hylocomium splendens (d)	5 5.2	IV 4.3	V 5.3	V 5.1	IV 3.0	2 +.3
Kindbergia oregana (d,cd)	4 5.3	V 5.7	V 7.9	V 6.3	V 3.8	2 +.0
Pseudotsuga menziesii (d,cd)	4 5.8	V 9.5	V 9.1	V 8.7	V 8.5	
Pteridium aquilinum (d)		IV 1.5	V 3.0	IV 1.3	III +.5	1 +.0
Rhytidiadelphus loreus (d)	2 1.6	II 2.8	IV 1.4	IV 1.3	I +.0	1 +.0
Tiarella laciniata (d,c)	1 +.0		I +.0	V 1.4	V 1.7	3 +.5
Trientalis latifolia (d)	3 1.8	IV 1.1	IV 1.0	IV 1.5	V 1.1	
Trillium ovatum (d,c)		II +.5	V +.7	V 1.2	V 1.7	3 +.1
Tsuga heterophylla (d,cd)		IV 4.8	V 6.0	V 7.5	V 5.1	2 3.3
Vaccinium parvifolium (d)	1 +.0	V 3.1	V 4.5	IV 3.8	IV 2.8	2 4.1
Association 3.11						
Festuca subuliflora (co)		I +.0	I 1.0	II +.5	I +.0	
Goodyera oblongifolia (d)	5 1.6	III 1.0	IV +.3	III +.2	I +.0	
Hylocomium splendens (cd)	5 5.2	IV 4.3	V 5.3	V 5.1	IV 3.0	2 +.3
Linnaea borealis (d)	2 +.3	II +.9	V 2.7	III 1.6	I +.0	1 1.0
Mahonia nervosa (d)	5 4.5	V 4.9	V 4.5	III 1.9	I 1.1	
Rhizomnium glabrescens (p)		II +.0	I +.0	IV 2.5	II 1.0	2 +.3
Rhytidiadelphus loreus (d)	2 1.6	II 2.8	IV 1.4	IV 1.3	I +.0	1 +.0
Rubus ursinus (d)	5 1.1	V 1.4	IV 1.1	IV +.5	II +.0	3 +.5
Association 3.12						
Adenocaulon bicolor (c)			II +.0	IV +.8	V 1.3	
Athyrium filix-femina (d)				II +.3	IV 2.3	5 5.7
Carex hendersonii (d)			I +.0	I +.0	III 1.0	
Claytonia sibirica (d)				II +.0	IV 1.4	4 2.8
Dicentra formosa (co)					II +.5	
Gymnocarpium dryopteris (d)				I +.0	III 1.0	
Leucolepis menziesii (d)		I +.6		I +.0	IV 2.9	3 1.7
Oplopanax horridus (co)				I +.0	II 1.0	1 1.6
Plagiomnium insigne (c)				IV +.6	V 4.4	4 3.6
Rubus spectabilis (d,c)			I +.0	III 1.0	V 2.2	5 4.7
Stachys cooleyae (d)					III 1.1	5 2.9
Trautvetteria caroliniensis (d)				I +.3	III 2.1	3 4.9
Trientalis latifolia (co,c)	3 1.8	IV 1.1	IV 1.0	IV 1.5	V 1.1	
Viola glabella (co)					II +.0	
Alliance 3.2, Association 3.21						
Alnus rubra (s,cd)				I 3.1	II 4.0	5 9.0
Athyrium filix-femina (d,cd)				II +.3	IV 2.3	5 5.7
Brachythecium frigidum (co)					I +.0	2 +.0
Carex deweyana (co)				I +.0	I +.0	.2 +.8
Carex obnupta (co)						2 4.6
Cinna latifolia (co)					I +.3	2 +.0
Circaea alpina (co)	1 1.0	I +.3		I +.0		2 +.0
Conocephalum conicum (co)						3 4.1
Equisetum telmateia (e)						4 3.7
Glyceria elata (co)						2 2.4
Kindbergia praelonga (e,c)					II +.0	5 4.3
Lysichitum americanum (e,cd)						5 8.5
Malus fusca (co)		I +.0			I +.0	2 1.8
Mitella ovalis (co)					I +.0	2 4.2
Oenanthe sarmentosa (co)						3 4.4
Picea sitchensis (co)						2 4.4
Ranunculus uncinatus (co)				I +.0	I +.0	2 1.5
Rubus spectabilis (c)			I +.0	III 1.0	V 2.2	5 4.7
Sambucus racemosa (co)					I +.0	2 1.4
Stachys cooleyae (s,c)					III 1.1	5 2.9
Veratrum viride (co)					I +.0	2 2.0

Table 19 - List of accidental species.

PLANT ORDER	1		2	3		
PLANT ALLIANCE	1.1	1.2	2.1	3.1		3.2
BIOGEOCOENOTIC ASSOCIATION (number of sample plots)	1.11 (5)	1.21 (10)	2.11 (11)	3.11 (10)	3.12 (10)	3.21 (5)
Adiantum pedatum					I +.1	1 +.0
Apocynum androsaemifolium	1 +.0					
Asarum caudatum					I +.0	
Aulacomnium androgynum						1 +.1
Boschniakia hookeri	1 +.0	I +.0				
Botrychium virginianum					I +.0	
Boykinia elata	1 +.1					
Calypso bulbosa		I +.0				
Camassia quamash	1 +.0					
Cardamine breweri						1 +.0
Cardamine oligosperma						1 +.0
Chiloscyphus pallescens						1 +.0
Chimaphila umbellata		I +.0	I +.0			
Cladonia coniocraea	1 +.0					
Cladonia multiformis	1 +.0					
Cladonia squamosa	1 +.0					
Cladonia uncialis	1 +.0					
Claopodium bolanderi						1 +.0
Corallorhiza mertensiana		I +.0	I +.0	I +.0		
Cornus nuttallii			I 1.0	I +.0		
Cystopteris fragilis		I +.0				
Cytisus scoparius	1 1.0					
Danthonia spicata	1 +.1					
Dicranum fuscescens			I +.0			
Dicranum howellii	1 3.4					
Disporum smithii		I +.0		I +.0		
Equisetum arvense						1 +.0
Erythronium revolutum		I +.3				
Fragaria vesca	1 +.1					
Geranium robertianum					I +.1	
Heuchera micrantha	1 +.0					
Hookeria lucens					I +.0	
Hylocomium umbratum					I +.0	
Ilex aquifolium					I +.0	
Isopterygium elegans			I +.0			
Isothecium stoloniferum		I +.0				
Juniperus communis	1 +.0					
Juniperus scopulorum	1 +.1					
Leptogium palmatum	1 1.0					
Listera banksiana			I +.0	I +.0		
Lotus micranthus	1 +.0					
Lupinus polyphyllus	1 +.1					
Lycopodium clavatum			I +.0	I +.0		
Mahonia aquifolium	1 +.0				I +.0	
Maianthemum dilatatum			II +.0	II +.6	II +.3	2 +.0
Mnium spinulosum				I +.0		
Monotropa uniflora				I +.0	I +.0	
Nemophila parviflora					I +.0	
Peltigera canina		I +.0	I +.0			
Peltigera membranacea	1 +.0	I +.0	I 1.0	I +.0		
Peltigera polydactyla		I +.0	I +.2			
Physocarpus capitatus			I +.0			
Pinus monticola			I +.0			
Plagiochila asplenioides				I +.0		
Plagiochila porelloides					I +.0	
Plagiothecium cavifolium						1 +.0
Platanthera chorisiana	1 +.1					
Pleurozium schreberi	1 +.1					
Poa marcida					I +.0	
Pogonatum alpinum	1 +.1					
Polypodium glycyrrhiza	1 +.0	I +.0			I +.0	
Polytrichum piliferum	1 +.0					
Populus trichocarpa					I 2.6	
Pterospora andromedea			I +.0			
Pyrola dentata			I +.0			
Pyrola picta			I +.0			
Rhacomitrium canescens	1 2.4					
Rhamnus purshianus		I +.0		I +.0	I +.0	1 +.1
Rhizomnium nudum						1 +.1
Rhytidiopsis robusta	1 +.0		I +.0			
Ribes divaricatum					I +.0	
Rubus parviflorus			I +.0	I +.0	I +.0	
Smilacina stellata			I +.0		I +.0	
Sorbus aucuparia				I +.0		
Sorbus sitchensis				I +.0		
Spiraea menziesii						1 +.0
Stellaria crispa				I +.0		
Streptopus roseus				I +.3		
Streptopus streptopoides						1 1.6
Symphoricarpos hesperius		I +.3				
Taxus brevifolia					I +.0	
Tellima grandiflora						1 +.0
Trisetum cernuum			I +.0			1 +.0
Urtica dioica						1 1.6
Vaccinium alaskaense			I +.0			
Vaccinium ovalifolium			I +.0			
Viola sempervirens	1 1.6	II +.7	II 1.1	II +.0		

stated that "forest undergrowth approximates climax status soon after the first seral trees form an essentially closed canopy". Henderson (1982) studied Douglas-fir stands in the TH zone in Washington. He found that most of the changes in understory communities occurred in the first fifty years following disturbance and that the ultimate understory dominants achieved their dominance early in the sere.

In a study of understory plant communities in the CWHa and CDFb on Vancouver Island, Mueller-Dombois (1959,1965) found that characteristic understory plant species were still present after logging and burning and appeared to maintain their original distribution during initial stages of secondary succession. He also found that characteristic understory species were present in sufficient quantities after disturbance to permit successful identification of the pre-existing communities. He noted that Gaultheria shallon (characteristic of dry sites) and Polystichum munitum (characteristic of moist sites) began to spread into the mesic moss sites shortly after forest canopy removal, but this movement was "held in check" by the rapid invasion of light-demanding weed species. After canopy closure, these intolerant and semi-tolerant weed species declined and the moss species were reestablished. A study done in Washington (Long and Turner, 1975; Turner and Long, 1975) showed a similar trend. This study, also done in second-growth Douglas-fir stands, showed that the percentage of understory biomass accounted for by mosses increased from less than 1% in a 22-year-old stand to over 57% in a 73-year-old stand. This increase in the importance of mosses was accompanied by a decrease in the importance of herbs and shrubs, particularly Gaultheria shallon and Pteridium aquilinum ((L.) Kuhn in Decken).

From the previous discussion, it would be expected that understory plant communities found in the immature Cowichan Lake forest ecosystems should closely resemble understory plant communities found in mature forest ecosystems influenced by similar climatic and edaphic conditions. To test this hypothesis, summary vegetation tables for three Cowichan Lake immature associations were compared to summary vegetation tables for three (climatically and edaphically similar) mature associations from a study done in Strathcona Park (Kojima, 1971; Kojima and Krajina, 1975). The Cowichan Lake immature $PM-GS association was compared to the Strathcona Park mature Gaultheria shallon association (Table 20), the Cowichan Lake immature $PM-KO association was compared to the Strathcona Park mature moss association (Table 21), and the Cowichan Lake immature $PM-PI association was compared to the Strathcona Park mature Achlys-Polystichum association var. polystichosum (Table 22). In these tables, presence class (PC) and mean species significance (MS) are shown for each species in each association.

Generally, the summary vegetation tables for the three immature asociations were quite similar to those for the mature associations. However, there were some notable differences. In all three comparisons, MS of Pseudotsuga menziesii was higher in the immature associations, and MS of Tsuga heterophylla was

Table 20 - Constant-species (c,cd) and differential-species (d) for the Cowichan Lake immature $PM-GS association compared to the Strathcona Park mature Gaultheria shallon association (Kojima and Krajina, 1975).

LOCATION (number of sample plots)	COWICHAN LAKE (10)	STRATHCONA PARK (11)
Constant-species		
Achlys triphylla (c)	V 1.5	V 4.1
Gaultheria shallon (cd)	V 8.8	V 8.4
Kindbergia oregana (cd & c)	V 5.7	V 4.3
Mahonia nervosa (c)	V 4.9	V 4.2
Pseudotsuga menziesii (cd)	V 9.5	V 8.0
Vaccinium parvifolium (c & cd)	V 3.1	V 5.0
Cowichan Lake		
Arbutus menziesii (d)	III 2.8	
Holodiscus discolor (d,c)	V 3.4	
Listera cordata (d)	IV +.6	I +.0
Pteridium aquilinum (d)	IV 1.5	II +.0
Rosa gymnocarpa (c)	V 2.5	IV 1.4
Rubus ursinus (d,c)	V 1.4	II +.0
Symphoricarpos albus (d)	IV 1.7	II +.0
Strathcona Park		
Chimaphila umbellata (d,c)	I +.0	V 2.8
Goodyera oblongifolia (d,c)	III 1.0	V +.3
Hylocomium splendens (cd)	IV 4.3	V 7.6
Linnaea borealis (d,c)	II +.9	V 3.8
Pinus monticola (d,c)		V 1.6
Pyrola picta (d)		III +.0
Rhytidiadelphus loreus (d,c)	II 2.8	V 3.9
Rhytidiopsis robusta (d,c)		V 3.0
Tsuga heterophylla (cd)	IV 4.8	V 7.4

Table 21 - Constant-species (c,cd) and differential-species (d) for the Cowichan Lake immature $PM-KO association compared to the Strathcona Park mature moss association (Kojima and Krajina, 1975).

LOCATION (number of sample plots)	COWICHAN LAKE (11)	STRATHCONA PARK (23)
Constant-species		
Achlys triphylla (c)	V 3.1	V 4.8
Hylocomium splendens (cd)	V 5.3	V 6.4
Kindbergia oregana (cd)	V 7.9	V 5.1
Linnaea borealis (c)	V 2.7	V 4.1
Mahonia nervosa (c & cd)	V 4.5	V 5.6
Pseudotsuga menziesii (cd)	V 9.1	V 7.6
Tsuga heterophylla (cd)	V 6.0	V 8.1
Vaccinium parvifolium (c)	V 4.5	V 4.9
Cowichan Lake		
Gaultheria shallon (cd)	V 5.8	IV 3.0
Listera cordata (d,c)	V 1.1	I +.0
Polystichum munitum (c)	V 4.4	IV 2.1
Pteridium aquilinum (d,c)	V 3.0	I +.0
Rubus ursinus (d)	IV 1.1	II +.0
Trientalis latifolia (d)	IV 1.0	I +.0
Trillium ovatum (d,c)	V +.7	
Strathcona Park		
Chimaphila menziesii (d)	II +.0	IV +.4
Chimaphila umbellata (d,c)	I +.0	V 3.4
Cornus canadensis (d)		IV 2.7
Goodyera oblongifolia (c)	IV +.3	V +.4
Homalothecium megaptilum (d)		III +.7
Orthilia secunda (d)		III +.0
Pyrola picta (d)	I +.0	III +.0
Rhytidiadelphus loreus (c)	IV 1.4	V 4.7
Rhytidiopsis robusta (d)	I +.0	IV 4.4
Smilacina stellata (d)	I +.0	III +.9
Vaccinium alaskaense (d)	I +.0	III 2.7
Viola sempervirens (d,c)	II 1.1	V 1.0

Table 22 - Constant-species (c,cd) and differential-species (d) for the Cowichan Lake immature $PM-PI association compared to the Strathcona Park mature Achlys-Polystichum association var. polystichosum (Kojima and Krajina, 1975).

LOCATION (number of sample plots)	COWICHAN LAKE (10)	STRATHCONA PARK (11)
Constant-species		
Achlys triphylla (cd)	V 5.3	V 5.9
Galium triflorum (c)	V 2.5	V 1.0
Kindbergia oregana (c & cd)	V 3.8	V 5.6
Polystichum munitum (cd)	V 8.7	V 7.2
Pseudotsuga menziesii (cd)	V 8.5	V 7.4
Tiarella laciniata (c)	V 1.7	V +.7
Tiarella trifoliata (c)	V 4.3	V 3.0
Trientalis latifolia (c)	V 1.1	V 1.0
Tsuga heterophylla (cd)	V 5.1	V 7.9
Cowichan Lake		
Acer macrophyllum (d)	IV 5.3	II 3.3
Adenocaulon bicolor (d,c)	V 1.3	III +.2
Blechnum spicant (d)	III 1.5	I +.0
Bromus vulgaris (d)	III +.5	
Carex hendersonii (d)	III 1.0	
Claytonia sibirica (d)	IV 1.4	II +.0
Leucolepis menziesii (d)	IV 2.9	II 1.1
Mycelis muralis (d,c)	V 3.1	III +.2
Plagiomnium insigne (c)	V 4.4	IV 2.6
Pteridium aquilinum (d)	III +.5	I +.0
Rubus spectabilis (d,c)	V 2.2	I +.0
Stachys cooleyae (d)	III 1.1	
Trautvetteria caroliniensis (d)	III 2.1	
Trillium ovatum (d,c)	V 1.7	
Strathcona Park		
Adiantum pedatum (d)	I +.1	IV 1.5
Chimaphila menziesii (d)		III +.0
Cornus canadensis (d)		III +.4
Dryopteris expansa (c)	IV 1.6	V +.8
Goodyera oblongifolia (d)	I +.0	III +.0
Hylocomium splendens (c)	IV 3.0	V 4.7
Linnaea borealis (d)	I +.0	IV 1.2
Mahonia nervosa (d,c)	I 1.1	V 3.6
Monotropa uniflora (d)	I +.0	III +.0
Rhytidiadelphus loreus (d)	I +.0	IV 3.0
Rhytidiadelphus triquetrus (d)	I 1.1	III 2.1
Rosa gymnocarpa (d,c)	I +.0	V 1.1
Vaccinium parvifolium (c)	IV 2.8	V 2.3
Viola sempervirens (d)		III +.0

higher in the mature associations. Pteridium aquilinum, an indicator of early seral conditions in humid climates had a higher PC and MS value in all three immature associations. Trends discussed earlier for the mesic moss sites (i.e. decrease in herbs and shrubs, and increase in mosses with successional stage) were evident in Table 21. The immature $PM-KO association had a higher PC and MS value, not only for Pteridium aquilinum, but also for Gaultheria shallon and Polystichum munitum, and the mature moss association had higher PC and MS values for both Rhytidiadelphus loreus and Rhytidiopsis robusta ((Hedw.) Broth.). These two moss species also had higher PC and MS values in the mature Gaultheria shallon association (Table 20). Another major difference which was felt to be attributable to stand age or successional stage was the considerably higher PC and MS of Acer macrophyllum and Rubus spectabilis (Pursh) in the immature $PM-PI association (Table 22).

Certain floristic differences between the immature and mature associations were probably due to thicker, more well developed ectorganic layers in plots belonging to the mature associations. Whereas the $PM-GS, $PM-KO, and $PM-PI associations had an average ectorganic thickness of 4, 5, and 1 cm respectively (Appendix G), the Gaultheria shallon association, moss association, and Achlys-Polystichum association var. polystichosum had an average ectorganic thickness of 6, 7, and 8 cm respectively. For example, in the Achlys-Polystichum association var. polystichosum (Table 22), Chimaphila menziesii ((R. Br. ex D. Don) Spreng.), Goodyera oblongifolia (Raf.), and Linnaea borealis (L.) which generally indicate dry to moist, nutrient-very poor to medium sites (Klinka et al., 1984) occur quite frequently, whereas they are relatively uncommon in the immature $PM-PI association.

The PC and MS of a number of other species was probably not a reflection of stand age or successional status but rather a reflection of differences in climate. For example, the presence of Arbutus menziesii and Holodiscus discolor ((Pursh) Maxim.), more characteristic of the CDFb subzone (Klinka et al., 1979) in the $PM-GS association would suggest that the Cowichan Lake study area was in a warmer, drier variant of the CWHa than the Strathcona Park study area. It should also be noted that Abies amabilis, more characteristic of the CWHb subzone (Klinka et al., 1979), had a low PC and MS value in the summary vegetation table for all three Strathcona Park associations. Since Abies amabilis was not a constant-species or a differential-species for any of the associations, it is not shown in Tables 20 to 22.

5.3 INDICATOR PLANT ANALYSIS

5.3.1 EISG Spectra

The relative species importance (RSI) of each edatopic indicator species group (EISG) in each plot is shown in Appendix I. This information is summarized in Figure 10 which shows an EISG spectrum for each of the six BA's. From BA 1 to BA 6, there is a decrease in the importance of species indicating very dry to dry soil moisture conditions, and a parallel increase in

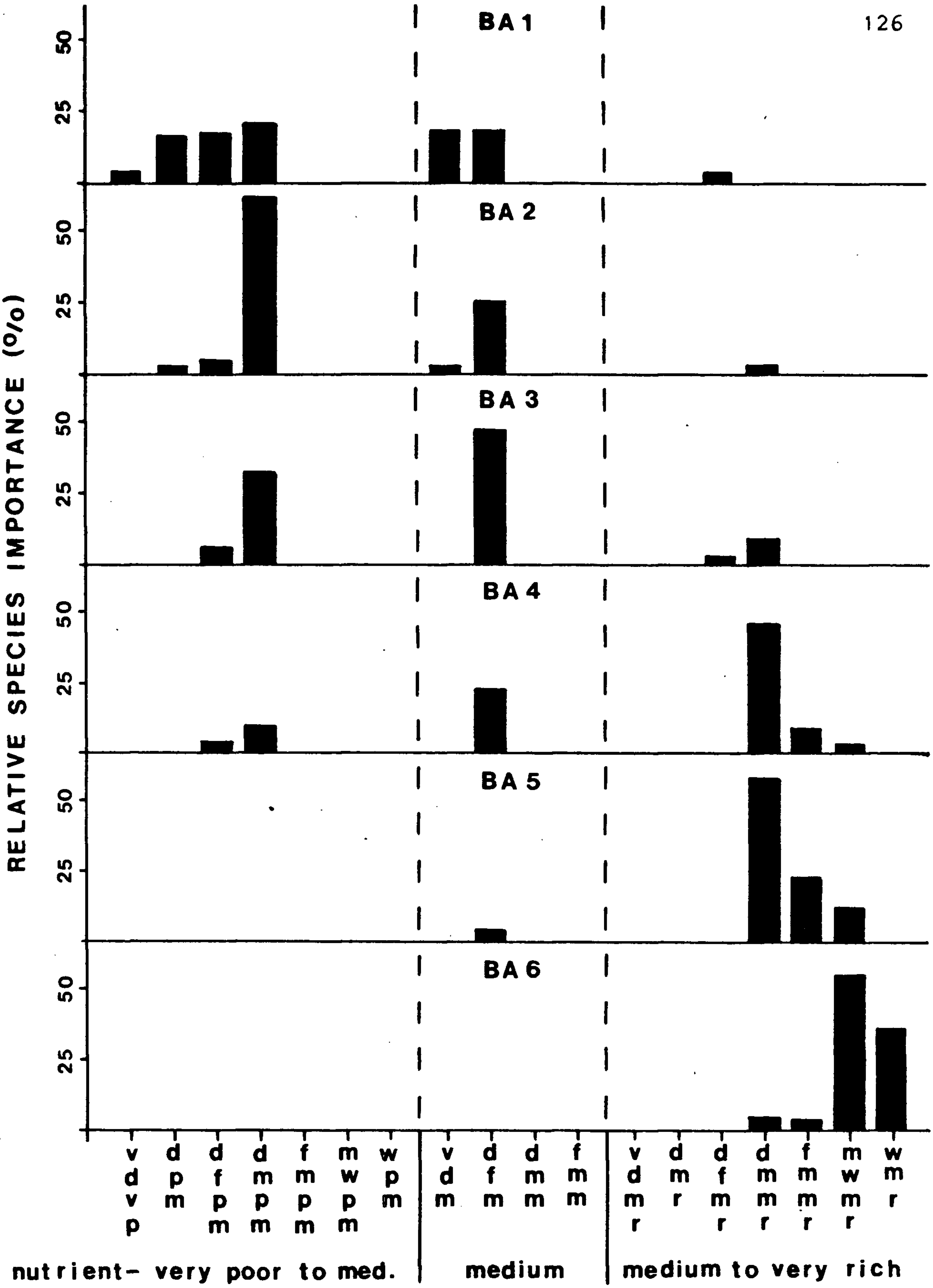

Figure 10 - Edatopic indicator species spectra for the 6 biogeocoenotic associations (N.B. values of RSI < 2.0 are not plotted).

the importance of species indicating fresh to wet conditions. There is also a decrease in the importance of species indicating nutrient-very poor to medium sites, and a parallel increase in the importance of species indicating nutrient-medium to very rich sites. Thus, this figure supports the suggestion made earlier that the order on axis 1 of the RA12 and DCA12 ordinations (i.e. from BA 1 to BA 6) corresponds to an increase in soil moisture and nutrients.

5.3.2 Discriminant Analysis By EISG's

Discriminant analysis of the plots by EISG matrix resulted in correct classification of 92% of the sample plots using the "inclusive" classification method, and 80% using the "exclusive" (jackknifed) method. Dixon (1983) suggested that the jackknifed classification method is preferable because it results in a classification with less bias. With the jackknifed method, a classification function is computed for each case with that particular case omitted from the calculations, and the derived function is then used to classify the omitted case, whereas with the "inclusive" method the case is included in computation of the classification function thereby producing biased results.

The ten EISG's selected as being the most important for discriminating between the six BA's are shown in Table 23. These EISG's are ranked in decreasing order of importance. Table 23 also shows coefficients and constants for the classification functions. A jackknifed classification matrix is

Table 23 - Coefficients and constants for the classification functions derived by discriminant analysis of the edatopic indicator species groups (EISG).

STEP	EISG	F[1]	BIOGEOCOENOTIC ASSOCIATION (number of sample plots) 1 (5)	2 (10)	3 (11)	4 (10)	5 (10)	6 (5)
1	3.7:wmr	46.0	0.27	0.27	0.18	0.59	1.16	4.77
2	3.4:dmmr	28.3	0.20	0.24	0.20	0.63	0.82	0.50
3	3.6:mwmr	17.1	0.22	0.24	0.16	0.55	1.12	3.28
4	3.5:fmmr	14.5	0.27	0.31	0.24	0.84	1.45	1.52
5	2.1:vdm	13.8	8.45	2.77	0.87	0.74	0.63	0.86
6	2.3:dmm	8.1	-181.85	-54.07	-13.21	-8.09	-3.94	-10.60
7	1.6:mwpm	5.7	1.25	0.80	0.32	1.26	3.63	21.45
8	1.4:dmpm	5.1	0.64	0.54	0.28	0.31	0.34	0.35
9	3.1:vdmr	5.9	38.10	14.04	5.77	6.35	6.56	6.83
10	2.4:fmm	3.5	2.96	1.85	1.11	4.58	3.81	0.76
		constant	-74.21	-21.34	-7.19	-25.61	-49.54	-189.50

[1] F to enter or remove

shown in Table 24. In this table, the $PC-PJ and $PM-HS associations showed the highest percentage of misclassified plots with 40% and 30% respectively.

The first three canonical variables produced by discriminant analysis of the EISG by plots matrix are shown in Appendix J, and a canonical variable plot of the first two canonical variables is shown in Figure 11. This plot gives a

Table 24 - Jackknifed classification matrix produced by discriminant analysis of the edatopic indicator species groups. Table entries indicate the number of plots classified into each biogeocoenotic association.

Biogeo. Assoc.			BIOGEOCOENOTIC ASSOCIATION (number of sample plots)					
code	name	percent correct	1 (5)	2 (10)	3 (11)	4 (10)	5 (10)	6 (5)
1	$PC-PJ	60.0	3	1	1	0	0	0
2	$PM-GS	90.0	1	9	0	0	0	0
3	$PM-KO	81.8	0	2	9	0	0	0
4	$PM-HS	70.0	0	0	1	7	2	0
5	$PM-PI	80.0	0	0	0	2	8	0
6	$AR-LA	100.0	0	0	0	0	0	5
	total	80.4	4	12	11	9	10	5

good visual representation of how distinct the BA's are in terms of EISG's. It is thus conceptually similar to the ordination graphs (Figures 2 and 7) discussed earlier which gave a visual representation of how similar the BA's are in terms of understory vegetation. In Figure 11, sample plots belonging to the six BA's formed relatively distinct groups of points with slightly greater overlap than was found in the RA12 and DCA12 ordinations. Again, sample plots in BA's 1 and 6 defined the ends of axis 1 (canonical variable 1).

Axis 1 scores for the canonical variable plot shown in Figure 11 showed a good relationship to axis 1 scores for the RA12 ordination (r^2 = .85**) and the DCA12 ordination (r^2 =

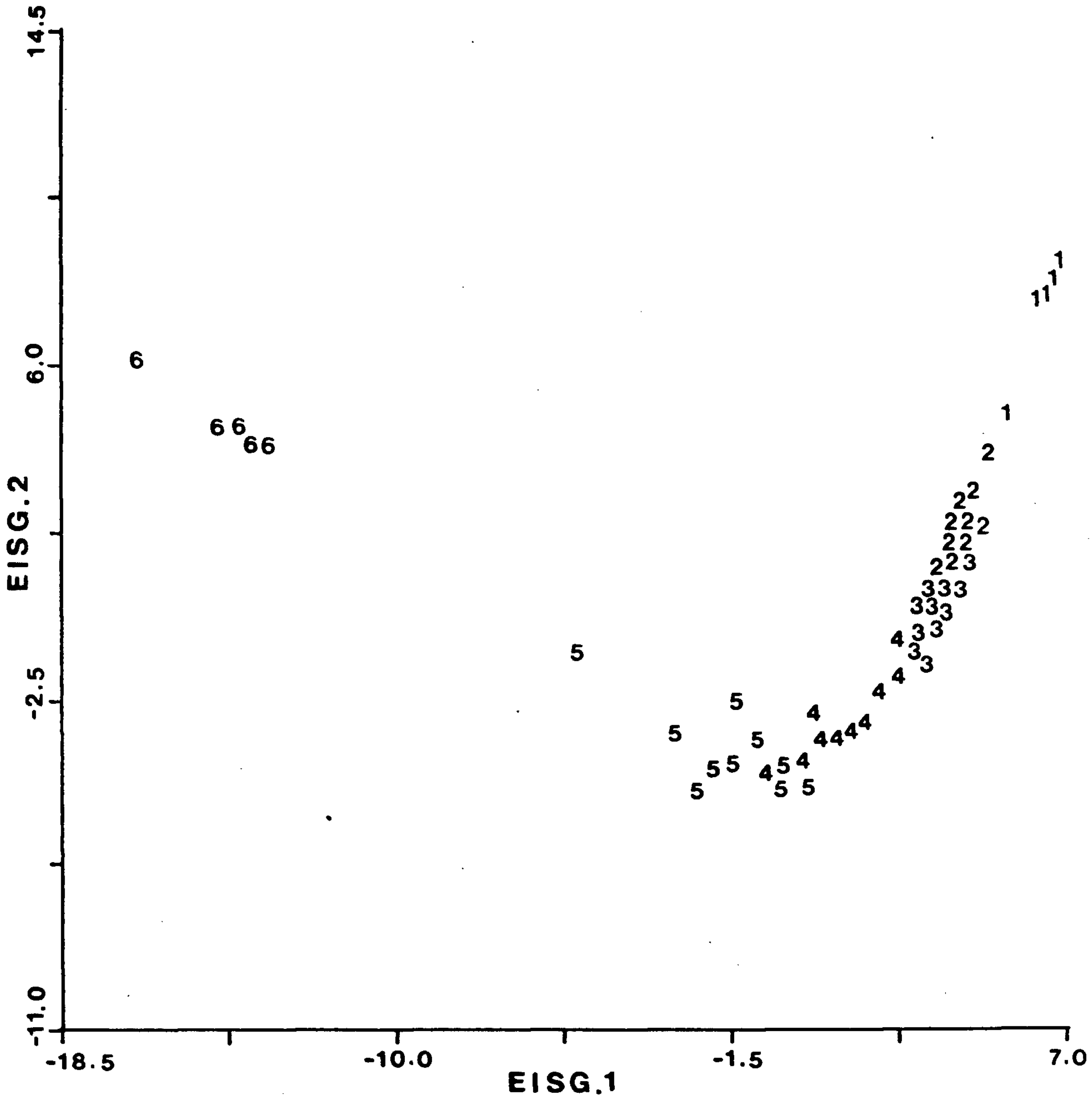

Figure 11 - Plot of canonical variables 1 (EISG.1) and 2 (EISG.2) for the discriminant analysis by edatopic indicator species groups (EISG). Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

.78**). Since indicator plant analysis is based on known relationships between plant species and soil moisture and nutrient conditions, these relatively high r^2 values lend further support to the suggestion made earlier that the order on axis 1 of the RA12 and DCA12 ordinations corresponds to an increase in soil moisture and nutrient availability.

5.4 ENVIRONMENTAL PATTERNS

5.4.1 Variation Between Associations

As mentioned previously, complete environment tables are shown in Appendix G. This information is summarized in Table 25. Descriptive statistics for the seven site morphological properties, thirteen soil physical, and fifty-seven soil chemical properties are shown in Appendix K. Means (MN) and 95% confidence intervals (CI) for the seven site morphological, and the fourteen selected soil physical and chemical properties (Table 13) are shown in Table 26 for all six associations.

Results of ordination and indicator plant analysis suggested that there was an increase in soil moisture and nutrient availability from BA 1 to BA 6. An investigation of Tables 25 and 26 and Appendices G and K tends to support this suggestion. However, definitive statements are not possible because of small sample sizes, and because of large and often unequal variances of the site and soil properties. Despite these limitations, the following general trends were observed.

Plots in BA 1 were located on level to gently sloping ridge

Table 25 - Summary of environmental features of the 6 biogeocoenotic associations.

ENVIRONMENTAL FEATURE	BIOGEOCOENOTIC ASSOCIATION (no. of sample plots)					
	1(5)	2(10)	3(11)	4(10)	5(10)	6(5)
Hygrotope (SMR)	0	(1-)2	3-4	5	6	7
Trophotope (SNR)	B-C	C	C-D	D	D-E	E
Slope position	ridge top	upper slope	mid-slope	lower slope	lower slope	depression
Slope gradient (%)	flat	21	10	7	3	0
Thickness of forest floor (cm)	3	4	5	1	1	1
Humus form[1]	mor	mor	mor-moder	mull	mull	mull
Thickness of Ae horizon (cm)	0	2	2	0	0	0
Thickness of Ah horizon (cm)	0	0	0	5	9	-
Particle size[2]	CL	CL	variable	CL-LS	CL-LS	organic
Rooting depth (cm)	19	55	64	78	86	43
Seepage	none	none	none (-temp.)	temp.	temp.	constant
Coarse fragments > 2 mm (%)	17	24	33	23	16	0
Coarse fragments > 2 cm (%)	4	11	10	14	9	0

[1] Klinka *et al.*, 1981b
[2] C.S.S.C., 1978 (CL = coarse-loamy , LS = loamy-skeletal)

Table 26 - Means (MN) and 95 % confidence intervals (CI) for the 7 site morphological, and 14 soil physical and chemical properties used in the discriminant analysis.

		BIOGEOCOENOTIC ASSOCIATION (number of sample plots)					
PROPERTY		1(5)	2(10)	3(11)	4(10)	5(10)	6(5)
MORPHOLOGICAL							
VCL	MN	4	11	10	14	9	0
(%)	CI	-3-10	8-15	7-13	5-22	1-17	---
VCT	MN	17	24	33	23	16	0
(%)	CI	1-32	16-32	23-42	12-34	1-30	---
THECT	MN	3	4	5	2	1	8
(cm)	CI	2-4	3-5	4-6	1-3	---	-5-21
THAE	MN	0	2	2	0	0	0
(cm)	CI	0-1	0-4	1-4	0-1	---	---
THAH	MN	0	0	0	5	9	5
(cm)	CI	---	---	0-1	3-7	6-12	-4-14
RTDPTH	MN	19	55	64	78	86	43
(cm)	CI	4-33	38-72	55-73	62-94	68-103	37-49
SLOPE	MN	6	21	10	7	3	2
(%)	CI	-5-16	11-30	0-20	2-12	0-7	-4-9
PHYSICAL AND CHEMICAL							
POR.123	MN	69	59	50	56	59	91
(%)	CI	58-80	54-64	45-56	51-61	52-66	89-94
PHHF	MN	3.5	4.2	3.8	4.2	4.5	4.8
	CI	3.1-3.9	4.0-4.4	3.6-3.9	3.8-4.7	4.3-4.7	3.8-5.8
PH.123	MN	3.9	4.4	4.2	4.5	4.5	4.8
	CI	3.5-4.4	4.3-4.5	4.1-4.4	4.2-4.9	4.3-4.6	3.8-5.8
TC.0123	MN	43,580	63,882	61,348	93,150	96,203	177,310
(kg/ha)	CI	28,842-58,318	43,580-84,184	45,605-77,090	64,848-121,450	70,510-121,900	123,440-231,190
TN.0123	MN	1,678	2,178	2,250	4,576	5,302	8,255
(kg/ha)	CI	1,061-2,295	1,234-3,122	1,514-2,986	2,777-6,376	3,708-6,896	7,188-9,323
MN.0123	MN	14	1	9	67	63	12
(kg/ha)	CI	0-29	-10-11	-3-20	26-108	26-99	-15-38

(continued)

Table 26 - (cont.)

PROPERTY		BIOGEOCOENOTIC ASSOCIATION (number of sample plots) 1(5)	2(10)	3(11)	4(10)	5(10)	6(5)
CNHF	MN	40	41	44	26	20	21
	CI	32-49	38-44	40-48	21-31	17-23	14-28
CN.123	MN	23	28	24	21	18	22
	CI	17-28	25-32	21-26	18-24	16-20	16-28
CA.0123	MN	258	607	405	1,822	2,787	8,235
(kg/ha)	CI	128-388	439-774	305-505	-340-3,984	1,872-3,702	2,090-14,380
MG.0123	MN	33	70	65	135	287	455
(kg/ha)	CI	23-43	49-91	49-81	57-212	173-401	224-687
K.0123	MN	53	128	137	164	196	135
(kg/ha)	CI	41-65	96-159	109-166	99-229	125-267	-46-315
NA.0123	MN	8	15	22	39	44	39
(kg/ha)	CI	4-12	10-20	15-30	18-60	28-61	19-59
CAT.0123	MN	352	819	630	2,160	3,314	8,864
(kg/ha)	CI	224-481	632-1,007	508-752	-62-4,382	2,260-4,368	2,687-15,041
CEC.0123	MN	203	385	527	899	944	843
(10^3e/ha)	CI	119-286	237-533	354-701	546-1,252	632-1,257	562-1,124

tops. Slope gradient decreased from an average high of 21% for BA 2 to an average low of 0% (flat) for BA 6. Also, slope position varied from upper slope for BA 2, mid-slope for BA 3, lower slopes for BA's 4 and 5, and depressions for BA 6. Rooting depth, which was often limited by a root restricting layer (either bedrock or a duric horizon) in BA's 1, 2, and 3, increased from an average low of 19 cm for plots in BA 1 to an average high of 86 cm for plots in BA 5. Average rooting depth for plots in BA 6 was 43 cm. This shallow rooting depth for BA 6 was due mainly to a very high water table. Total soil carbon content increased from an average low of 43,580 kg•ha^{-1} for BA 1 to an average high of 177,310 kg•ha^{-1} for BA 6. This suggested an increase in soil organic matter content from BA 1 to BA 6. In summary, lower slope positions, lower slope gradients, deeper soils, and higher organic matter contents all suggested an increased availability of soil water from BA 1 to BA 6.

The suggestions made above regarding trends in soil water conditions are supported by the results of studies done by McMinn (1965), Kojima and Krajina (1975), and Giles (1983). McMinn (1965) found that the availability of soil moisture during the growing season was lowest on "lichen" sites and increased from "salal" sites, to "moss" sites, to "sword fern" sites, to a high on "skunk cabbage" sites. A similar trend was observed by Kojima and Krajina (1975) who studied associations similar to those studied in the Cowichan Lake study. Giles (1983) determined the duration of growing season soil water deficits (difference between actual and potential maximum transpiration) for eight plots on the Cowichan Lake Research Station. These plots were the same eight plots sampled by MOF staff that were used in the Cowichan Lake study (i.e. plots 40-47). Data provided by Giles suggests a decrease in growing season soil water deficits from BA 1 to BA 6. The average deficit for two years of measurement (1980 and 1981) was 67 mm for one plot in BA 1, 35 mm for two plots in BA 2, 19 mm for two plots in BA 3, 2 mm for one plot in BA 4, 2 mm for one plot in

BA 5, and 0 mm for one plot in BA 6. This trend is illustrated in Figure 12 where sample plot numbers are arranged according to axis 1 order in the RA12 ordination. Kojima and Krajina (1975)

```
PLOT      535443311334340400042401204221210212001432123241331
NUMBER    051977212486341836733289845160475042295165690703198

ASSOC.    111112222222222323333333334444444444555555555566666

DEFICIT       6      4 2     2 1
  (mm)        7      3 7     1 7    2            2      0
```

Figure 12 - Growing season soil water deficit (mm) for 8 plots (Giles, 1983) used in the Cowichan Lake Study. Sample plot numbers are arranged according to axis 1 order in the RA12 ordination.

concluded that, given the same macroclimate and parent material, moisture regime appears to be the most influential factor controlling the differentiation of vegetation. They also noted that, because seepage is an important source of mineral nutrients, moisture regime is highly correlated with the nutritional status of a particular site.

In addition to probable seepage effects, variation in humus form between associations, and the results of soil chemical analyses suggested improved soil nutrient conditions from BA 1 to BA 6. The ectorganic layer was thickest on plots in BA's 1, 2, and 3, and thinnest on plots in BA's 4 and 5. Also Ah horizons were absent from plots in BA's 1, 2, and 3, but were well developed on plots in BA's 4 and 5. Because of these differences in ectorganic layers and Ah horizons, the humus form for plots in BA's 1, 2, and 3, were mors and moders, whereas most (80%) of the plots in BA 4, and all of the plots in BA's 5 and 6 had a mull humus form. Changes in humus form along axis 1 in the RA12 ordination are shown in Figure 13. Klinka et

```
PLOT      535443311334340400042401204221210212001432123241331
NUMBER    051977212486341836733289845160475042295165690703198

ASSOC.    1111122222222232333333333344444444444555555555566666

HUMUS     MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
 FORM     DRRRRDRRRRRDRRRRRDRRDRDRDDDDLLLLLLLLLLLLLLLLLLLLLLL
```

Figure 13 - Humus form of the 51 sample plots (MR=mor, MD=moder, and ML=mull). Sample plot numbers are arranged according to axis 1 order in the RA12 ordination.

al. (1981b) noted that, compared to mors and moders, mull humus forms are characterized by faster nutrient cycling and more favorable soil nutrient conditions (discussed later in greater detail). Thus, the change in humus form from mors and moders to mulls along axis 1 of the RA12 ordination (Figure 13) agrees with the statement made earlier that this axis corresponds to improved soil nutrient status.

More favorable soil nutrient conditions for BA's 4, 5, and 6 are also suggested by the results of soil chemical analyses. These analyses showed a general increase in soil N content (both total and mineralizable N) and exchangeable cations, and a decrease in C:N ratios (in both the humus form and the mineral soil) from BA 1 to BA 6. The increase in soil depth and organic matter content from BA 1 to BA 6 is reflected in an increase in cation exchange capacity, a situation which favors nutrient retention and also improves soil nutrient status.

5.4.2 Discriminant Analysis Of Site And Soil Properties

Table 27 shows the percentage of plots correctly classified by discriminant analysis using the inclusive and exclusive

Table 27 - Percentage of plots correctly classified using the inclusive and exclusive (jackknifed) classification methods.

			percent correct	
code	number of plots (associations)	variables	inclusive	exclusive
DA01	51 (1-6)	7 morphological	63	55
DA02	51 (1-6)	14 physical and chemical	86	75
DA03	41 (2-5)	7 morphological	61	54
DA04	41 (2-5)	14 physical and chemical	93	78

(jackknifed) classification methods. From this table, it can be seen that the two discriminant analyses which used the fourteen physical and chemical properties (DA02 and DA04) had a considerably higher percentage of correctly classified plots than the two which used the seven morphological properties (DA01 and DA03). For this reason, only DA02 and DA04 will be discussed further.

Soil properties selected as being the most important for characterizing differences between the biogeocoenotic associations are shown in Table 28. These variables are ranked in decreasing order of importance. Table 28 also shows coefficients and constants for the classification functions. Jackknifed classification matrices for the DA02 and DA04 analyses are shown in Table 29. In both cases, biogeocoenotic association 4 ($PM-HS) had the lowest percentage of correctly classified plots.

The first three canonical variables for the DA01, DA02, DA03, and DA04 discriminant analyses are shown in Appendix L. Canonical variable plots of the first two canonical variables for the DA02 and DA04 analyses are shown in Figures 14 and 15 respectively. These two figures give a good visual representation of how distinct the biogeocoenotic associations (BA's) are in terms of soil properties. They are thus conceptually similar to the ordination graphs (Figures 2 to 7) presented earlier which demonstrated how similar the biogeocoenotic associations are in terms of understory vegetation.

In summary, Figures 14 and 15 did not produce groups of points as distinct as those observed in the ordination graphs. With the exception of plots in BA 6, there is considerable overlap between groups along axis 1 (canonical variable 1) in Figure 14. However, axis 2 (canonical variable 2) helps separate plots in BA 4 and 5 from those in BA's 1, 2, and 3. Considering both axes simultaneously, plots belonging to BA 6

Table 28 - Coefficients and constants for the classification functions derived by the DA02 and DA04 discriminant analyses.

			BIOGEOCOENOTIC ASSOCIATION (number of sample plots)					
STEP	VARIABLE	F[1]	1 (5)	2 (10)	3 (11)	4 (10)	5 (10)	6 (5)
DA02								
1	CNHF	29.2	1.19	1.17	1.49	0.80	0.55	-0.08
2	POR.123	17.2	1.41	1.22	0.98	1.09	1.15	1.83
3	MG.0123	5.4	-0.03	-0.04	-0.04	-0.04	-0.01	0.05
4	CEC.0123	4.4	0.01	0.01	0.01	0.01	0.01	-0.01
5	TC.0123	10.0	-0.01	-0.01	-0.01	-0.01	-0.01	0.01
6	CN.123	2.9	1.95	2.37	2.00	2.14	1.79	1.46
7	MN.0123	2.5	0.08	0.06	0.06	0.09	0.06	-0.02
	constant		-94.03	-92.47	-83.41	-69.52	-60.68	-124.82
DA04								
1	PH.123	2495.3	----	235.39	229.08	222.59	215.10	----
2	CNHF	38.6	----	6.68	6.68	5.87	5.64	----
3	CA.0123	12.7	----	-0.06	-0.05	-0.05	-0.05	----
4	PHHF	6.9	----	123.35	115.71	111.58	112.78	----
5	CN.123	4.0	----	3.42	2.87	3.06	2.93	----
6	MG.0123	3.0	----	0.27	0.26	0.25	0.27	----
	constant		----	-954.98	-883.26	-816.27	-784.70	----

[1] F to enter or remove

Table 29 - Jackknifed classification matrix for the DA02 and DA04 discriminant analyses. Table entries indicate the number of plots classified into each biogeocoenotic association.

Biogeo. Assoc.			BIOGEOCOENOTIC ASSOCIATION (number of sample plots)					
code	name	percent correct	1 (5)	2 (10)	3 (11)	4 (10)	5 (10)	6 (5)
DA02								
1	$PC-PJ	60.0	3	2	0	0	0	0
2	$PM-GS	80.0	0	8	2	0	0	0
3	$PM-KO	81.8	0	1	9	1	0	0
4	$PM-HS	40.0	1	3	0	4	2	0
5	$PM-PI	90.0	0	0	0	1	9	0
6	$AR-LA	100.0	0	0	0	0	0	5
	total	75.0	4	14	11	6	11	5
DA04								
2	$PM-GS	80.0	-	8	1	1	0	-
3	$PM-KO	81.8	-	1	9	1	0	-
4	$PM-HS	60.0	-	0	1	6	3	-
5	$PM-PI	90.0	-	0	0	1	9	-
	total	78.0	-	9	11	9	12	-

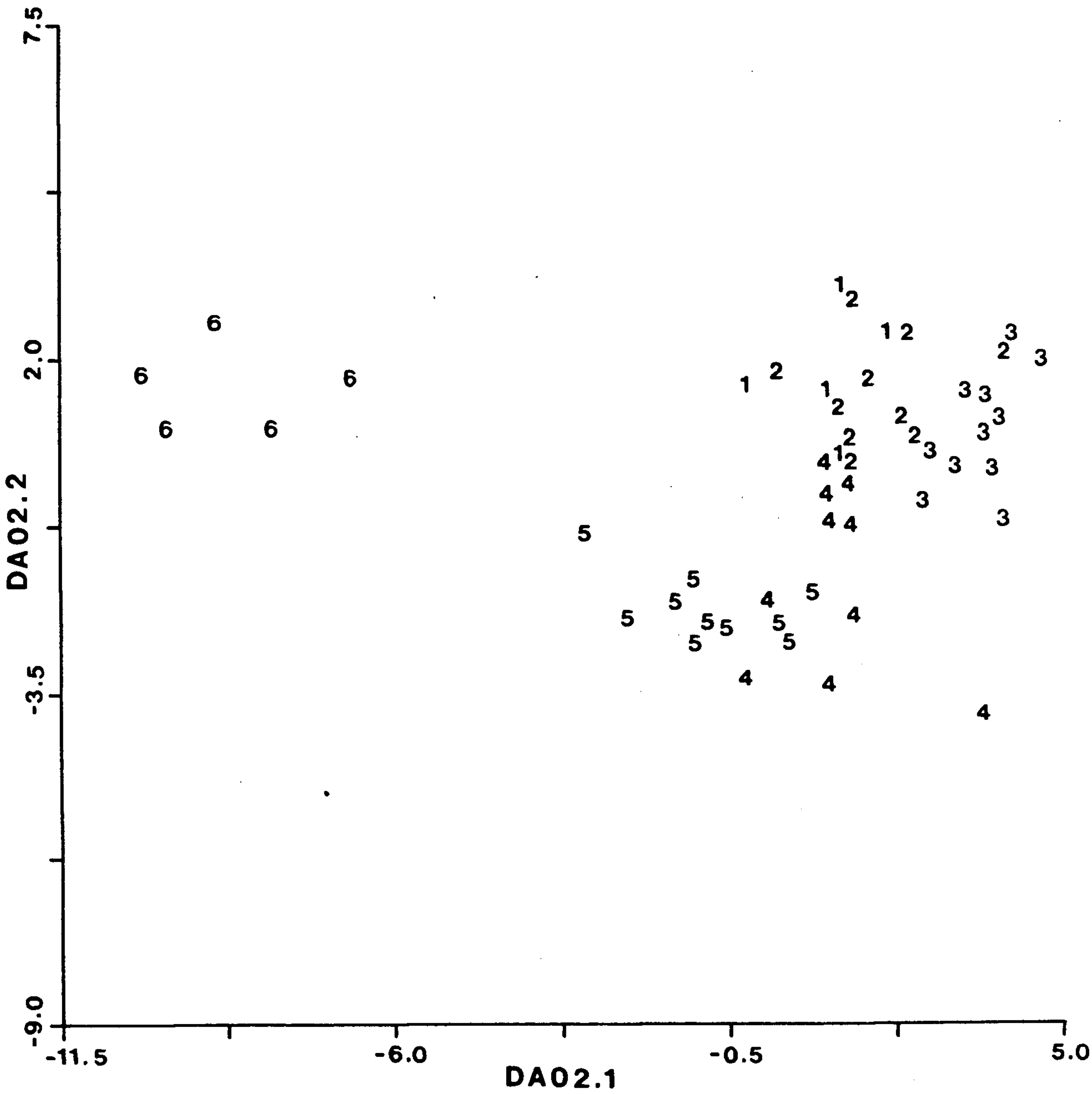

Figure 14 - Plot of canonical variables 1 (DA02.1) and 2 (DA02.2) for the DA02 discriminant analysis. Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

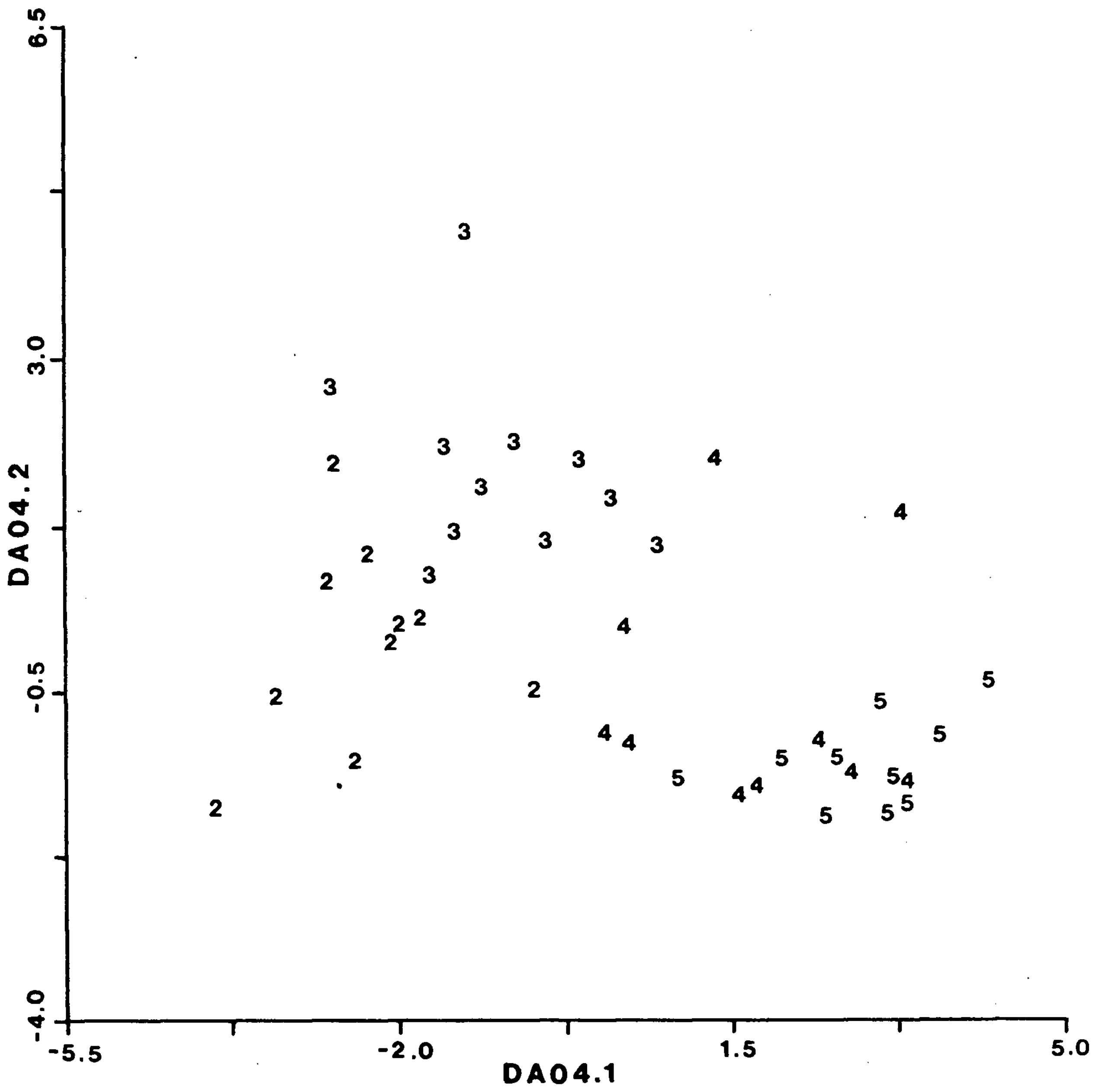

Figure 15 - Plot of canonical variables 1 (DA04.1) and 2 (DA04.2) for the DA04 discriminant analysis. Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

were very clearly separated indicating the great dissimilarity of their waterlogged, high organic matter content soils to the soils of plots in other BA's. Plots in BA's 4 and 5 were separated from the remaining plots but exhibited considerable overlap between each other. Plots in BA 3 formed a relatively distinct group of points but plots in BA's 1 and 2 exhibited considerable overlap. In Figure 15, there is a general trend from plots in BA 2 to plots in BA 5 along axis 1 but there is considerable overlap along this axis. When axes 1 and 2 are considered simultaneously, plots in BA 2 and BA 3 form distinct groups of points but there is considerable overlap between plots in BA's 4 and 5.

5.4.3 Relationships Between Soil And Vegetation Patterns

Axis 1 of detrended correspondence analysis (DCA) follows the direction of maximum variation in the vegetation data. Similarly, the first axis (canonical variable 1) of discriminant analysis (DA) follows the direction of maximum variation in the soil properties under consideration. Relationships between soil and vegetation patterns were investigated by plotting canonical variable 1 from the DA02 discriminant analysis over axis 1 scores from the DCA12 ordination (Figure 16), and canonical variable 1 from the DA04 discriminant analysis over axis 1 scores from the DCA14 ordination (Figure 17). The first figure suggested that there was no strong linear correlation between understory vegetation and the selected soil properties. Only

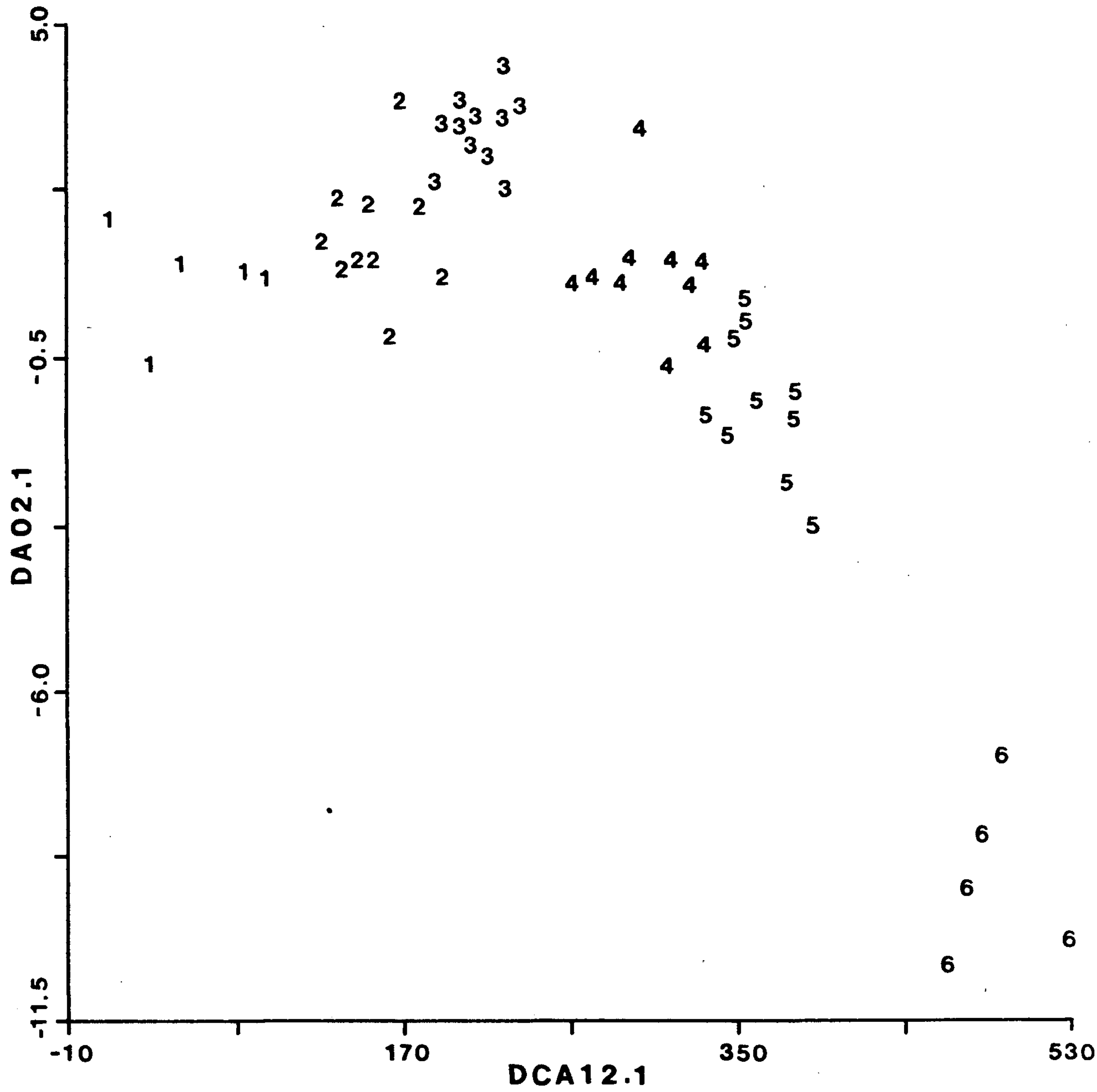

Figure 16 - Relationship between canonical variable 1 of the DA02 discriminant analysis (DA02.1) and axis 1 score of the DCA12 ordination (DCA12.1). Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

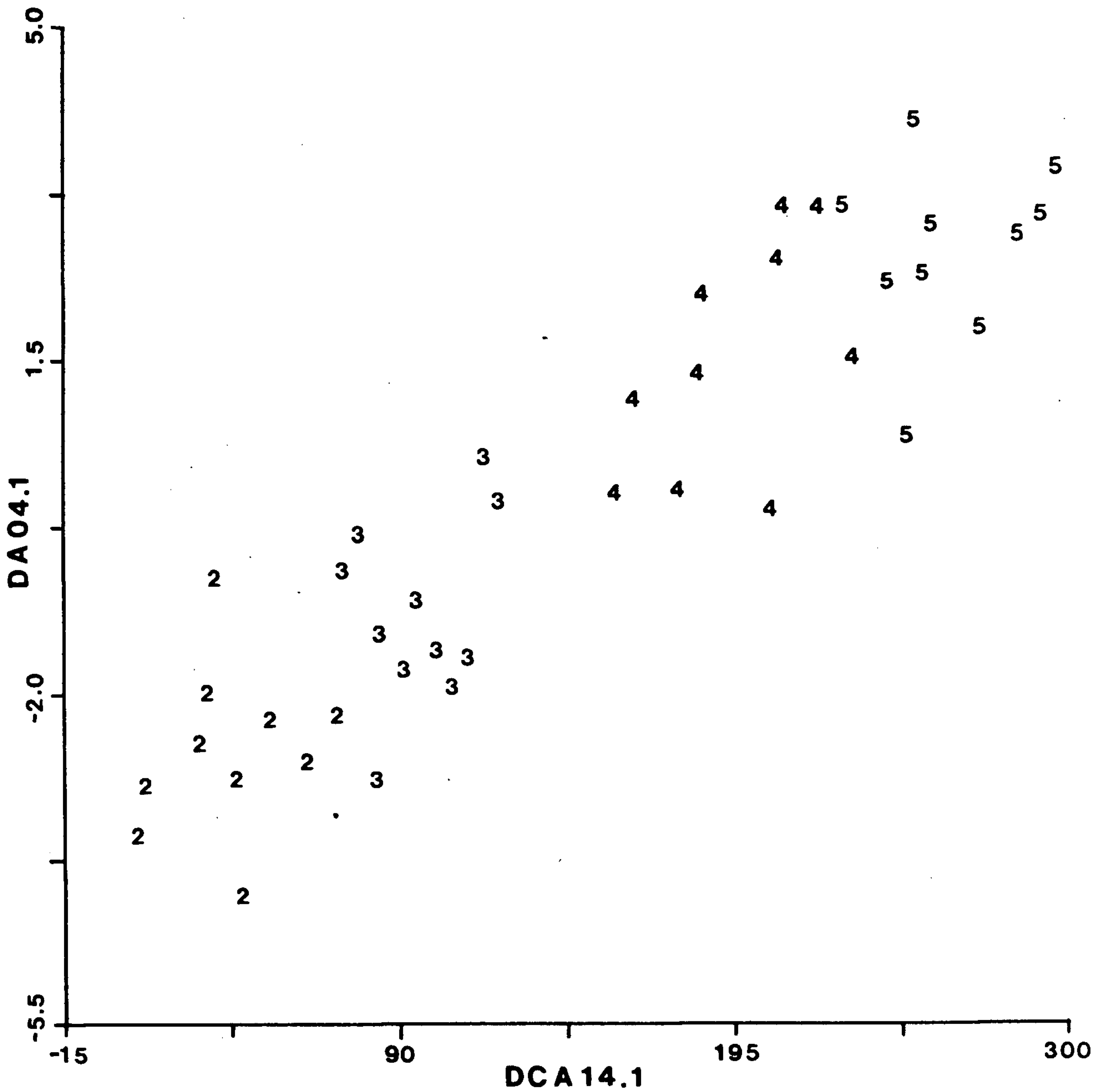

Figure 17 - Relationship between canonical variable 1 of the DA04 discriminant analysis (DA04.1) and axis 1 score of the DCA14 ordination (DCA14.1). Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

52% (r = -.72**) of the variation in understory vegetation was related to changes in soil properties. However, a considerably stronger linear relationship was observed when only the forty-one intermediate plots for which site index of Douglas-fir was determined (i.e. plots in BA's 2, 3, 4, and 5) were considered (Figure 17). In this case, 83% (r = .91**) of the variation in understory vegetation was related to changes in the selected soil properties.

In Figures 16 and 17, a large "r" value does not necessarily imply a causal relationship between the development of the understory vegetation and the selected soil properties. However, it does seem safe to assume that the properties (Table 28) found to be strongly related are good indicators of, and/or exert a strong influence on, the site factors which do strongly influence plant development, i.e. soil moisture and nutrients.

Limitations on the interpretation of Figures 16 and 17 discussed above include: 1) the use of only the first (most informative) axis of DCA and DA, 2) the possibility of non-linear relationships, and 3) the selection of variables for inclusion in the analysis. When using only the first axis, information provided by the second and higher axes will be lost. This may create a serious problem unless the first axis accounts for a very large portion of the total variation. An examination of Figure 14 suggests that the poor relationship in Figure 16 is in part due to the loss of information provided by the second canonical variable. In Figure 14, axis 2 was useful for separating BA 4 from BA's 2 and 3. The r value calculated to express the degree of relationship only expresses the degree of linear relationship. If a strong non-linear relationship exists, it may not be detected by the r value. An examination of Figure 16 suggests that the relationship between the two axes was non-linear.

Discriminant analysis selects from among the variables included in the analysis, those which are most important for characterizing differences between the specified groups, in this case, between the biogeocoenotic associations. The addition or deletion of specific variables from the analysis might change results. For this reason, no two groups can be proven identical. The addition or deletion of variables might segregate the groups better or make the segregation worse (Pimentel, 1979). Thus the discriminant analyses performed in this study, as in any study, were limited by the selection of variables for inclusion in the analysis (Table 13).

5.5 PRODUCTIVITY RELATIONSHIPS

5.5.1 Variation Between Associations

Descriptive statistics for eight mensuration variables are shown for each BA in Appendix M. Means (MN) and 95% confidence intervals (CI) for these variables are shown in Table 30 for all six BA's. The forest canopy of plots in BA 1 was dominated by lodgepole pine, the forest canopy of plots in BA 6 was dominated by red alder, and the forest canopy of the forty-one intermediate plots in BA's 2 to 5 was dominated by Douglas-fir.

Table 30 - Means (MN) and 95% confidence intervals (CI) for the 8 mensuration variables for the 6 biogeocoenotic associations.

MENSURATION VARIABLE		BIOGEOCOENOTIC ASSOCIATION (number of sample plots)					
		1(5)	2(10)	3(11)	4(10)	5(10)	6(5)
SI	MN	--	29	44	54	55	--
	CI	--	26-32	41-46	50-58	52-58	--
GC	MN	--	6	4	2	2	--
	CI	--	6-7	3-4	1-3	1-2	--
VOLUME	MN	266	247	591	878	964	279
	CI	113-419	204-290	500-683	776-980	748-1179	109-449
STEMS	MN	1724	1271	996	556	484	580
	CI	-648-4095	889-1652	620-1372	393-720	379-588	289-870
AGE	MN	69	60	62	65	68	55
	CI	62-76	54-66	54-71	58-71	60-76	43-67
MAI	MN	4	4	10	14	14	5
	CI	1-6	4-5	8-12	12-16	12-16	2-8
DBH	MN	22	21	30	42	45	29
	CI	16-29	18-24	26-34	36-48	39-51	23-35
BA	MN	52	40	60	70	73	36
	CI	13-91	34-45	52-67	61-79	63-84	25-47

N.B.
SI = site index of Douglas-fir (m/100 yrs)
GC = growth class of Douglas-fir
VOLUME = gross volume (m^3/ha)
STEMS = number of stems (stems/ha)
AGE = stand age (years)
MAI = mean annual increment (m^3/ha/yr)
DBH = diameter breast height (cm)
BA = basal area (m^2/ha)

Thus, in terms of mensuration variables, BA's 1 and 6 are not strictly comparable to BA's 2, 3, 4, and 5. For this reason, only BA's 2 to 5 will be considered further.

In summary, Table 30 indicates the following trends. From BA 2 to BA 5, there is a decrease in the number of stems/ha, and parallel increases in average stand d.b.h., basal area, volume, and age. Although part of the reason for the trends in stems/ha, d.b.h., basal area, and volume was no doubt due to differences in stand age, it was felt that, because variation in average stand age was so slight, these trends were mainly related to differences in site properties (discussed later). Mean annual increment (MAI) also increased from BA 2 to BA 5. Although not strictly comparable because of the slight differences in stand age mentioned above, it seems safe to conclude that there was an increase in stand productivity from BA 2 to BA 5. This conclusion is supported by trends in site index (SI), an index of productivity which is independent of stand age. Site index also increased from BA 2 to BA 5. It should be noted that average MAI values for BA's 4 and 5 were identical (i.e. 14 m^3/ha/yr), and average SI values for BA's 4 and 5 were nearly identical (i.e. 54 and 55 m/100yrs respectively) suggesting that there was probably no difference in productivity between these 2 BA's.

Mean SI values for BA's 2 ($PM-GS), 3 ($PM-KO), and 5 ($PM-PI) were compared to mean SI values for similar associations studied by Eis (1962), and Kojima and Krajina (1975). These values are shown in Table 31. The trends in SI suggested by

Table 31 - Comparison of site index (m/100 yrs) values for Douglas-fir (Pseudotsuga menziesii) in 3 forested associations. The Cowichan Lake data is compared to values obtained by Eis (1962) and Kojima and Krajina (1975).

ASSOCIATION NAME	STUDY AREA	sample size	mean	standard deviation
SALAL				
$PM-GS	Cowichan Lake	10	29	5
Salal	Southwestern Mainland[1]	16	31	7
Gaultheria shallon	Strathcona Park[2]	11	33	7
MOSS				
$PM-KO	Cowichan Lake	11	44	4
moss	Southwestern Mainland	26	44	6
moss	Strathcona Park	23	42	6
SWORD FERN				
$PM-PI	Cowichan Lake	10	55	4
Polystichum	Southwestern Mainland	24	50	4
Achlys-Polystichum (var. polystichosum)	Strathcona Park	11	50	4

[1] Eis (1962) [2] Kojima and Krajina (1975)

results of the Cowichan Lake study agreed with trends found in these other two studies (i.e. increase in SI from salal-dominated sites to sword fern-dominated sites). Absolute values of average SI for the "salal" association were very similar for all three locations (range = 29-33), as were absolute values for the "moss" association (range = 42-44). The greatest differences were found when the Cowichan Lake $PM-PI association was compared to the other two "sword fern" associations. In this latter case, average SI differed by a value of 5 m/100 yrs.

5.5.2 Relationship With Vegetation Patterns

The relationship between SI and understory vegetation patterns was investigated by plotting SI values for each plot over their axis 1 score from the DCA14 ordination (Figure 18). This figure suggested a relatively good linear relationship between understory vegetation and SI of Douglas-fir. In Figure 18, 78% (r = .88**) of the variation in SI appears to be related to changes in understory vegetation. No causal relationship is implied here. The only conclusion that can be suggested is that soil conditions causing (affecting) the observed changes in understory vegetation from the salal-dominated BA 2 to the sword fern-dominated BA 5 correspond to an improvement in soil conditions with respect to growth requirements of Douglas-fir. Thus, Figure 18 tends to support the hypothesis that understory plant communities are useful indicators of site quality for growth of Douglas-fir.

5.5.3 Relationship With Soil Properties

Indicator plant analysis suggested that there was an increase in soil moisture and nutrient availability from BA 1 to BA 6. This suggestion was supported when soil properties were investigated. Using limited data, it was found that (from BA 1 to BA 6) there was a decrease in growing season soil water deficits and soil C:N ratios, and increases in soil N content, exchangeable cations, and C.E.C.. There was also a transition from mor and moder to mull humus forms. It was also observed

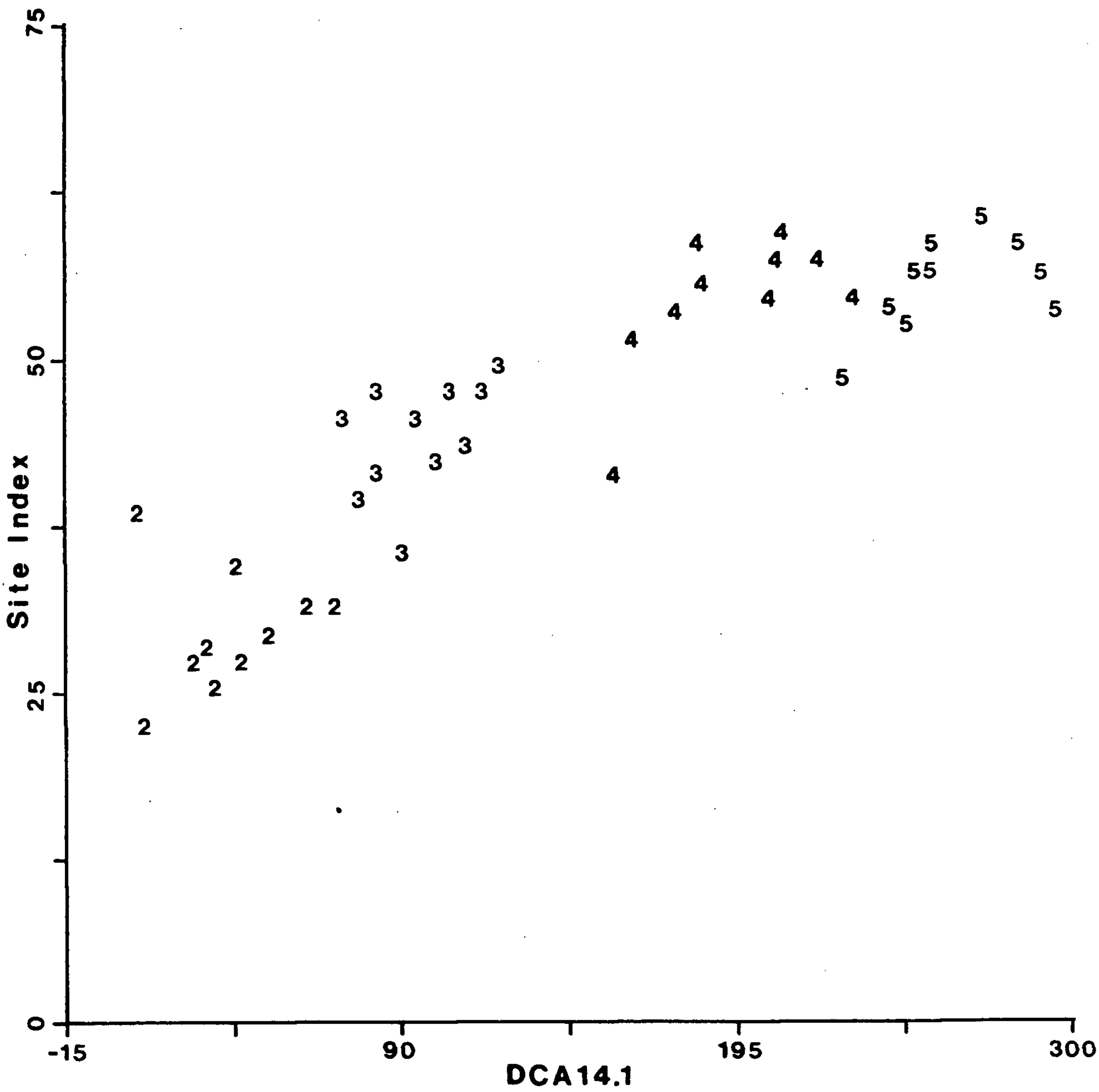

Figure 18 - Relationship between site index (m/100 yrs) of Douglas-fir (Pseudotsuga menziesii) and axis 1 score of the DCA14 ordination (DCA14.1). Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

that there was an increase in SI of Douglas-fir from BA 2 to BA 5. Thus, it seems reasonable to suggest that the increases in SI from BA 2 to BA 5 were related to more favorable soil moisture and nutrient conditions.

The relationship between SI and trends in soil properties was investigated by plotting SI values for each plot over their canonical variable 1 value from the DA04 discriminant analysis (Figure 19). Despite the limitations associated with such graphs, limitations which were discussed earlier (i.e. the use of only the first axis (canonical variable), the possibility of non-linear relationships, and the selection of variables to be used in the analysis), this figure suggests a relatively good linear relationship. The trend shown in Figure 19 suggests that 71% (r = 0.84**) of the variation in SI of Douglas-fir can be explained by changes in the soil properties selected by the DA04 discriminant analysis, i.e. PH.123, CNHF, CA.0123, PHHF, CN.123, and MG.0123 (Table 28).

It must be stressed that discriminant analysis selects the linear combination of variables that best characterizes differences between groups (Dixon, 1983). In this particular application, discriminant analysis was used to select the linear combination of soil properties that best characterizes differences between BA's 2, 3, 4, and 5. Although there was an increase in SI of Douglas-fir from BA 2 to BA 5, this does not imply that the selected soil properties are necessarily the best for explaining (predicting) differences in productivity.

Fertilization trials have shown that the productivity of

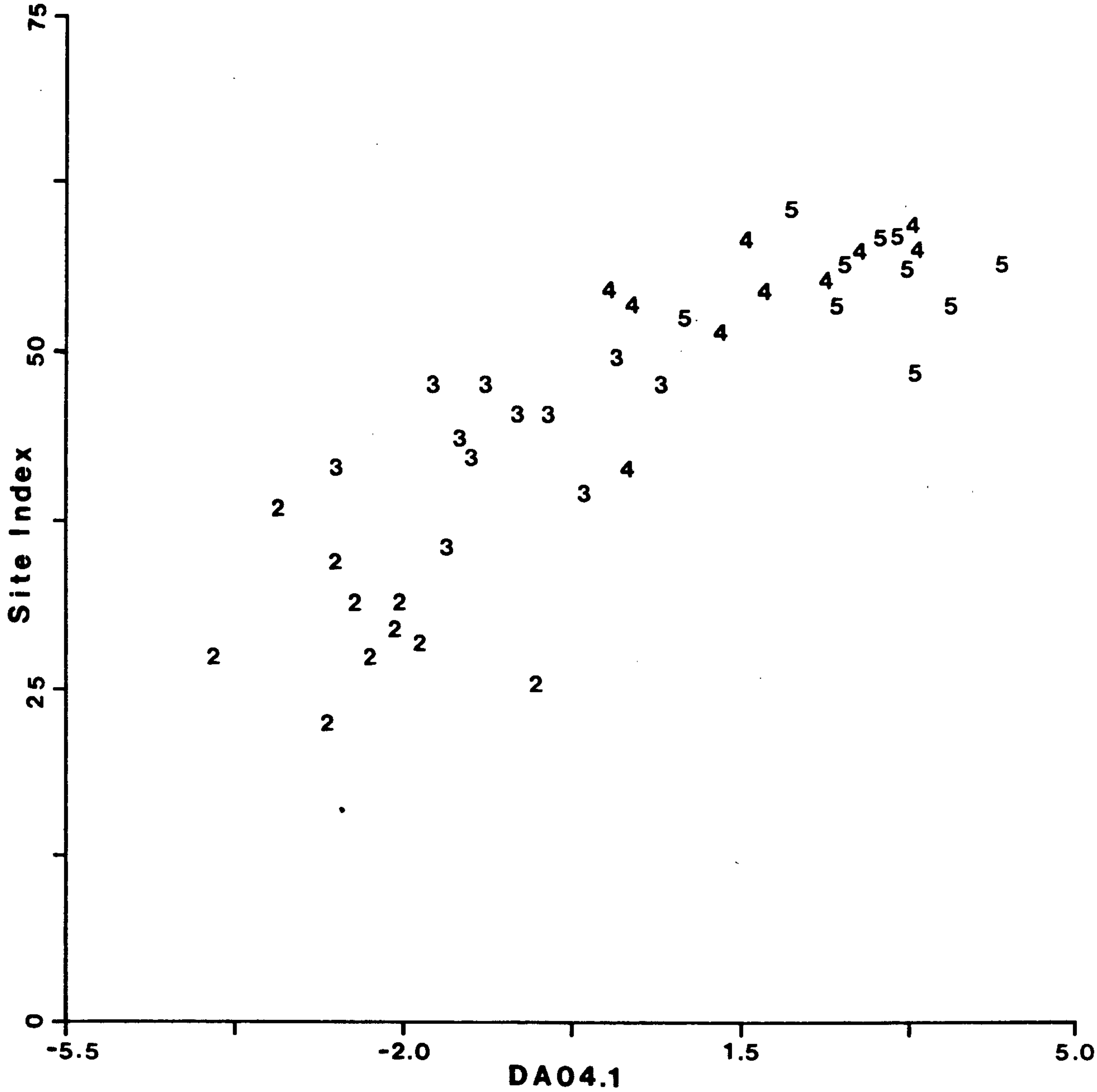

Figure 19 - Relationship between site index (m/100 yrs) of Douglas-fir (Pseudotsuga menziesii) and canonical variable 1 from the DA04 discriminant analysis (DA04.1). Symbols plotted indicate the association to which a sample plot belongs.

1 = the $PC-PJ association (association 1.11)
2 = the $PM-GS association (association 1.21)
3 = the $PM-KO association (association 2.11)
4 = the $PM-HS association (association 3.11)
5 = the $PM-PI association (association 3.12)
6 = the $AR-LA association (association 3.21)

many Douglas-fir stands is limited by low N-availability (Gessel and Atkinson, 1979). Heilman (1979) noted that nitrogen is the only nutrient giving rather consistent fertilizer responses in Douglas-fir stands and, because of this, is the only fertilizer element being commercially used in these stands. Shumway and Atkinson (1978) also noted that, in many instances, the application of nitrogen fertilizer has been shown to increase Douglas-fir yield.

An examination of Table 26 revealed that there were considerable differences in TN.0123 and MN.0123 between BA's 2 and 3, and BA's 4 and 5. It was speculated that these variables were not selected by discriminant analysis because the trend in these two indices of soil N status from BA 2 to BA 5 appeared to be curvilinear. Because of the frequent importance of soil N status in controlling productivity of Douglas-fir stands (mentioned above), it was felt that the relationship between soil N status and productivity of Douglas-fir in the Cowichan Lake sample plots should be investigated in greater detail. The results of this investigation are presented and discussed below.

The forty-one intermediate sample plots for which SI of Douglas-fir could be determined (i.e. plots in BA's 2, 3, 4, and 5) were subdivided into seven groups. These groups were composed of all plots belonging to the same growth class (GC). Descriptive statistics for sixteen indices of soil N status were calculated for each group using the MIDAS statistical package (Fox and Guire, 1976). These statistics are shown in Appendix N. Of these, total nitrogen (TN), mineralizable nitrogen (MN), and carbon:nitrogen ratio (CN) for the 0-30 cm mineral soil layer (layer .1) and for the mineral soil weighted to rooting depth (layer .123) were selected for further consideration.

The relationship between these indices of soil N status and growth class of Douglas-fir are shown in Figures 20 to 25. These figures suggest the following trends. Total N appears to be quite variable, but Figures 20 and 21 suggest that the highest levels of total soil N are associated with the most productive plots (i.e. those in GC's 1 and 2). A much more distinct trend is observed when mineralizable N is considered. In Figures 22 and 23, mean mineralizable N remains relatively constant in GC's 7, 6, and 5, but increases in a curvilinear manner from GC 4 to GC 1. Figure 23 suggests that MN.123 varies from a low of about 0 $kg \bullet ha^{-1}$ on the poorest sites to a high of over 100 $kg \bullet ha^{-1}$ on the most productive sites. Figures 24 and 25 suggest that there is a decrease in C:N ratio with increasing site productivity. This trend appears to be linear. CN.123 ranges from a high of about 31 for GC 7 to a low of about 19 for GC 1.

Keeney (1980) noted that only recently has research been directed towards relating results of N availability indices to actual tree growth or response to fertilization. Heilman (1979) stated that the determination of total N content has been the method most frequently used for evaluating the N fertility status of forest soils in the "Douglas-fir Region". He also noted that total N content has been "related in a general way to N fertilization response for limited numbers of soils".

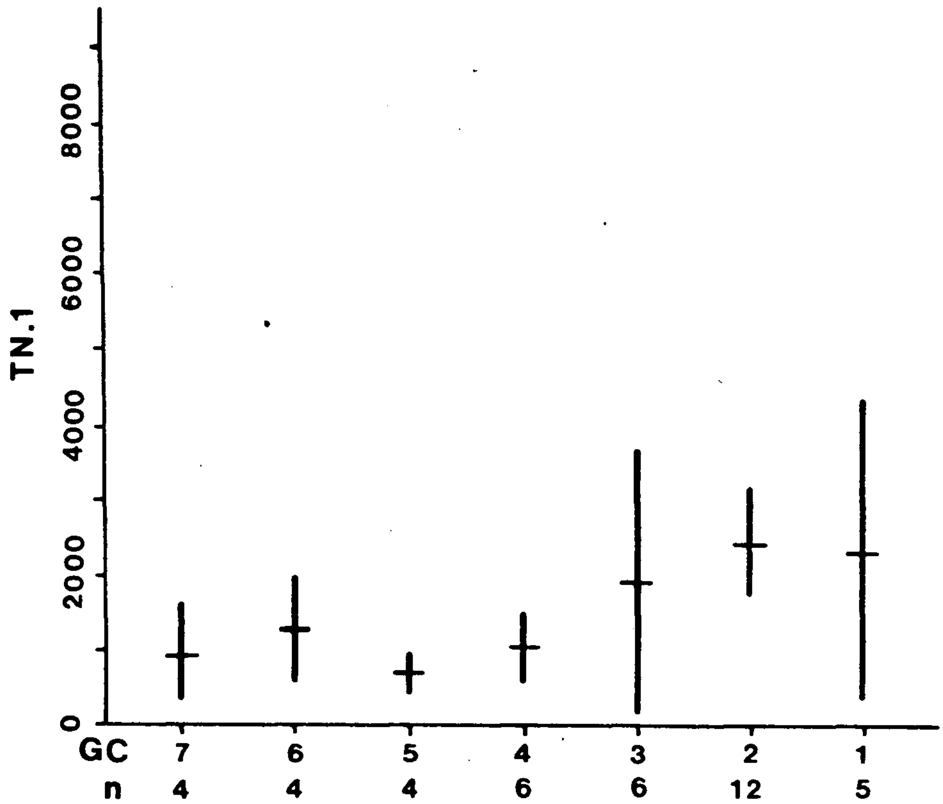

Figure 20 - Relationship between total N (kg/ha) in soil layer 1 (TN.1) and growth class (GC) of Douglas-fir (Pseudotsuga menziesii). Means (horizontal bars), 95% confidence intervals (vertical bars), and sample sizes (n) are shown.

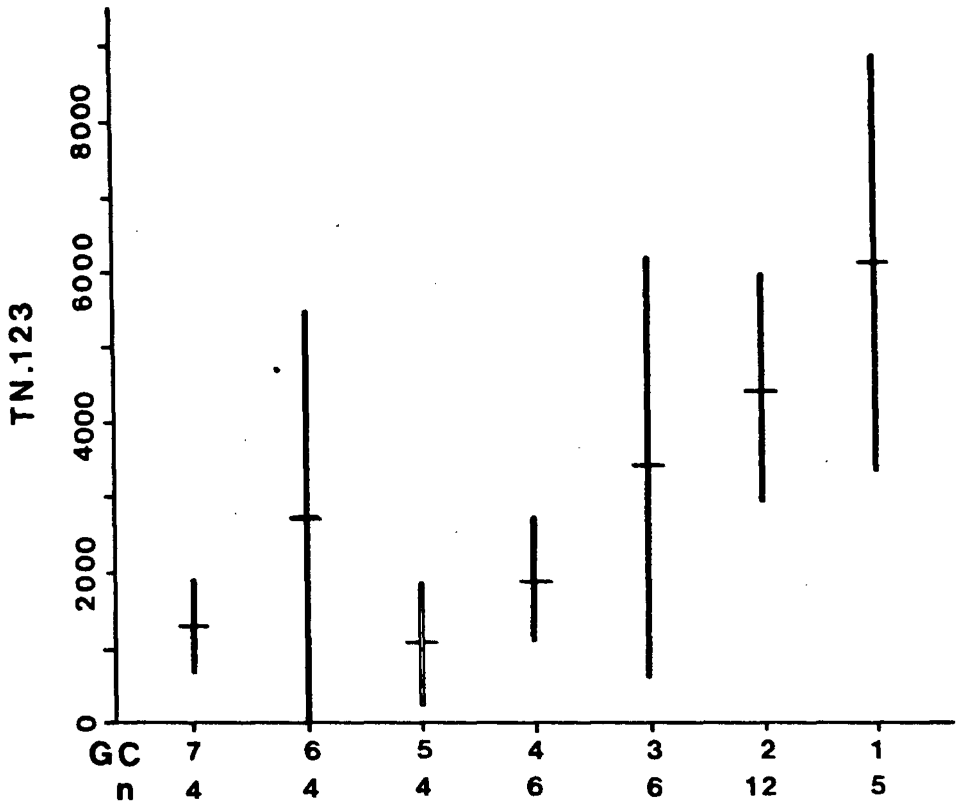

Figure 21 - Relationship between total N (kg/ha) in the mineral soil (TN.123) and growth class (GC) of Douglas-fir (Pseudotsuga menziesii). Means (horizontal bars), 95% confidence intervals (vertical bars), and sample sizes (n) are shown.

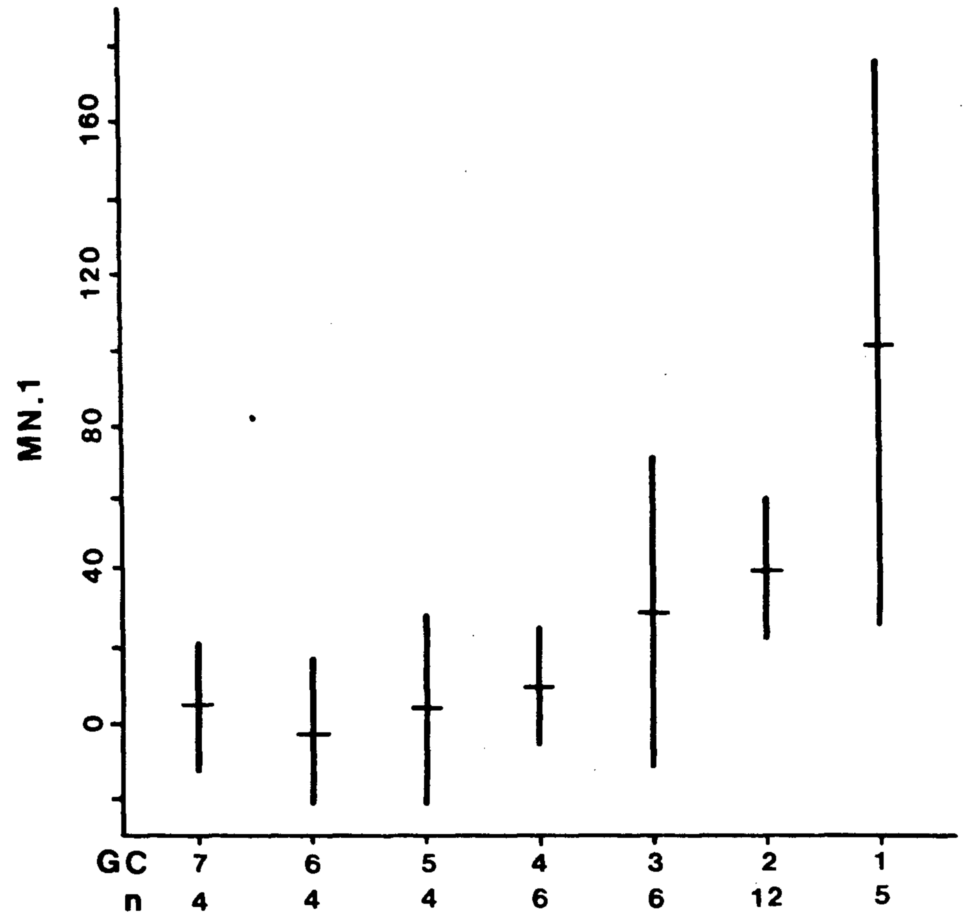

Figure 22 - Relationship between mineralizable N (kg/ha) in soil layer 1 (MN.1) and growth class (GC) of Douglas-fir (*Pseudotsuga menziesii*). Means (horizontal bars), 95% confidence intervals (vertical bars) and sample sizes (n) are shown.

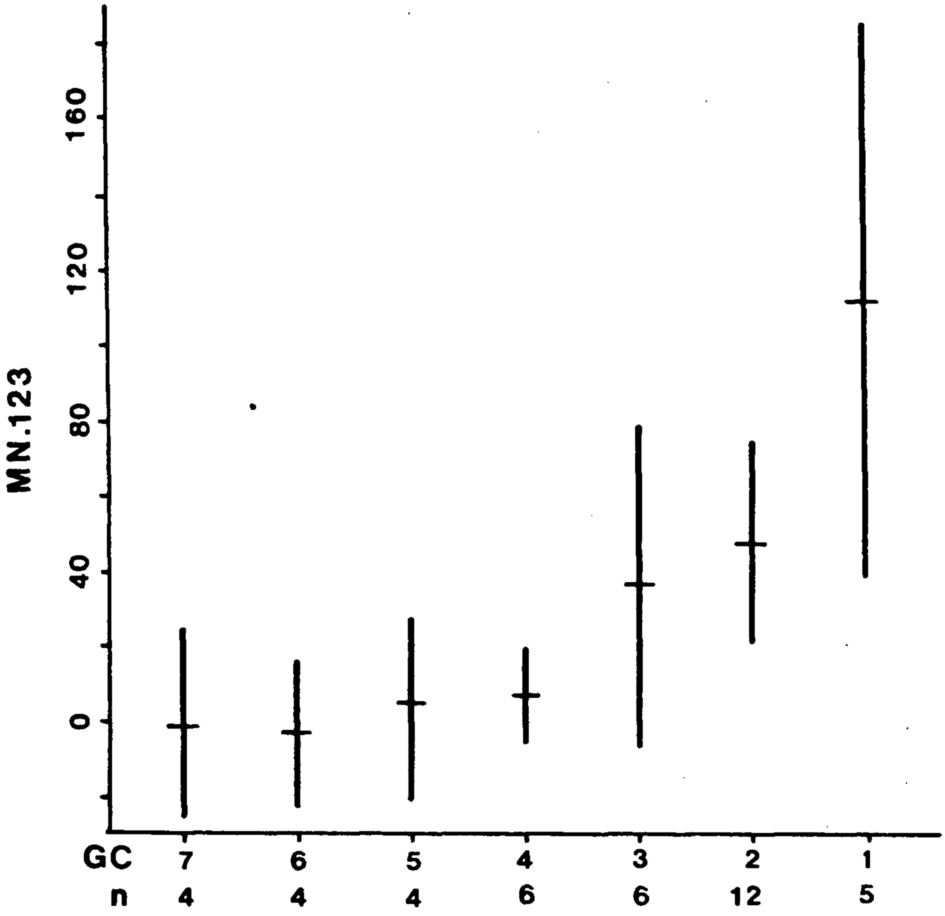

Figure 23 - Relationship between mineralizable N (kg/ha) in mineral soil (MN.123) and growth class (GC) of Douglas-fir (Pseudotsuga menziesii). Means (horizontal bars), 95% confidence intervals (vertical bars) and sample sizes (n) are shown.

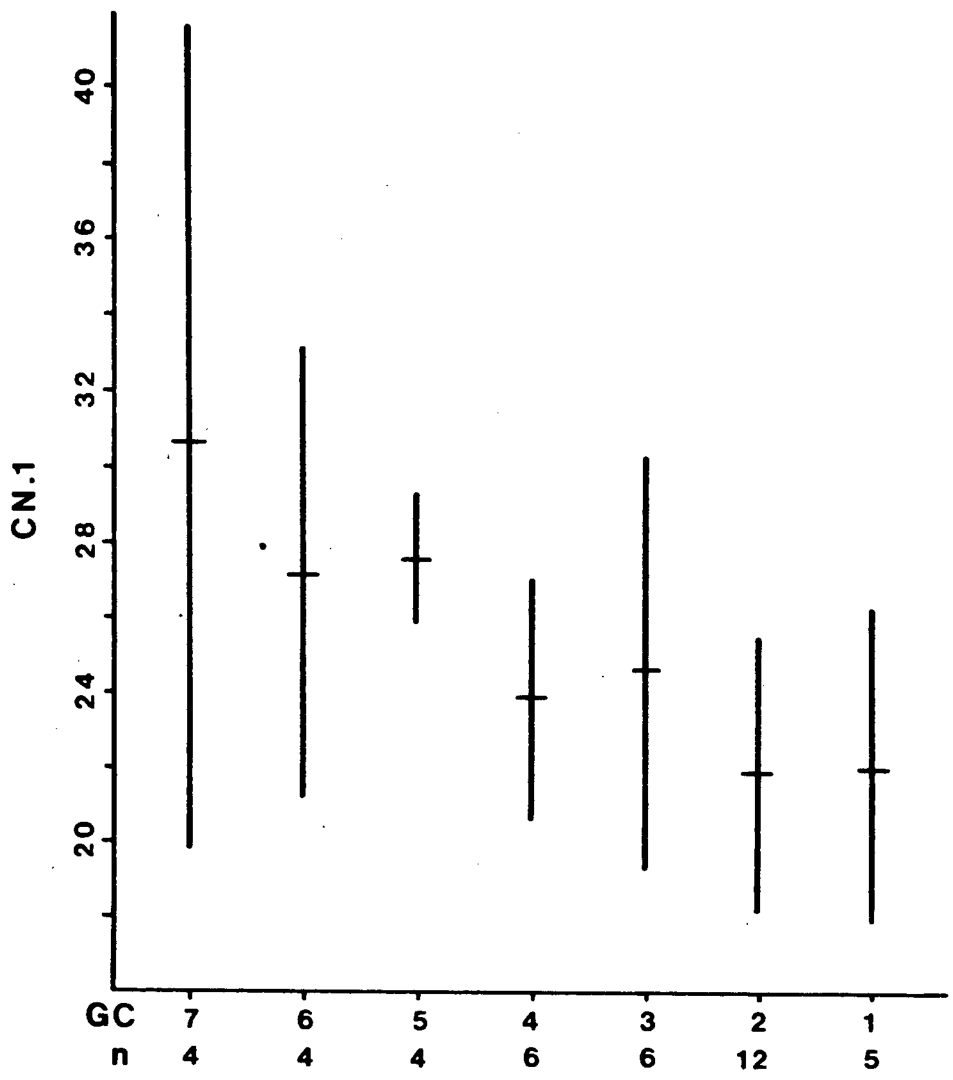

Figure 24 - Relationship between C:N ratio in soil layer 1 (CN.1) and growth class (GC) of Douglas-fir (Pseudotsuga menziesii). Means (horizontal bars), 95% confidence intervals (vertical bars), and sample sizes (n) are shown.

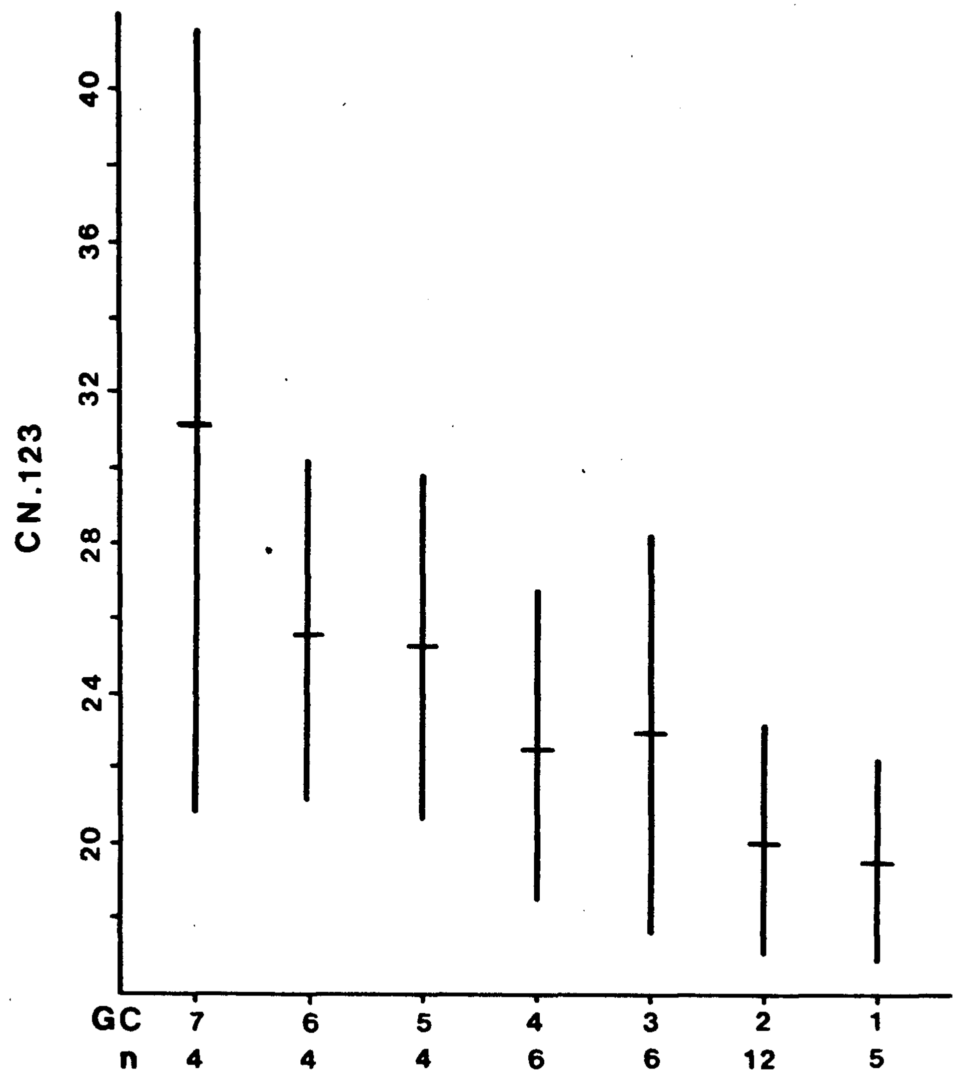

Figure 25 - Relationship between C:N ratio in the mineral soil (CN.123) and growth class (GC) of Douglas-fir (Pseudotsuga menziesii). Means (horizontal bars), 95% confidence intervals (vertical bars) and sample sizes (n) are shown.

However, this method does not appear to hold much promise because significant fertilization responses have been observed on soils with a very high total nitrogen content (Gessel and Atkinson, 1979). Shumway and Atkinson (1978) noted that Douglas-fir stands have responded to nitrogen fertilization even where the soil contains as much as 15,960 kg of total N per hectare (14,250 lb/acre). As Shumway and Atkinson (1978) and Gessel and Atkinson (1979) noted, an adequate nitrogen supply for tree growth depends to a great extent on N-mineralization rates which are only partially controlled by total N content of the soil. Bremner (1965) concluded that the determination of total N content appears to have limited value as an index of N availability.

Keeney (1980) stated that results to date indicate that the anaerobic incubation procedure is the most satisfactory laboratory N availability test. This conclusion is supported by studies done by Shumway and Atkinson (1978) and Powers (1980). Shumway and Atkinson (1978) determined mineralizable N content of the mineral soil in second-growth Douglas-fir stands in western Washington and Oregon. These stands were fertilized and growth response determined. They found that mineralizable N in responding stands was significantly lower than in non-responding stands. Powers (1980) found a significant correlation between mineralizable N and site index of Ponderosa pine (*Pinus ponderosa* Dougl. *ex* P.&C. Lawson) stands in northern California and southern Oregon.

Results of the Cowichan Lake study suggested that mineralizable N as determined by the anaerobic incubation technique of Waring and Bremner (1964) may be useful for assessing site quality for Douglas-fir. Figures 22 and 23 suggest that, on poorer sites, N availability is quite low and does not vary substantially. Other factors such as moisture and the levels of other nutrients may be responsible for differences in site productivity. But, on the better sites, site index of Douglas-fir appears to increase with the amount of mineralizable N. This would suggest that other factors such as moisture level and the levels of other nutrients are adequate and site productivity is controlled by N availability.

The carbon:nitrogen ratio of soil organic matter affects its decomposition rate and the rate at which nitrogen becomes available for uptake by plants (Bartholomew, 1965; Scarsbrook, 1965; Brady, 1974; Richards, 1974; Heilman, 1979; Pritchett, 1979; and Youngberg, 1979). Lower C:N ratios are associated with faster decomposition rates and more rapid release of available forms of nitrogen (Heilman, 1979). Lowe and Klinka (1981) collected samples of forest humus (ectorganic and/or endorganic horizons) from thirty ecosystems in the CWH zone of British Columbia. They found a significant correlation ($r = 0.82^{**}$) between the C:N ratio of the humus form and growth class of Douglas-fir. In the Cowichan Lake study, a statistically significant correlation ($r = 0.69^{**}$) was also found between the C:N ratio of the humus form (CNHF) and GC of Douglas-fir (Appendix N). In this study, a significant correlation ($r = 0.62^{**}$) was also found between CN.123 and GC of Douglas-fir.

Klinka et al. (1981a) found an average C:N ratio of 19 in the A horizon of GC 1 Douglas-fir "benchmark" ecosystems. On the most productive plots in the Cowichan Lake study (i.e. plots in GC 1), a similar value (CN.1 = 22) was found.

Heilman (1979) stated that high C:N ratios (above 25-30 in mineral soil) indicate low availability of N for plant growth, but that relatively little use has been made of C:N ratios for evaluating N-supplying potential of forest soils. Recent work suggests that this ratio does indeed appear to be useful for this purpose. Powers (1980), in his study of forest soils in northern California and southern Oregon, found a significant correlation between the C:N ratio of mineral soil samples (collected from the 18-22 cm mineral soil layer) and the amount of N released during anaerobic incubation. In his study, he found that, as the C:N ratio of mineral soil samples increased, the amount of available N (as estimated by the anaerobic incubation method) decreased. The same trend was observed in the Cowichan Lake study. Figures 26 and 27 show the relationship between mineralizable N and C:N ratio found in this study. Growth class values are plotted at the intersection of mean mineralizable N value and mean C:N ratio for that growth class. These two figures summarize trends observed in previous figures. They suggest that lower C:N ratios correspond with increased N availability (as estimated by mineralizable N) and that these corresponding trends are related to increases in site productivity as estimated by growth class of Douglas-fir.

The critical C:N value of 25-30 suggested by Heilman (1979)

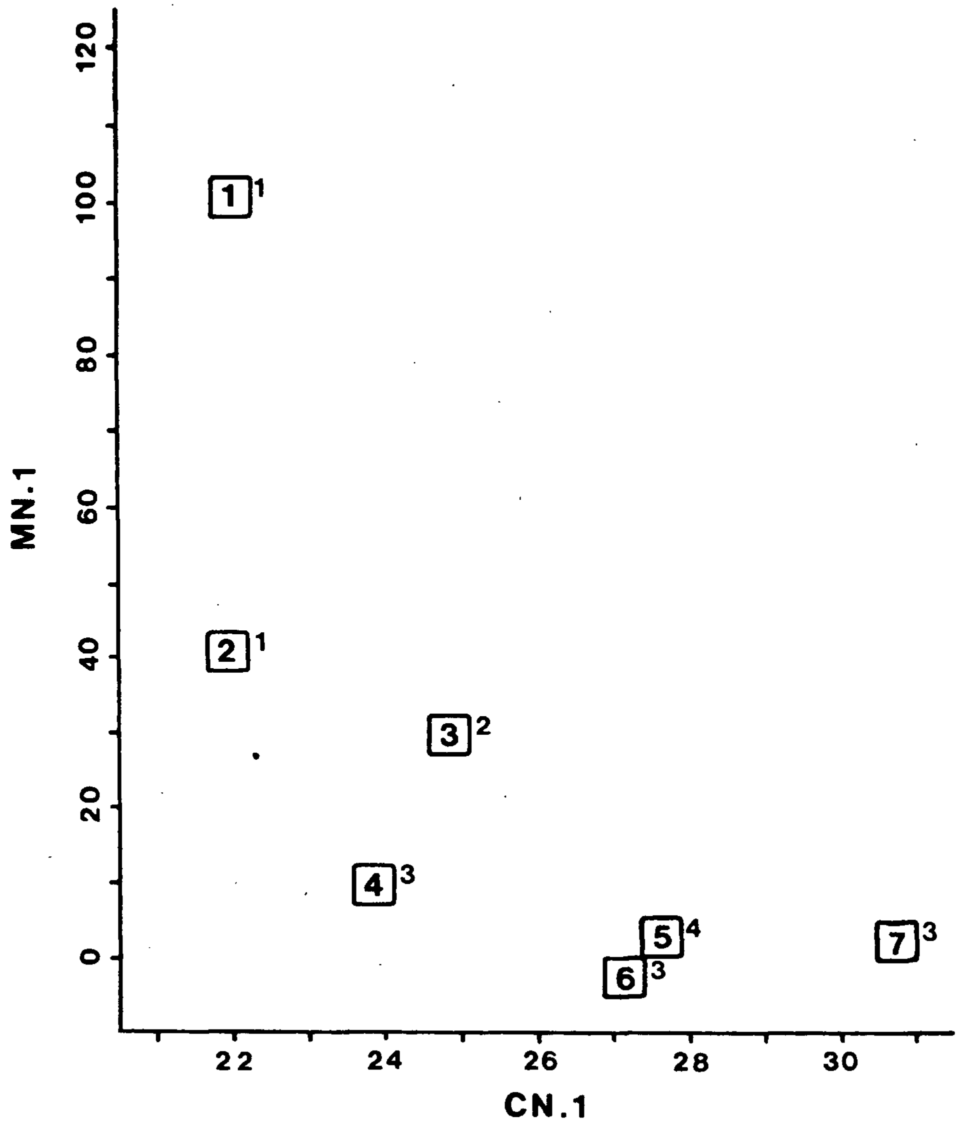

Figure 26 - Relationship between mineralizable N (kg/ha) and C:N in soil layer 1 (MN.1, CN.1), and growth class of Douglas-fir (*Pseudotsuga menziesii*). Growth class values are plotted at mean MN and C:N value for that growth class.

[1] includes plots with mull humus form only
[2] includes plots with mull, moder and mor humus form
[3] includes plots with moder and mor humus form
[4] includes plots with mor humus form only

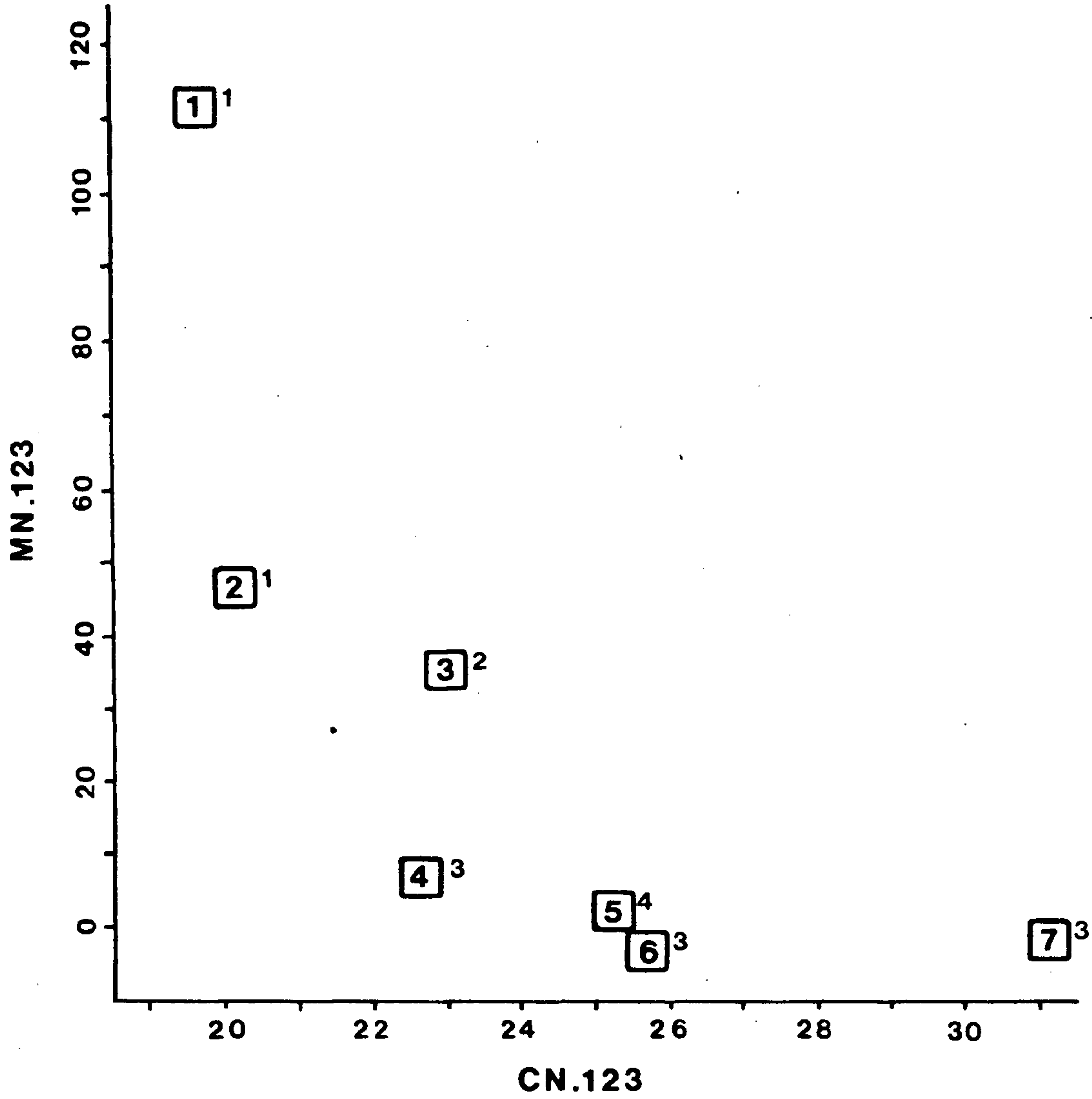

Figure 27 - Relationship between mineralizable N (kg/ha) and C:N in the mineral soil (MN.123, CN.123), and growth class of Douglas-fir (Pseudotsuga menziesii). Growth class values are plotted at mean MN and C:N value for that growth class.

[1] includes plots with mull humus form only
[2] includes plots with mull, moder and mor humus form
[3] includes plots with moder and mor humus form
[4] includes plots with mor humus form only

appears to be supported by results of the Cowichan Lake study. An examination of Figure 26 suggests that when the C:N ratio of the 0-30 cm soil layer is less than about 26, net mineralization as estimated by the Waring and Bremner (1964) method increases quite rapidly with a decrease in C:N ratio, but, when the C:N ratio is greater than 26, net mineralization is negligible and remains relatively constant with an increase in C:N ratio.

Figures 26 and 27 also demonstrate that the most productive sites in the study area, sites which had the highest mineralizable N values and the lowest C:N ratios, also had a very obvious morphological feature, i.e. a mull humus form. The actual humus form Group (Klinka et al., 1981b) for each plot is shown in Table 32. This data is organized by growth class (GC) of Douglas-fir.

Klinka et al. (1981b) stated that the mor order encompasses the least biologially active humus forms and that decomposition of organic materials takes place most rapidly in humus forms of the mull order. This relationship between humus forms and the rate of biological activity has been recognized by many authors (Krajina, 1969; Van Praage and Brigode, 1973; Youngberg, 1979; Spurr and Barnes, 1980; Lowe and Klinka, 1981; Gosz, 1981; Krajina et al., 1982: and many others). Youngberg (1979) noted that mull humus forms are characteristic of soil conditions where decomposition is rapid and where moisture and temperature favor biological activity. On the other hand, he noted that mor humus forms are characteristic of soil conditions where decomposition processes are not as rapid, resulting in an

Table 32 - Humus form Group (Klinka et al., 1981b) for all plots in biogeocoenotic associations (BA) 2, 3, 4, and 5. Data is organized according to growth class (GC) of Douglas-fir (Pseudotsuga menziesii).

GC	PLOT-BA	HUMUS FORM	GC	PLOT-BA	HUMUS FORM	GC	PLOT-BA	HUMUS FORM
GOOD			MEDIUM			POOR		
1	16-5	VL	3	02-5	VL	6	11-2	HUR
	20-4	VL		04-3	MD		44-2	UR
	24-4	VL		07-3	UR		46-2	MD
	30-5	VL		21-4	MD		48-2	HUR
	36-5	VL		28-3	MD			
				42-3	HR	7	12-2	HUR
2	05-4	VL					34-2	HUR
	09-5	VL	4	01-3	HUR		37-2	MD
	10-4	VL		06-3	MD		38-2	HUR
	14-4	VL		08-3	MD			
	15-5	VL		19-3	HUR			
	17-4	VL		23-3	MD			
	22-4	VL		45-4	MD			
	25-5	VL						
	26-4	VL	5	03-3	HUR			
	27-5	VL		32-2	HUR			
	29-5	VL		33-2	HUR			
	41-5	VL		43-3	HUR			

HR = Hemimor
HUR = Hemihumimor
UR = Humimor
MD = Mormoder
VL = Vermimull

accumulation of organic material on the forest floor.

Spurr and Barnes (1980) stated that an excessive development of mor humus forms usually indicates poor N supply in the soil. Van Praage and Brigode (1973) also noted a relationship between the N cycle and the type of humus form. They observed that N cycling was more rapid in mull and moder than in mor humus forms. Klinka et al. (1981b) stated that "In comparison to the other orders, mulls may be considered as providing the greatest amount of available nutrients to plants, in particular, nitrogen.". A similar relationship between N availability and humus form was suggested by Gosz (1981).

Spurr and Barnes (1980) suggested that, on sites with a mor humus form, low N availability may result in lowered growth of forest trees. This observation is supported by results of the Cowichan Lake study. The least productive sites in the study area were characterized by mor humus forms and the most productive sites by mull humus forms (Table 32). Also, Figures 26 and 27 suggest that relatively high N availability is associated with mull humus forms and relatively low N availability with mor humus forms. The relationship between humus form and productivity of Douglas-fir found in the Cowichan Lake study also agrees with the conclusions of Lowe and Klinka (1981). They cited several studies which indicated that sites supporting the best growth of Douglas-fir are characterized by mull humus forms.

Krajina (1969) and Krajina et al. (1982) also observed that the best growth of Douglas-fir occurs where the humus form is mull or moder. They stated that Douglas-fir grows poorly where ammonium is the only form of available N in the soil, and that this species requires nitrates for its best growth. They also stated that nitrification is carried out mainly in soils where calcium is readily available and the humus form is mull or moder, and that the rate of nitrification is decreased where there is an acid mor humus form.

Descriptive statistics for five indices of soil Ca status were calculated using the MIDAS (Fox and Guire, 1976) statistical package. These statistics are shown in Appendix O.

Figures 28 and 29 show the relationship between two of these and GC of Douglas-fir in the Cowichan Lake sample plots. Figure 28 shows the relationship between GC and soil Ca content in the 0-30 cm soil layer (CA.1) and Figure 29 shows the relationship between GC and soil Ca content in the mineral soil weighted to rooting depth (CA.123). These figures suggest that the most productive sites have the highest levels of soil calcium. Thus, according to the statements made by Krajina (1969) and Krajina et al. (1982) discussed above, these figures suggest that increased productivity of Douglas-fir in the GC 1 and GC 2 plots may have been influenced by increased nitrification rates and, consequently, increased availability of nitrate.

Finally, it should be noted that the trends in soil N and Ca status discussed above are almost identical when figures considering N and Ca in soil layer 1 are compared to figures considering N and Ca in mineral soil to rooting depth. This would suggest that sampling layer 1 only may be adequate for deriving an index of soil N and Ca status in terms that are useful for assessing (predicting) site productivity.

5.5.4 Synthesis Of Vegetation/Soil/Productivity Relationships

The information in Figures 18 and 19 is summarized in Figure 30. This figure is the same as Figure 17 with the exception that growth class of Douglas-fir is plotted instead of the biogeocoenotic association symbol. Figure 30 suggests that there is a good relationship between growth performance of

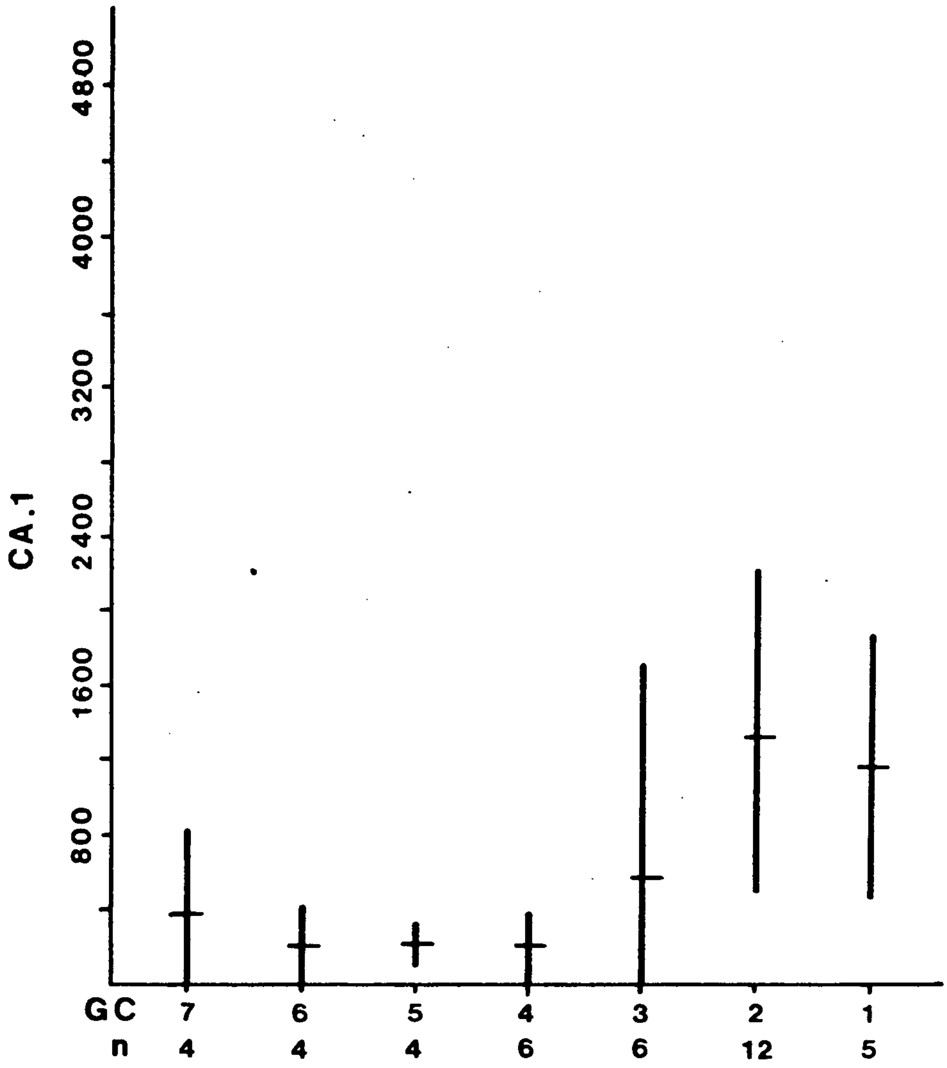

Figure 28 - Relationship between Ca (kg/ha) in soil layer 1 (CA.1) and growth class (GC) of Douglas-fir (Pseudotsuga menziesii). Means (horizontal bars), 95% confidence intervals (vertical bars), and sample sizes (n) are shown.

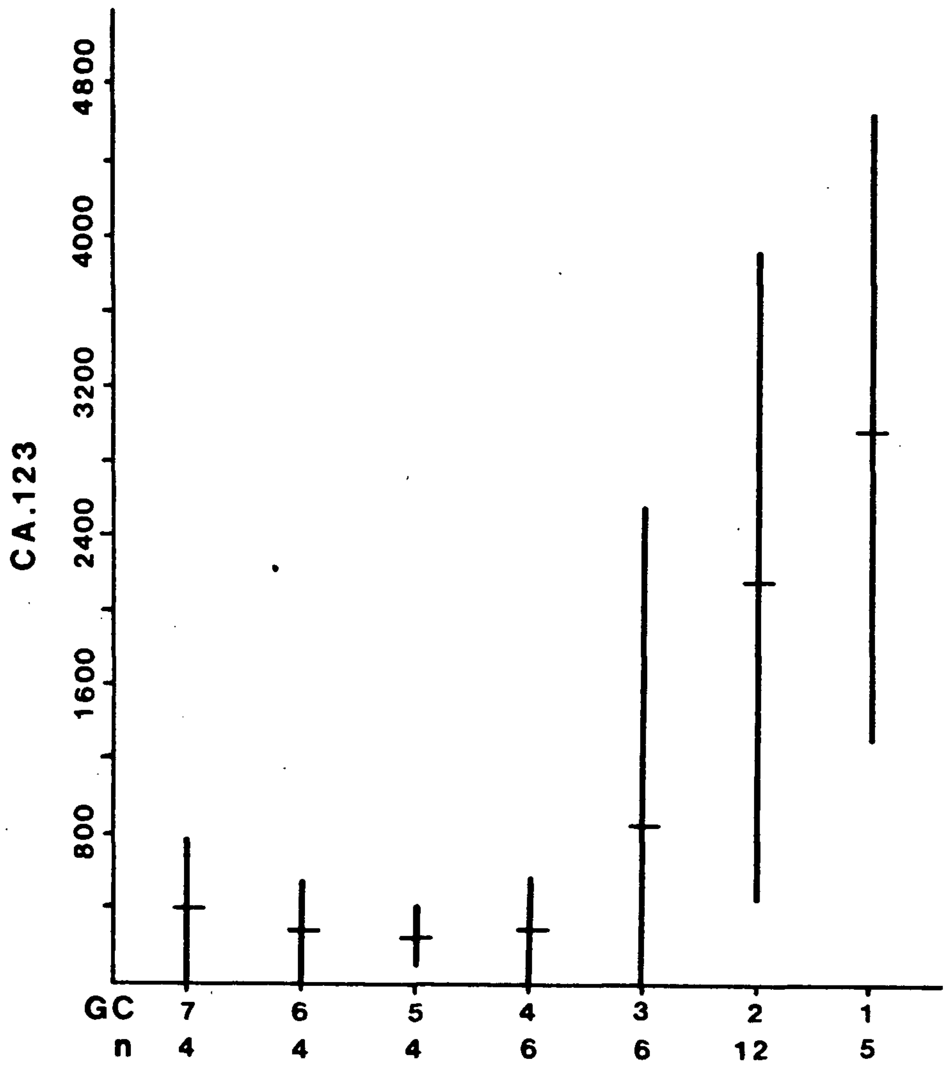

Figure 29 - Relationship between Ca (kg/ha) in the mineral soil (CA.123) and growth class (GC) of Douglas-fir (<u>Pseudotsuga menziesii</u>). Means (horizontal bars), 95% confidence intervals (vertical bars), and sample sizes (n) are shown.

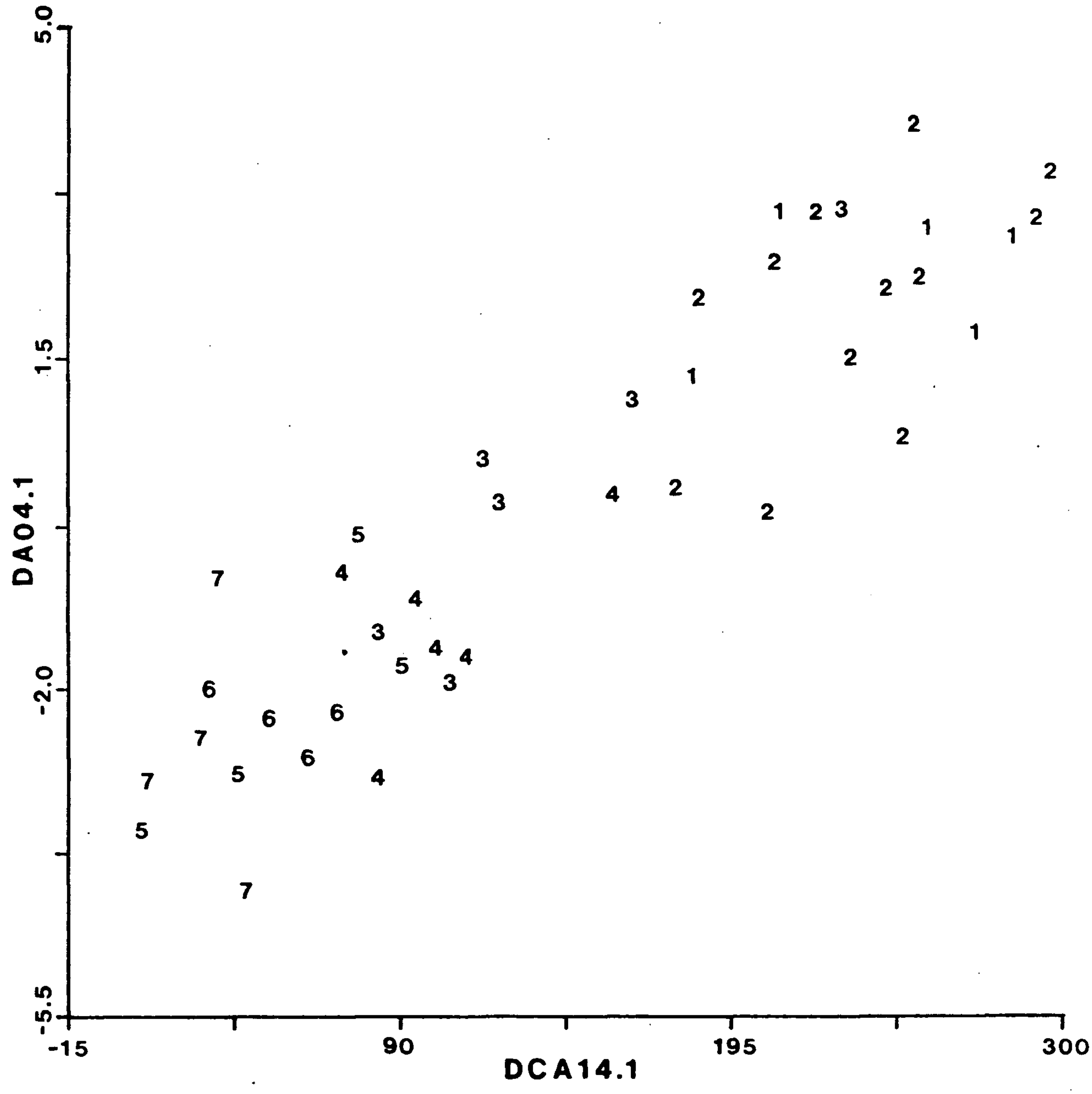

Figure 30 - Relationship between canonical var. 1 of the DA04 discriminant analysis (DA04.1) and axis 1 score of the DCA14 ordination (DCA14.1). Symbols plotted indicate the growth class of Douglas-fir (Pseudotsuga menziesii) on each plot.

Douglas-fir and the corresponding changes in understory vegetation and soil properties. Low DA04 and DCA14 scores correspond to poor productivity of Douglas-fir while high DA04 and DCA14 scores correspond to good productivity of Douglas-fir. Possible reasons for these observed trends were suggested earlier.

VI. SUMMARY AND CONCLUSIONS

Fifty-one sample plots were located in second-growth forest ecosystems surrounding Cowichan Lake on Vancouver Island. Floristic composition, general site properties, selected soil physical and chemical properties, and site productivity as estimated by site index of Douglas-fir were determined for each plot. A classification of these immature forest ecosystems was produced, and relationships between floristic composition, site properties, soil properties, and productivity were examined. Methods employed included: 1) standard methods used in the biogeoclimatic ecosystem classification system as applied by the B.C. Ministry of Forests, and 2) multivariate analysis techniques including ordinations (polar, reciprocal averaging, and detrended correspondence analysis) and cluster analysis of the vegetation data, and stepwise discriminant analysis of edatopic indicator species groups (EISG's) and site and soil properties.

The main results of this study are summarized as follows:

1. The number of classes and class membership of each plot was finalized after consideration of environment data and the results of multivariate analysis (particularly RA and DCA) applied to the floristic data. Three orders, five alliances, and six biogeocoenotic associations (BA's) were established.
2. An arranged species-stratum-unit by plots matrix provided a useful summary of species distributions. This matrix showed that, to varying degrees, species distributions tend to be concentrated in particular BA's, supporting the contention that

different combinations of species can be used to characterize different BA's.

3. An objective, repeatable procedure for extracting from summary vegetation tables the characteristic combination of species (CCS) for orders, alliances, and associations was developed and proposed for use in future studies. This procedure was applied and the CCS of all syntaxa were derived.

4. A comparison of the summary vegetation tables of three of the immature Cowichan Lake associations to the summary vegetation tables of three (climatically and edaphically similar) mature associations revealed strong similarities in understory species abundance and composition. This suggested that understory plant communities of the immature forest ecosystems had already sufficiently stabilized to permit successful identification of the probable climax association.

5. Based on a consideration of estimated hygrotope and trophotope values of the sample plots, it was suggested that axis 1 of the floristic data ordinations corresponded to a complex environmental gradient related to increasing availability of soil moisture and nutrients. This suggestion was supported by the results of indicator plant analysis. This analysis suggested that axis 1 corresponded to a change in species composition from dry-site to wet-site indicators, and from nutrient-poor to nutrient-rich site indicators. Discriminant analysis (DA) of EISG's produced classification functions which could subsequently be used to classify additional plots not used in the original analysis.

6. Trends in a limited number of quantitatively assessed site morphological and soil physical and chemical properties also supported the suggestion that axis 1 of the floristic data ordinations corresponded to increasing availability of soil moisture and nutrients. It was observed that, from BA 1 to BA 6, there appeared to be a decrease in growing season soil water deficits and soil C:N ratios, and parallel increases in soil N content, exchangeable cations, and C.E.C.. There was also a transition from mor and moder to mull humus forms, suggesting more rapid nutrient cycling (particularly N).

7. Discriminant analysis of the site and soil properties selected linear combinations of properties which best characterized differences between the BA's. It was found that the use of soil physical and chemical properties was more successful than the use of site properties for differentiating between the BA's. As with EISG's, discriminant analysis of the soil properties produced classification functions which could subsequently be used to classify additional sample plots not used in the original analysis.

8. The possibility of parallel trends in soil and vegetation patterns was investigated by considering relationships between axis 1 scores from the DCA floristic data ordinations and canonical variable 1 from the soil properties DA. It was found that, when considering all fifty-one plots in BA's 1 to 6, only 52% of the variation in understory vegetation was related to differences in the selected soil properties but, when considering the forty-one intermediate plots in BA's 2, 3, 4,

and 5, 83% of the variation was explained.

9. The data suggested an increase in productivity from BA 2 to BA 4 and no differences in productivity between BA's 4 and 5. Mean site index (m/100 yrs) of Douglas-fir was 29, 44, 54, and 55 for BA's 2 to 5 respectively. Growth of Douglas-fir on the other two BA's (i.e. BA's 1 and 6) was severely limited by edaphic conditions.

10. The relationship between site index of Douglas-fir and axis 1 scores of the DCA14 ordination suggested that 78% of the variation in site index appeared to be related to changes in understory vegetation. This observation supports the contention that understory plant communities are useful indicators of site quality for growth of Douglas-fir.

11. The relationship between site index of Douglas-fir and canonical variable 1 of DA04 suggested that 71% of the variation in site index appeared to be related to changes in the soil properties which best discriminated between BA's 2, 3, 4, and 5.

12. Relationships between growth class of Douglas-fir and several indices of soil N status were investigated. It was found that mineralizable N values were highest and C:N ratios lowest on the most productive sites. This suggested that increases in productivity were at least partially due to higher N availability. The most productive sites were also characterized by a mull humus form, suggesting that these sites were characterized by more rapid decomposition rates and more rapid nutrient cycling. It was also noted that the most productive sites had the highest levels of soil Ca suggesting

more rapid nitrification rates and more nitrate, an available form of N often found to be associated with the best growth of Douglas-fir.

In conclusion, the application of multivariate analysis techniques (particularly reciprocal averaging, detrended correspondence analysis, and stepwise discriminant analysis) proved very useful in the Cowichan Lake study. Results of these analyses were useful not only for classification purposes but also for the investigation of trends in environmental properties and site productivity. These techniques provide a rapid, computer-assisted approach to data synthesis; a consideration of great importance when dealing with large data sets. They also provide a more objective basis for interpretations. For these reasons, it is recommended that proponents of the biogeoclimatic system make greater use of these techniques in future studies.

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APPENDIX A - LIST OF PLANT SPECIES

Nomenclature of vascular plants (with some exceptions) follows that of Taylor and MacBryde (1977), while Ireland *et al*. (1980) was followed for mosses (two exceptions), Stotler and Crandall-Stotler (1977) for hepatics, and Hale and Culberson (1970) for lichens. Exceptions followed Krajina *et al*. (1984) and Ochyra (1982).

VASCULAR PLANTS

Abies grandis	(Dougl. *ex* D. Don) Lindl.
Acer macrophyllum	Pursh
Achillea millefolium	L.
Achlys triphylla	(Sm.) DC.
Adenocaulon bicolor	Hook.
Adiantum pedatum	L.
Alnus rubra	Bong.
Amelanchier alnifolia	(Nutt.) Nutt.
Anemone lyallii	Britt.
Apocynum androsaemifolium *	L.
Arbutus menziesii	Pursh
Arctostaphylos uva-ursi *	(L.) Spreng.
Asarum caudatum	Lindl.
Athyrium filix-femina	(L.) Roth
Blechnum spicant	(L.) Roth
Boschniakia hookeri	Walp.
Botrychium virginianum	(L.) Swartz *in* Schrad.
Boykinia elata	(Nutt.) Greene
Bromus sitchensis	Trin.
Bromus vulgaris	(Hook.) Shear
Calypso bulbosa	(L.) Oakes *in* Thomps.
Camassia quamash	(Pursh) Greene
Cardamine breweri	Wats.
Cardamine oligosperma	Nutt. *in* Torr. & Gray
Carex deweyana	Schwein.
Carex hendersonii	Bailey
Carex obnupta	Bailey
Chimaphila menziesii *	(R. Br. *ex* D. Don) Spreng.
Chimaphila umbellata *	(L.) Barton
Cinna latifolia	(Trev. *ex* Gopp.) Griseb. *in* Ledeb.
Circaea alpina	L.
Claytonia sibirica	L.
Collomia heterophylla	Hook.
Corallorhiza mertensiana	Bong.
Cornus nuttallii	Audub. *ex* Torr. & Gray
Cystopteris fragilis	(L.) Bernh. *in* Schrad.
Cytisus scoparius	(L.) Link
Danthonia spicata	(L.) Beauv. *ex* Roem. & Schult.
Dicentra formosa	(Haw.) Walp.
Disporum hookeri	(Torr.) Nicholson
Disporum smithii	(Hook.) Piper
Dryopteris expansa	(Presl) Fraser-Jenkins & Jermy
Elymus glaucus	Buckl.
Equisetum arvense	L.
Equisetum telmateia	Ehrh.
Erythronium revolutum	Sm. *in* Rees
Festuca occidentalis	Hook.
Festuca subuliflora	Scribn. *in* Macoun
Fragaria vesca *	L.
Fragaria virginiana *	Duchesne
Galium triflorum	Michx.
Gaultheria shallon	Pursh

Geranium robertianum	L.
Glyceria elata	(Nash) M.E. Jones
Goodyera oblongifolia	Raf.
Gymnocarpium dryopteris	(L.) Newm.
Hemitomes congestum	Gray
Heuchera micrantha	Dougl. ex Lindl.
Hieracium albiflorum	Hook.
Holodiscus discolor	(Pursh) Maxim.
Hypochoeris radicata	L.
Hypopithys lanuginosa	(Michx.) Nutt.
Ilex aquifolium	L.
Juniperus communis	L.
Juniperus scopulorum	Sarg.
Lilium columbianum	Hanson ex Baker
Linnaea borealis *	L.
Listera banksiana	Lindl.
Listera cordata	(L.) R. Br. in Ait.
Lonicera ciliosa	(Pursh) DC.
Lotus micranthus	Benth.
Lupinus polyphyllus	Lindl.
Luzula parviflora	(Ehrh.) Desv.
Lycopodium clavatum	L.
Lysichitum americanum	Hult. & St. John
Mahonia aquifolium	(Pursh) Nutt.
Mahonia nervosa	(Pursh) Nutt.
Maianthemum dilatatum	(Wood) Nels. & Macbr.
Malus fusca	(Raf.) Schneid.
Melica subulata	(Griseb.) Scribn.
Mitella ovalis	Greene
Monotropa uniflora	L.
Montia parvifolia	(Moc. ex DC.) Greene
Mycelis muralis	(L.) Dumort.
Nemophila parviflora	Dougl. ex Benth.
Oenanthe sarmentosa	Presl ex DC.
Oplopanax horridus	(Sm.) Miq.
Osmorhiza chilensis	Hook. & Arn.
Physocarpus capitatus	(Pursh) Ktze.
Picea sitchensis	(Bong.) Carr.
Pinus contorta	Dougl. ex Loud.
Pinus monticola	Dougl. ex D. Don in Lamb.
Platanthera chorisiana	(Cham.) Reich.
Platanthera unalascensis	(Spreng.) Kurtz
Poa marcida	Hitchc.
Polypodium glycyrrhiza	D.C. Eaton
Polystichum munitum	(Kaulf.) Presl
Populus trichocarpa	Torr. & Gray ex Hook.
Prunella vulgaris	L.
Pseudotsuga menziesii	(Mirb.) Franco
Pteridium aquilinum	(L.) Kuhn in Decken
Pterospora andromedea	Nutt.
Pyrola dentata *	Sm. in Rees
Pyrola picta *	Sm. in Rees
Ranunculus uncinatus	D. Don in G. Don
Rhamnus purshianus	DC.

Ribes divaricatum	Dougl.
Rosa gymnocarpa	Nutt. in Torr. & Gray
Rubus parviflorus	Nutt.
Rubus spectabilis	Pursh
Rubus ursinus *	Cham. & Schlecht.
Salix sitchensis	Sanson in Bong.
Sambucus racemosa	L.
Selaginella wallacei	Hieron.
Smilacina stellata	(L.) Desf.
Sorbus aucuparia	L.
Sorbus sitchensis	M. J. Roem.
Spiraea menziesii	Hook.
Stachys cooleyae	Heller
Stellaria crispa	Cham. & Schlecht.
Streptopus amplexifolius	(L.) DC. in Lam. & DC.
Streptopus roseus	Michx.
Streptopus streptopoides	(Ledeb.) Frye & Rigg
Symphoricarpos albus	(L.) Blake
Symphoricarpos hesperius	G. N. Jones
Taxus brevifolia	Nutt.
Tellima grandiflora	(Pursh) Dougl. ex Lindl.
Thuja plicata	Donn ex D. Don in Lamb.
Tiarella laciniata	Hook.
Tiarella trifoliata	L.
Trautvetteria caroliniensis	(Walt.) Vail
Trientalis latifolia	Hook.
Trillium ovatum	Pursh
Trisetum cernuum	Trin.
Tsuga heterophylla	(Raf.) Sarg.
Urtica dioica	L.
Vaccinium alaskaense	How.
Vaccinium ovalifolium	Sm. in Rees
Vaccinium parvifolium	Sm. in Rees
Veratrum viride	Ait.
Viola adunca	Sm. in Rees
Viola glabella	Nutt. in Torr. & Gray
Viola orbiculata	Geyer ex Hook.
Viola sempervirens	Greene

BRYOPHYTES

Aulacomnium androgynum	(Hedw.) Schwaegr.
Brachythecium frigidum	(C. Mull.) Besch.
Chiloscyphus pallescens	(Ehrh. ex Hoffm.) Dum.
Claopodium bolanderi	Best
Conocephalum conicum	(L.) Lindb.
Dicranum fuscescens	Turn.
Dicranum howellii	Ren. & Card.
Dicranum scoparium	Hedw.
Homalothecium megaptilum	(Sull.) Robins.
Hookeria lucens	(Hedw.) Sm.
Hylocomium splendens	(Hedw.) B.S.G.
Hylocomium umbratum	(Hedw.) B.S.G.

Isopterygium elegans	(Brid.) Lindb.
Isothecium stoloniferum	Brid.
Kindbergia oregana	(Sull.) Ochyra
Kindbergia praelonga	(Hedw.) Ochyra
Leucolepis menziesii	(Hook.) Steere *ex* L. Koch
Mnium spinulosum	B.S.G.
Plagiochila asplenioides	(L.) Dum.
Plagiochila porelloides	(Torr. *ex* Nees) Lindb.
Plagiomnium insigne	(Mitt.) Kop.
Plagiothecium cavifolium	(Brid.) Iwats.
Plagiothecium undulatum	(Hedw.) B.S.G.
Pleurozium schreberi	(Brid.) Mitt.
Pogonatum alpinum	(Hedw.) Rohl.
Polytrichum commune	Hedw.
Polytrichum juniperinum	Hedw.
Polytrichum piliferum	Hedw.
Rhacomitrium canescens	(Hedw.) Brid.
Rhizomnium glabrescens	(Kindb.) Kop.
Rhizomnium nudum	(Britt. & Williams) Kop.
Rhytidiadelphus loreus	(Hedw.) Warnst.
Rhytidiadelphus triquetrus	(Hedw.) Warnst.
Rhytidiopsis robusta	(Hedw.) Broth.

LICHENS

Cladina rangiferina	(L.) Harm.
Cladonia coniocraea	(Florke) Spreng.
Cladonia furcata	(Huds.) Schrad.
Cladonia gracilis	(L.) Willd.
Cladonia multiformis	Merr.
Cladonia squamosa	(Scop.) Hoffm.
Cladonia uncialis	(L.) Wigg.
Leptogium palmatum	(Huds.) Mont.
Peltigera aphthosa	(L.) Willd.
Peltigera canina	(L.) Willd.
Peltigera membranacea	(Ach.) Nyl.
Peltigera polydactyla	(Neck.) Hoffm.

* Low woody species and species of doubtful lifeform assigned to the herb (C) layer (Walmsley *et al.*, 1980)

APPENDIX B - FORMULAE FOR DETERMINING VCL, SBD, CFFBD AND POR

A. Variable reported on a whole pit basis:

The following formula was used to calculate the percent volume of large (>2 cm) coarse fragments in the whole soil pit.

$$VCL = (Vcl / Vp) \bullet 100$$

where Vcl = Mcl / 2.65 $g \bullet cm^{-3}$
and VCL = volume of large (>2 cm) coarse fragments in whole soil pit (%)
Vp = volume of soil pit (cm^3)
Vcl = volume of large (>2 cm) coarse fragments in whole soil pit (cm^3)
Mcl = weight of large (>2 cm) coarse fragments in whole soil pit (g)

B. Variables reported on a soil layer basis:

The following formulae were used to determine standard (whole soil) bulk density (Brady, 1974; Lavkulich, 1981), coarse fragment-free bulk density (Nuszdorfer, 1981), and porosity (modified from Brady (1974) to account for differences in organic matter content) for each soil layer:

$$SBD = (Mc + Mf) / Vt$$

$$CFFBD = Mf / (Vt - Vc)$$

$$POR = 100 - ((Vs / Vt) \bullet 100)$$

where Vs = Vc + Vfm + Vfo
Vc = Mc / 2.65 $g \bullet cm^{-3}$
Vfm = Mfm / 2.65 $g \bullet cm^{-3}$
Vfo = Mfo / 1.5 $g \bullet cm^{-3}$
Mfm = Mf • (1 - (OM% / 100))
Mfo = Mf • (OM% / 100)
and SBD = standard bulk density ($g \bullet cm^{-3}$)
CFFBD = coarse fragment-free bulk density ($g \bullet cm^{-3}$)
POR = porosity (%)
OM% = organic matter (%)
Mc = weight of coarse (≥2 mm) fragments (g)
Mf = weight of fine (<2 mm) fraction (g)
Mfm = weight of fine mineral fraction (g)
Mfo = weight of fine organic fraction (g)
Vt = total sample volume (cm^3)
Vs = volume of solids (cm^3)
Vc = volume of coarse (≥2 mm) fragments (cm^3)
Vfm = volume of fine mineral fraction (cm^3)
Vfo = volume of fine organic fraction (cm^3)

APPENDIX C - PROCEDURE FOR DETERMINING EN, MEN, AND MN

The following procedure was used to determine EN, MEN, and MN. This procedure is a modification of the anaerobic technique used by Waring and Bremner (1964).

A. Determination of exchangeable nitrogen (EN):

1. combine 5 g air-dried (<2 mm) soil and 25 ml 1N KCl in a 60 ml plastic screw cap container
2. screw cap on firmly
3. shake for 2 hours
4. filter sample through an Ashley #42 filter
5. using Technicon Autoanalyzer, determine concentration of ammonium (NH4) in filtered solution

B. Determination of mineralizable (plus exchangeable) nitrogen (MEN):

1. combine 5 g air-dried (<2 mm) soil and 12.5 ml distilled water in a 60 ml plastic screw cap container
2. screw cap on firmly and seal with masking tape
3. incubate sample at 30°C for 14 days
4. shake sample for 15 seconds
5. add 12.5 ml 2 N KCl (final solution will be 25 ml 1N KCl, the same as for EN above)
6. shake for 2 hours
7. filter sample through an Ashley #42 filter
8. using Technicon Autoanalyzer, determine concentration of ammonium (NH4) in filtered solution

C. Determination of mineralizable nitrogen (MN):

$$
\begin{aligned}
MN &= \text{MEN} - \text{EN} \\
&= (\text{incubated}) - (\text{non-incubated}) \\
&= (\text{Min} + \text{Exch} - \text{Imm}) - (\text{Exch}) \\
&= \text{net mineralized } NH_4
\end{aligned}
$$

where Min = mineralized NH4
Exch = exchangeable NH4
Imm = immobilized NH4

This procedure differs from the original procedure used by Waring and Bremner (1964). The main differences include:

1. use of a different extracting solution (i.e. 1N KCL was used instead of 2N KCl),
2. use of a different type of container for incubations (i.e. plastic screw cap bottles were used instead of glass

test tubes), and

3. use of a different technique for determining the concentration of ammonium in the filtered solution (i.e. a Technicon Autoanalyzer was used instead of the steam distillation technique)

It should be noted that Waring and Bremner (1964) used MN as an index of available nitrogen while Powers (1980) used MEN. Also, the amount of mineralized nitrogen (MN) will have a net negative value if the amount of ammonium immobilized during incubation is greater than the amount mineralized (Lowe, 1971).

APPENDIX D - CONVERSION FROM CONCENTRATION TO KG/HA

To convert the quantity of nutrient "n" from concentration (ppm, %, or m.e. per 100 g) to weight on an areal basis ($kg \bullet ha^{-1}$) for a given soil layer, the following procedure was used. This procedure was modified from Lewis (1976) (see also Zinke, 1960; and Nuszdorfer, 1981).

1. Calculate the proportion of the soil fine (<2 mm) fraction (f) which consists of nutrient "n" (P):

a) for concentration given in ppm -

$$P = \text{ppm n} \bullet 10^{-6}$$

$$\frac{\text{kg of n}}{\text{kg of soil f}} = \frac{\text{mg of n}}{\text{kg of soil f}} \bullet \frac{1 \text{ kg}}{10^6 \text{ mg}}$$

b) for concentration given in % -

$$P = (\text{\%n}) \bullet 10^{-2}$$

$$\frac{\text{kg of n}}{\text{kg of soil f}} = \frac{(\text{kg of n} \bullet 10^2)}{\text{kg of soil f}} \bullet \frac{1}{10^2}$$

c) for concentration given in m.e. per 100 g -

$$P = \frac{\text{m.e. of n}}{10^2 \text{ g of soil f}} \bullet 10^3 \bullet \text{equivalent weight} \bullet 10^{-6}$$

$$\frac{\text{kg of n}}{\text{kg of soil f}} = \frac{\text{m.e. of n}}{10^2 \text{ g of soil f}} \bullet \frac{10^3\text{g}}{1 \text{ kg}} \bullet \frac{\text{mg n}}{\text{m.e. n}} \bullet \frac{1 \text{ kg}}{10^6\text{mg}}$$

$$(= \text{m.e. of n} \bullet \text{equivalent weight} \bullet 10^{-5})$$

2. Calculate the weight of soil fine (<2 mm) fraction (f) on an areal basis for the same soil layer (CF):

$$CF = A \bullet B \bullet C \bullet TH$$

$$= \frac{Mf}{Vt} \bullet 10^{-3} \bullet 10^{8} \bullet \text{layer thickness}$$

$$\frac{\text{kg of soil f}}{\text{ha}} = \frac{\text{g of soil f}}{\text{cm}^3 \text{ of soil}} \bullet \frac{1 \text{ kg}}{10^3 \text{g}} \bullet \frac{10^8 \text{cm}^2}{1 \text{ ha}} \bullet \text{cm}$$

where A is the weight of the soil fine fraction (Mf) per unit volume of whole soil (Vt)

B converts A from g of soil $f \bullet cm^{-3}$ to kg of soil $f \bullet cm^{-3}$

C converts the results of (A • B) from kg of soil $f \bullet cm^{-3}$ to kg of soil $f \bullet cm^{-1} \bullet ha^{-1}$

TH converts the results of (A • B • C) from kg of soil $f \bullet cm^{-1} \bullet ha^{-1}$ to kg of soil $f \bullet ha^{-1}$

3. Calculate the weight of nutrient "n" in that soil layer (N):

$$N = P \bullet CF$$

$$\frac{\text{kg of n}}{\text{ha}} = \frac{\text{kg of n}}{\text{kg of soil f}} \bullet \frac{\text{kg of soil f}}{\text{ha}}$$

where P is the proportion of soil fine (<2 mm) fraction (f) which consists of nutrient "n" (see item 1 above)

CF is the conversion factor which converts this proportion to kg of $n \bullet ha^{-1}$ (see item 2 above)

APPENDIX E - ORDINATION SCORES

In this appendix, axis 1, 2, and 3 scores are given for the four reciprocal averaging (RA) ordinations, the four detrended correspondence analysis (DCA) ordinations, and the four polar ordinations (PO).

PLOT	ASSOC.	RA11 axis 1	RA11 axis 2	RA11 axis 3	RA12 axis 1	RA12 axis 2	RA12 axis 3
1.	3.	33.09	94.63	22.68	33.27	93.77	26.66
2.	5.	47.05	95.57	77.00	53.75	93.11	58.10
3.	3.	33.50	95.27	27.07	34.25	94.89	27.90
4.	3.	36.61	95.85	35.93	39.28	94.48	38.05
5.	4.	45.35	93.55	53.15	50.53	94.53	54.67
6.	3.	34.28	96.71	28.13	34.93	94.87	30.00
7.	3.	34.33	97.70	28.09	34.95	95.99	29.38
8.	3.	36.29	96.59	37.04	37.63	95.72	37.12
9.	5.	46.81	99.99	86.82	54.30	98.39	65.94
10.	4.	40.24	99.19	55.79	46.47	100.00	54.04
11.	2.	25.95	77.85	24.97	26.81	83.17	23.13
12.	2.	29.65	88.11	19.50	28.16	85.86	25.18
13.	6.	86.25	55.01	33.90	83.49	54.61	31.69
14.	4.	47.46	93.12	55.14	51.93	98.84	61.01
15.	5.	45.08	97.47	79.53	55.18	95.25	67.49
16.	5.	47.37	97.07	80.96	59.23	93.80	67.68
17.	4.	41.73	97.42	67.47	49.18	96.48	61.12
18.	6.	100.00	38.68	9.10	100.00	26.26	0.33
19.	3.	35.60	97.86	33.21	37.76	97.55	33.47
20.	4.	43.71	98.50	64.73	51.57	96.73	55.81
21.	4.	38.37	100.00	43.84	43.89	97.45	48.87
22.	4.	43.39	97.75	63.46	52.86	95.59	61.66
23.	3.	34.56	97.35	30.15	35.90	96.15	32.64
24.	4.	40.62	98.61	55.02	47.29	98.32	52.79
25.	5.	46.79	95.47	64.91	56.48	91.22	60.98
26.	4.	40.41	97.49	54.08	45.77	97.07	51.82
27.	5.	61.26	82.59	66.13	63.84	86.47	62.95
28.	3.	35.67	96.34	37.89	37.79	95.11	39.60
29.	5.	48.83	97.94	92.97	60.35	95.40	72.34
30.	5.	49.25	95.76	80.96	60.61	93.14	67.63
31.	6.	94.31	42.64	0.00	86.94	39.19	0.00
32.	2.	29.42	89.03	17.08	25.91	84.92	15.71
33.	2.	31.55	91.87	21.23	30.57	90.64	19.72
34.	2.	30.89	90.69	21.47	28.17	86.60	20.27
35.	1.	5.36	16.61	84.61	4.74	14.44	91.07
36.	5.	45.96	98.55	80.37	56.24	96.33	67.51
37.	2.	21.89	67.83	31.45	24.99	81.37	20.34
38.	2.	30.19	89.95	18.52	28.56	87.18	20.91
39.	6.	90.14	51.77	32.37	87.69	50.97	30.29
40.	6.	77.51	65.63	45.07	80.86	58.42	29.91
41.	5.	49.47	89.85	67.84	55.66	88.91	60.85
42.	3.	35.54	97.19	32.22	36.76	97.10	34.64
43.	3.	34.35	97.48	28.12	35.48	96.89	31.19
44.	2.	32.55	95.21	18.96	32.02	95.07	19.45
45.	4.	38.95	97.29	45.48	42.84	95.49	46.41
46.	2.	30.66	88.02	15.50	30.02	85.36	27.25
47.	1.	21.86	67.52	21.99	19.32	62.24	40.39
48.	2.	32.20	91.55	29.79	33.42	92.06	28.58
49.	1.	15.92	52.06	37.12	17.64	64.43	26.71
50.	1.	0.00	0.00	100.00	0.00	0.00	100.00
51.	1.	7.57	24.42	70.80	9.27	32.33	64.72

PLOT	ASSOC.	RA13 axis 1	RA13 axis 2	RA13 axis 3	RA14 axis 1	RA14 axis 2	RA14 axis 3
1.	3.	31.86	12.45	53.20	23.52	26.52	28.22
2.	5.	74.81	32.81	65.97	77.70	62.17	65.71
3.	3.	32.90	19.30	59.35	24.97	52.64	20.10
4.	3.	42.47	10.99	56.76	40.80	34.68	20.30
5.	4.	61.44	14.08	73.01	70.13	38.47	18.87
6.	3.	35.07	15.55	57.24	27.45	49.38	27.02
7.	3.	35.03	10.13	56.93	27.34	42.04	18.24
8.	3.	40.67	10.84	60.45	36.97	41.18	26.86
9.	5.	77.24	19.39	76.36	82.93	47.13	23.66
10.	4.	56.08	9.03	65.96	62.64	27.91	16.04
11.	2.	13.87	50.02	70.10	7.96	67.22	45.72
12.	2.	23.88	23.88	55.52	12.75	36.60	44.91
14.	4.	64.89	13.35	79.76	75.76	41.61	14.62
15.	5.	72.86	23.94	80.38	86.08	49.46	23.66
16.	5.	76.16	24.01	80.88	92.71	50.65	27.79
17.	4.	62.56	20.94	72.33	71.02	47.78	30.82
19.	3.	38.42	14.67	58.65	33.80	47.68	19.36
20.	4.	64.47	19.94	64.88	71.58	50.33	25.73
21.	4.	48.68	0.23	58.62	55.37	30.47	7.96
22.	4.	64.14	13.92	67.34	78.91	39.07	20.18
23.	3.	36.72	7.85	58.38	31.54	36.98	5.91
24.	4.	54.82	13.51	69.34	62.25	42.54	17.05
25.	5.	69.57	19.12	57.30	84.68	48.49	73.09
26.	4.	55.91	15.71	58.34	60.00	41.31	20.90
27.	5.	100.00	70.59	0.00	100.00	73.03	64.78
28.	3.	42.13	16.32	56.23	39.08	43.23	25.45
29.	5.	84.45	36.44	74.96	98.52	73.40	54.94
30.	5.	80.09	31.68	72.74	96.34	64.56	49.28
32.	2.	19.58	32.61	62.08	0.00	100.00	30.75
33.	2.	25.32	29.78	63.98	11.12	91.09	12.83
34.	2.	24.43	27.30	61.92	6.88	86.64	22.72
36.	5.	74.02	22.71	78.01	87.45	53.84	25.44
37.	2.	0.00	100.00	100.00	1.15	89.22	60.49
38.	2.	22.80	33.37	61.44	9.06	80.73	39.14
41.	5.	76.61	16.73	79.84	85.81	40.20	3.10
42.	3.	40.05	0.00	53.41	35.46	6.38	24.32
43.	3.	36.17	6.78	54.29	30.09	22.45	20.85
44.	2.	27.96	17.26	57.38	14.78	60.41	0.00
45.	4.	50.22	2.54	60.24	53.18	14.52	31.65
46.	2.	26.56	16.13	42.55	19.77	0.00	100.00
48.	2.	29.04	28.01	64.23	22.69	57.55	41.82

		DCA11			DCA12		
PLOT	ASSOC.	axis 1	axis 2	axis 3	axis 1	axis 2	axis 3
1.	3.	218.00	82.00	88.00	175.00	109.00	73.00
2.	5.	345.00	97.00	5.00	319.00	88.00	111.00
3.	3.	222.00	47.00	82.00	182.00	146.00	87.00
4.	3.	254.00	90.00	88.00	220.00	98.00	93.00
5.	4.	323.00	95.00	105.00	301.00	83.00	66.00
6.	3.	233.00	58.00	83.00	187.00	127.00	110.00
7.	3.	232.00	60.00	83.00	187.00	129.00	99.00
8.	3.	255.00	80.00	56.00	209.00	108.00	83.00
9.	5.	358.00	76.00	1.00	334.00	101.00	51.00
10.	4.	298.00	95.00	58.00	278.00	92.00	52.00
11.	2.	154.00	45.00	67.00	126.00	123.00	91.00
12.	2.	180.00	85.00	59.00	135.00	90.00	89.00
13.	6.	518.00	131.00	58.00	459.00	47.00	146.00
14.	4.	339.00	86.00	109.00	317.00	98.00	93.00
15.	5.	337.00	80.00	62.00	337.00	91.00	58.00
16.	5.	353.00	81.00	61.00	362.00	87.00	60.00
17.	4.	311.00	79.00	54.00	298.00	97.00	78.00
18.	6.	566.00	128.00	111.00	525.00	70.00	77.00
19.	3.	249.00	50.00	76.00	211.00	140.00	86.00
20.	4.	327.00	68.00	70.00	310.00	112.00	107.00
21.	4.	279.00	93.00	98.00	258.00	98.00	89.00
22.	4.	320.00	90.00	85.00	319.00	82.00	76.00
23.	3.	234.00	65.00	105.00	195.00	121.00	101.00
24.	4.	302.00	62.00	75.00	284.00	114.00	72.00
25.	5.	343.00	108.00	64.00	339.00	60.00	107.00
26.	4.	299.00	83.00	85.00	273.00	105.00	84.00
27.	5.	415.00	99.00	47.00	376.00	86.00	125.00
28.	3.	250.00	65.00	75.00	211.00	115.00	94.00
29.	5.	366.00	61.00	0.00	367.00	95.00	97.00
30.	5.	363.00	83.00	29.00	365.00	84.00	80.00
31.	6.	537.00	129.00	91.00	466.00	53.00	114.00
32.	2.	183.00	11.00	73.00	121.00	190.00	92.00
33.	2.	204.00	2.00	84.00	156.00	202.00	91.00
34.	2.	198.00	20.00	79.00	138.00	176.00	93.00
35.	1.	30.00	108.00	90.00	22.00	18.00	57.00
36.	5.	349.00	73.00	63.00	346.00	102.00	62.00
37.	2.	126.00	0.00	38.00	113.00	162.00	96.00
38.	2.	189.00	39.00	60.00	139.00	168.00	95.00
39.	6.	532.00	117.00	52.00	476.00	62.00	185.00
40.	6.	483.00	97.00	82.00	448.00	116.00	0.00
41.	5.	352.00	131.00	149.00	330.00	89.00	65.00
42.	3.	246.00	132.00	27.00	202.00	67.00	23.00
43.	3.	234.00	92.00	75.00	193.00	98.00	66.00
44.	2.	214.00	37.00	99.00	166.00	178.00	79.00
45.	4.	278.00	127.00	54.00	248.00	65.00	49.00
46.	2.	189.00	156.00	46.00	149.00	24.00	68.00
47.	1.	122.00	174.00	56.00	84.00	0.00	76.00
48.	2.	215.00	51.00	51.00	177.00	126.00	80.00
49.	1.	83.00	15.00	51.00	72.00	163.00	64.00
50.	1.	0.00	70.00	56.00	0.00	56.00	46.00
51.	1.	37.00	33.00	46.00	38.00	114.00	97.00

PLOT	ASSOC.	DCA13 axis 1	DCA13 axis 2	DCA13 axis 3	DCA14 axis 1	DCA14 axis 2	DCA14 axis 3
1.	3.	212.00	85.00	76.00	64.00	82.00	103.00
2.	5.	64.00	45.00	146.00	221.00	129.00	27.00
3.	3.	206.00	47.00	65.00	69.00	50.00	61.00
4.	3.	174.00	72.00	88.00	113.00	89.00	85.00
5.	4.	105.00	92.00	31.00	198.00	101.00	78.00
6.	3.	198.00	41.00	76.00	75.00	67.00	60.00
7.	3.	200.00	48.00	87.00	75.00	61.00	81.00
8.	3.	176.00	57.00	100.00	103.00	91.00	45.00
9.	5.	53.00	17.00	83.00	235.00	86.00	2.00
10.	4.	123.00	80.00	80.00	176.00	103.00	59.00
11.	2.	264.00	58.00	82.00	21.00	104.00	75.00
12.	2.	239.00	76.00	87.00	33.00	113.00	72.00
14.	4.	89.00	92.00	0.00	213.00	79.00	50.00
15.	5.	68.00	56.00	35.00	244.00	99.00	44.00
16.	5.	57.00	48.00	33.00	264.00	95.00	16.00
17.	4.	101.00	63.00	63.00	200.00	95.00	38.00
19.	3.	186.00	40.00	86.00	93.00	51.00	51.00
20.	4.	95.00	37.00	82.00	202.00	78.00	65.00
21.	4.	149.00	49.00	76.00	155.00	76.00	88.00
22.	4.	98.00	69.00	60.00	224.00	97.00	76.00
23.	3.	194.00	52.00	70.00	87.00	62.00	93.00
24.	4.	125.00	38.00	66.00	175.00	72.00	16.00
25.	5.	79.00	50.00	132.00	241.00	145.00	46.00
26.	4.	123.00	67.00	73.00	169.00	83.00	76.00
27.	5.	0.00	80.00	86.00	288.00	113.00	96.00
28.	3.	172.00	53.00	72.00	108.00	71.00	67.00
29.	5.	33.00	29.00	74.00	283.00	97.00	0.00
30.	5.	45.00	65.00	70.00	276.00	111.00	18.00
32.	2.	246.00	0.00	63.00	0.00	23.00	54.00
33.	2.	227.00	6.00	39.00	31.00	0.00	53.00
34.	2.	230.00	11.00	54.00	19.00	31.00	60.00
36.	5.	62.00	41.00	54.00	249.00	89.00	20.00
37.	2.	298.00	40.00	96.00	2.00	99.00	21.00
38.	2.	237.00	10.00	72.00	24.00	56.00	39.00
41.	5.	61.00	159.00	9.00	246.00	86.00	145.00
42.	3.	182.00	115.00	109.00	98.00	127.00	86.00
43.	3.	196.00	82.00	85.00	83.00	87.00	95.00
44.	2.	221.00	45.00	33.00	41.00	0.00	101.00
45.	4.	146.00	93.00	98.00	149.00	130.00	85.00
46.	2.	231.00	143.00	128.00	53.00	187.00	92.00
48.	2.	214.00	41.00	97.00	62.00	85.00	20.00

		PO11		PO12	
PLOT	ASSOC.	axis 1	axis 2	axis 1	axis 2
1.	3.	40.94	84.88	37.29	80.30
2.	5.	52.02	18.09	52.38	25.29
3.	3.	42.64	78.39	39.49	77.75
4.	3.	42.18	54.20	38.92	53.55
5.	4.	53.97	38.34	48.62	25.57
6.	3.	41.57	71.95	37.42	64.13
7.	3.	41.59	69.46	37.50	70.09
8.	3.	42.15	46.26	38.71	58.63
9.	5.	49.92	0.00	48.02	20.37
10.	4.	45.49	44.80	43.77	43.71
11.	2.	28.19	83.29	28.55	69.68
12.	2.	34.53	84.46	29.32	70.71
13.	6.	90.90	17.93	85.19	16.34
14.	4.	58.75	48.85	51.13	29.41
15.	5.	50.37	29.79	50.42	0.00
16.	5.	54.05	21.41	55.82	5.44
17.	4.	46.06	39.43	44.40	23.36
18.	6.	100.00	42.68	100.00	38.13
19.	3.	42.66	67.02	39.45	75.11
20.	4.	48.39	40.30	47.58	40.97
21.	4.	45.91	42.10	44.13	51.50
22.	4.	50.74	30.54	51.25	19.71
23.	3.	43.52	70.46	40.26	71.69
24.	4.	45.99	39.45	44.25	35.34
25.	5.	52.00	21.06	52.55	18.98
26.	4.	43.77	44.08	41.41	44.12
27.	5.	67.09	19.76	59.44	18.29
28.	3.	42.66	66.53	39.41	61.00
29.	5.	56.74	14.81	59.37	11.77
30.	5.	57.88	20.14	60.62	5.67
31.	6.	83.57	39.27	70.51	39.72
32.	2.	38.24	81.58	32.87	84.51
33.	2.	41.69	87.41	38.14	88.75
34.	2.	38.64	80.66	32.78	79.91
35.	1.	6.97	67.58	8.53	59.00
36.	5.	51.21	20.47	51.60	14.38
37.	2.	23.27	82.78	27.40	69.03
38.	2.	38.30	85.60	32.37	78.88
39.	6.	92.45	28.22	86.38	28.07
40.	6.	78.11	15.24	75.80	29.25
41.	5.	58.41	37.25	56.58	31.21
42.	3.	42.82	51.28	39.72	66.69
43.	3.	41.68	70.47	38.02	77.69
44.	2.	46.20	100.00	44.49	100.00
45.	4.	44.69	35.67	42.39	39.80
46.	2.	39.09	68.69	34.93	58.06
47.	1.	26.37	70.96	22.44	62.65
48.	2.	36.92	62.64	34.43	69.62
49.	1.	16.19	83.55	21.46	71.41
50.	1.	0.00	48.99	0.00	45.69
51.	1.	8.73	80.55	13.09	72.84

		PO13		PO14	
PLOT	ASSOC.	axis 1	axis 2	axis 1	axis 2
1.	3.	37.47	69.66	21.37	62.85
2.	5.	74.08	54.42	72.57	76.91
3.	3.	29.61	67.18	16.25	38.11
4.	3.	52.21	69.96	41.59	36.05
5.	4.	64.11	34.83	71.57	54.00
6.	3.	38.66	53.87	27.24	46.26
7.	3.	35.54	70.21	28.48	51.60
8.	3.	42.38	72.26	34.53	53.30
9.	5.	76.42	47.59	81.57	38.85
10.	4.	57.63	55.22	57.54	72.74
11.	2.	17.76	69.76	8.19	60.74
12.	2.	23.11	67.08	13.89	76.61
14.	4.	59.60	0.00	68.75	32.52
15.	5.	60.97	14.11	78.27	54.40
16.	5.	65.81	19.67	85.92	52.59
17.	4.	59.60	27.81	63.37	47.39
19.	3.	36.86	71.77	27.90	43.21
20.	4.	68.73	33.82	64.97	26.24
21.	4.	63.31	46.15	51.16	0.00
22.	4.	64.20	37.20	80.35	31.29
23.	3.	37.80	60.77	27.32	19.01
24.	4.	54.01	42.10	58.72	39.45
25.	5.	74.83	37.75	81.80	52.02
26.	4.	65.69	50.97	65.68	42.63
27.	5.	100.00	32.27	100.00	62.25
28.	3.	44.09	51.95	36.49	49.66
29.	5.	74.41	23.01	93.29	36.89
30.	5.	72.95	26.23	93.96	54.75
32.	2.	23.13	61.76	0.00	53.43
33.	2.	27.11	47.87	5.03	40.37
34.	2.	27.34	54.20	6.39	52.63
36.	5.	70.24	35.37	84.23	53.26
37.	2.	0.00	54.50	2.01	62.77
38.	2.	22.83	52.77	5.84	63.12
41.	5.	77.01	47.58	81.47	65.31
42.	3.	47.88	100.00	37.66	81.06
43.	3.	42.35	76.81	27.23	56.96
44.	2.	30.16	50.97	3.82	24.10
45.	4.	59.21	74.34	54.99	100.00
46.	2.	32.02	82.30	25.28	91.01
48.	2.	30.03	73.99	18.41	67.91

APPENDIX F - CLUSTERING LEVELS

In this appendix, clustering levels are given for all four cluster analyses (CA11, CA12, CA13, and CA14). "Grouping order" refers to the order in which clusters were formed (N.B. number of clusters at a given level = number of plots used in the analysis - grouping order). "Clusters" refers to the plots (or clusters) joined at a given level. In the case of clusters containing more than one plot, the cluster number refers to plot (in the cluster) with the smallest plot number. The clustering level (Euclidean Distance at which clusters were joined) is shown under the heading Euclidean Distance.

CA11			CA12		
Grouping order	clusters	Euclidean Distance	Grouping order	clusters	Euclidean Distance
1	32 - 34	21.5	1	33 - 34	15.8
2	32 - 33	33.0	2	32 - 33	21.9
3	29 - 30	38.5	3	37 - 38	22.3
4	01 - 03	41.0	4	29 - 30	25.3
5	06 - 28	49.0	5	06 - 07	26.5
6	16 - 36	54.3	6	06 - 28	32.3
7	12 - 38	54.8	7	01 - 03	35.0
8	01 - 44	57.3	8	16 - 36	41.3
9	07 - 19	66.3	9	09 - 14	45.8
10	07 - 43	72.6	10	32 - 44	48.5
11	05 - 14	75.0	11	01 - 19	50.5
12	12 - 32	75.2	12	04 - 21	50.8
13	13 - 18	75.5	13	12 - 37	54.9
14	04 - 26	78.5	14	05 - 22	56.5
15	01 - 12	80.7	15	09 - 24	57.4
16	20 - 24	88.0	16	01 - 06	58.4
17	06 - 07	89.6	17	04 - 26	58.9
18	08 - 23	90.0	18	15 - 17	59.0
19	16 - 29	90.3	19	01 - 43	63.5
20	35 - 50	90.3	20	12 - 48	65.1
21	15 - 17	94.0	21	09 - 20	65.8
22	01 - 48	98.1	22	08 - 23	67.0
23	13 - 39	99.0	23	35 - 50	67.3
24	13 - 31	105.3	24	05 - 25	73.0
25	22 - 25	107.0	25	16 - 29	73.1
26	35 - 51	112.9	26	12 - 32	73.7
27	01 - 06	114.6	27	13 - 18	74.5
28	04 - 08	114.6	28	02 - 16	83.1
29	05 - 20	118.1	29	05 - 09	83.7
30	15 - 16	129.5	30	35 - 51	84.4
31	11 - 37	130.3	31	01 - 12	85.0
32	05 - 22	132.8	32	04 - 08	87.2
33	04 - 21	145.4	33	05 - 15	90.0
34	02 - 09	149.3	34	31 - 39	96.0
35	05 - 15	149.5	35	02 - 05	98.2
36	11 - 49	154.9	36	13 - 31	99.0
37	46 - 47	169.0	37	01 - 11	99.2
38	02 - 05	169.7	38	10 - 45	116.0
39	01 - 04	180.2	39	02 - 27	118.6
40	42 - 45	189.0	40	46 - 47	135.0
41	10 - 42	211.5	41	01 - 04	136.7
42	01 - 10	232.9	42	10 - 42	163.0
43	11 - 35	240.6	43	35 - 49	174.4
44	02 - 27	247.4	44	01 - 35	188.4
45	02 - 41	261.8	45	02 - 41	194.4
46	01 - 02	274.2	46	01 - 10	208.0
47	01 - 46	364.2	47	01 - 02	227.1
48	01 - 11	374.4	48	01 - 13	298.0
49	13 - 40	421.6	49	01 - 46	315.3
50	01 - 13	567.3	50	01 - 40	537.3

CA13			CA14		
Grouping order	clusters	Euclidean Distance	Grouping order	clusters	Euclidean Distance
1	32 - 34	21.5	1	33 - 34	15.8
2	32 - 33	33.0	2	32 - 33	21.9
3	29 - 30	38.5	3	37 - 38	22.3
4	01 - 03	41.0	4	29 - 30	25.3
5	06 - 28	49.0	5	06 - 07	26.5
6	16 - 36	54.3	6	06 - 28	32.3
7	12 - 38	54.8	7	01 - 03	35.0
8	01 - 44	57.3	8	16 - 36	41.3
9	07 - 19	66.3	9	09 - 14	45.8
10	07 - 43	72.6	10	32 - 44	48.5
11	05 - 14	75.0	11	01 - 19	50.5
12	12 - 32	75.2	12	04 - 21	50.8
13	04 - 26	78.5	13	12 - 37	54.9
14	01 - 12	80.7	14	05 - 22	56.5
15	20 - 24	88.0	15	09 - 24	57.4
16	06 - 07	89.6	16	01 - 06	58.4
17	08 - 23	90.0	17	04 - 26	58.9
18	16 - 29	90.3	18	15 - 17	59.0
19	15 - 17	94.0	19	01 - 43	63.5
20	01 - 48	98.1	20	12 - 48	65.1
21	22 - 25	107.0	21	09 - 20	65.8
22	01 - 06	114.6	22	08 - 23	67.0
23	04 - 08	114.6	23	05 - 25	73.0
24	05 - 20	118.1	24	16 - 29	73.1
25	15 - 16	129.5	25	12 - 32	73.7
26	11 - 37	130.3	26	02 - 16	83.1
27	05 - 22	132.8	27	05 - 09	83.7
28	04 - 21	145.4	28	01 - 12	85.0
29	02 - 09	149.3	29	04 - 08	87.2
30	05 - 15	149.5	30	05 - 15	90.0
31	01 - 11	161.6	31	02 - 05	98.2
32	02 - 05	169.7	32	01 - 11	99.2
33	42 - 45	189.0	33	10 - 45	116.0
34	01 - 04	192.0	34	02 - 27	118.6
35	10 - 42	211.5	35	01 - 04	136.7
36	01 - 46	236.7	36	10 - 42	163.0
37	01 - 10	246.4	37	01 - 10	188.8
38	02 - 27	247.4	38	02 - 41	194.4
39	02 - 41	261.8	39	01 - 46	204.4
40	01 - 02	287.1	40	01 - 02	223.8

APPENDIX G - ENVIRONMENT TABLES

In this appendix, selected environment and mensurational variables are shown in tables produced by the F405:ENV program (Klinka and Phelps, 1979). To understand these tables, several terms and abbreviations must first be defined. These definitions are as follows:

1. FOREST COVER TYPE: Con.= coniferous, Dec.= deciduous, PC = lodgepole pine, PM = Douglas-fir, TH = western hemlock

2. ASPECT: f = flat

3. SOIL SUBGROUP (C.S.S.C., 1978): T.H = Terric Humisol, O.HG = Orthic Humic Gleysol, DU.HFP = Duric Humo-Ferric Podzol, O.HFP = Orthic Humo-Ferric Podzol, SM.HFP = Sombric Humo-Ferric Podzol (g = gleyed phase, l = lithic phase, s = sombric phase, t = turbic phase)

4. SOIL FAMILY OR PARTICLE SIZE (C.S.S.C., 1978): CL = coarse-loamy, FL = fine-loamy, LS = loamy-skeletal, SS = sandy-skeletal, O = organic

5. DEPTH TO RESTR. HOR./LAYER: refers to the depth from the ground surface down to a restricting layer were K = compacted material, L = lithic (bedrock) contact

6. COARSE FRAGMENTS >2 MM (%): refers to the % volume of >2 mm coarse fragments (weighted to rooting depth)

7. PARENT MATERIALS (E.L.U.C., 1975): C = colluvial, F = fluvial, M = morainal, O = organic, R = Bedrock, (b = blanket, t = terraced, v = veneer)

8. THICKNESS OF MIN. SOIL (CM): refers to the thickness of the mineral soil horizons measured from the top of the first mineral horizon down to the compacted (K) layer, the lithic contact (L), or to the C horizon

9. ROOTING DEPTH (CM): refers to the depth from the ground surface down to the bottom of the effective rooting zone (the level at which the majority of roots stop)

10. SEEPAGE WATER DEPTH (CM): depth from the ground surface down to the level where free water is encountered at the time of sampling

11. SOIL DRAINAGE (C.S.S.C., 1978): r = rapidly, w = well, mw = moderately well, i = imperfectly, p = poorly, vp = very poorly

12. COARSE FRAGMENTS > 2CM (%): refers to the % volume (whole pit) of large (> 2 cm) coarse fragments

13. THICKNESS OF HUM. HOR. (CM): refers to the thickness of the ectorganic materials

14. HUMUS FORM: refers to the humus form Group classified according to the system proposed by Klinka et al. (1981b) where HR = Hemimor, HUR = Hemihumimor, MD = Mormoder, SL = Saprimull, UR = Humimor, VL = Vermimull, XD = Xeromoder, XR = Xeromor, YL = Hydromull

15. PH OF MINERAL SOIL: pH of mineral soil weighted to rooting depth

16. AGE (YEARS): stand age (years)

17. GC AND SI OF DOUGLAS-FIR: growth class (Lowe and Klinka, 1981) and site index (m/100 yrs) of Douglas-fir (Pseudotsuga menziesii)

18. NS/HA: number of stems (>7.5 cm d.b.h.) per hectare

19. BA/HA (SQ.M): stand basal area (m^2) per hectare

20. DBH (CM): average diameter breast height (cm)

21. VOL/HA (CU.M): gross stand volume (m^3/ha)

22. MAI (CU.M/HA/YR): mean annual increment (m^3/ha/yr)

23. STRATA COVERAGE (%): refers to the % of the sample plot covered by a vertical projection of each vegetation stratum where A LAYER = trees, B LAYER = shrubs, C LAYER = herbs, D LAYER = mosses, liverworts, and lichens

24. GROUND COVERAGE (%): refers to the % of the sample plot covered by H = humus layer, MS = mineral soil, DW = decaying wood, R & S = rocks and coarse fragments

Environment table for biogeocoenotic association 1.11 ($PC-PJ)

FOREST COVER TYPE.		PC				PM
PLOT NUMBER	MEAN	35	49	50	51	47
BIOGEOCLIMATIC UNIT		CWHa	CWHa	CWHa	CWHa	CWHa
ENVIRONMENT :						
ELEVATION (M)	316.0	210	300	380	400	290
SLOPE GRADIENT (%)	5.6	0	20	0	0	8
ASPECT		F	330	F	F	300
SOIL		non-	1/0	1/0	1/0	1/0
SUBGROUP (CSSC, 1978)		soil	.HFP	.HFP	.HFP	.HFP
SOIL FAMILY (PARTICLE SIZE)		CL	CL	CL	CL	CL
DEPTH TO RESTR. HOR./LAYER	18.6	L 9	L 13	L 14	L 18	L 39
COARSE FRAGMENTS >2MM (%)	16.6	2	33	15	9	24
SOIL MOIST.REGIME(HYGROTOPE)		0	0	0	0	0
SOIL NUTR.REGIME(TROPHOTOPE)		B	C	B	B	C
PARENT MATERIALS		MvR	MvR	MvR	MvR	MvR
THICKNESS OF MIN. SOIL (CM)		6	10	12	15	35
ROOTING DEPTH (CM)	18.6	9	13	14	18	39
SEEPAGE WATER DEPTH (CM)	0.0					
SOIL DRAINAGE (CSSC, 1978)		r	r	r	r	r
COARSE FRAGMENTS >2CM (%)*	3.8	1	13	2	1	2
THICKNESS OF HUM. HOR. (CM)	3.0	3	3	2	3	4
HUMUS FORM		XR	XR	XD	XR	XR
PH OF HUMUS	3.5	3.7	4.0	3.2	3.3	3.5
C/N OF HUMUS	40.0	35	33	49	46	37
PH OF MINERAL SOIL	3.9	3.6	4.2	3.8	3.7	4.4
VEGETATION :						
AGE (YEARS)	68.8	70	62	71	65	76
GC AND SI OF DOUGLAS-FIR	0- 0.0	-	-	-	-	-
NS/HA	1723.8	692	1100	1000	5125	702
BA/HA (SQ.M)	52.2	48	44	44	105	20
DBH (CM)	22.2	30	22	24	16	19
VOL/HA (CU.M)	265.8	264	290	232	443	100
MAI (CU.M/HA/YR)	4.0	4	5	3	7	1
STRATA A LAYER	64.0	55	60	60	85	60
COVERAGE B LAYER	39.0	5	90	25	15	60
(%) C LAYER	12.0	20	5	10	5	20
D LAYER	53.0	50	60	40	20	95
GROUND H	82.2	98	75	85	85	68
COVERAGE MS	0.0	0	0	0	0	0
(%) DW	7.8	2	3	2	2	30
R & S	10.0	0	22	13	13	2

Environment table for biogeocoenotic association 1.21 ($PM-GS)

FOREST COVER TYPE		PM-PC		PM-TH							
PLOT NUMBER	MEAN	37	11	12	32	33	34	38	44	46	48
BIOGEOCLIMATIC UNIT		CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa
ENVIRONMENT :											
ELEVATION (M)	256.0	340	200	200	240	240	230	370	230	240	270
SLOPE GRADIENT (%)	20.6	40	10	10	5	12	10	40	20	34	25
ASPECT		120	20	360	330	330	300	130	320	310	340
SOIL		1/O	1/O	1/O	1/O	1/O	1/O	O	DU	1/O	1/O
SUBGROUP (CSSC, 1978)		.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP
SOIL FAMILY (PARTICLE SIZE)		CL	CL	CL	CL	CL	CL	LS	CL	CL	CL
DEPTH TO RESTR. HOR./LAYER	58.2	L 32	L 93	L 33	L 59	L 33	L 37		K 96	L 58	L 83
COARSE FRAGMENTS >2MM (%)	23.9	32	28	16	33	3	22	41	27	17	20
SOIL MOIST.REGIME(HYGROTOPE)		2	2	2	2	2	2	2	2	1	2
SOIL NUTR.REGIME(TROPHOTOPE)		C	C	C	C	C	C	C	C	C	C
PARENT MATERIALS		CvR	MvR	MvR	MvR	MvR	MvR	Cb	Mb	MvR	MvR
THICKNESS OF MIN. SOIL (CM)		29	90	30	55	30	33	+95	91	52	77
ROOTING DEPTH (CM)	55.1	32	80	30	59	33	37	90	65	42	83
SEEPAGE WATER DEPTH (CM)	0.0										
SOIL DRAINAGE (CSSC, 1978)		r	r	r	r	r	r	r	w	r	r
COARSE FRAGMENTS >2CM (%)	11.2	20	10	15	14	11	9	12	11	2	8
THICKNESS OF HUM. HOR. (CM)	4.1	3	3	3	4	3	4	4	5	6	6
HUMUS FORM		MD	HUR	HUR	HUR	HUR	HUR	HUR	UR	MD	HUR
PH OF HUMUS	4.2	4.1	4.1	3.9	4.8	4.2	4.1	3.9	4.2	4.3	4.3
C/N OF HUMUS	41.0	45	38	44	40	50	45	34	39	36	39
PH OF MINERAL SOIL	4.4	4.5	4.5	4.6	4.3	4.0	4.2	4.5	4.4	4.6	4.4
VEGETATION :											
AGE (YEARS)	59.7	50	72	64	53	49	50	62	67	68	62
GC AND SI OF DOUGLAS-FIR	6-29.2	7-22	6-28	7-27	5-38	5-34	7-27	7-25	6-29	6-31	6-31
NS/HA	1270.6	1504	1458	1952	572	528	1197	2017	1415	663	1400
BA/HA (SQ.M)	39.5	42	48	48	36	30	30	51	38	30	42
DBH (CM)	21.0	19	20	18	28	27	18	18	18	24	20
VOL/HA (CU.M)	247.1	150	341	305	286	223	163	254	235	235	279
MAI (CU.M/HA/YR)	4.2	3	5	5	5	5	3	4	4	3	5
STRATA A LAYER	78.4	99	70	70	65	60	70	90	95	85	80
COVERAGE B LAYER	83.1	50	80	90	99	99	99	60	99	65	90
(%) C LAYER	5.4	2	10	5	2	2	4	2	4	15	8
D LAYER	34.2	20	80	25	15	4	8	20	25	95	50
GROUND H	77.1	90	65	68	80	85	75	75	80	68	85
COVERAGE MS	0.2	0	0	2	0	0	0	0	0	0	0
(%) DW	12.5	5	10	15	10	7	10	8	20	30	10
R & S	10.2	5	25	15	10	8	15	17	0	2	5

Environment table for biogeocoenotic association 2.11 ($PM-KO)

FOREST COVER TYPE		PM							PM-TH			
PLOT NUMBER	MEAN	01	03	04	06	08	19	28	07	23	42	43
BIOGEOCLIMATIC UNIT		CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa
ENVIRONMENT :												
ELEVATION (M)	204.5	180	230	170	270	170	180	200	210	200	210	230
SLOPE GRADIENT (%)	10.2	3	3	0	51	0	20	0	4	2	17	12
ASPECT		135	150	F	225	F	135	F	135	360	300	270
SOIL		DU	DU	O	O	O	O	O	O	O	DU	O
SUBGROUP (CSSC, 1978)		.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP
SOIL FAMILY (PARTICLE SIZE)		CL	CL	SS	LS	CL	CL	CLLS	SS	SS	CL	CL
DEPTH TO RESTR. HOR./LAYER	83.0	K 79	K 81								K 89	
COARSE FRAGMENTS >2MM (%)	32.6	32	29	59	43	9	28	11	42	43	33	30
SOIL MOIST.REGIME(HYGROTOPE)		3	3	4	3	4	3	4	3	4	4	3
SOIL NUTR.REGIME(TROPHOTOPE)		C	C	D	C	D	C	C	C	C	C	C
PARENT MATERIALS		Mb	Mb	Fb	CvMv	Fb	Mb	Ft	Mb	Fb	Mb	Mb
THICKNESS OF MIN. SOIL (CM)		75	75	90	+90	80	+85	+70	60	+85	86	63
ROOTING DEPTH (CM)	64.1	52	70	60	70	70	60	80	38	85	65	55
SEEPAGE WATER DEPTH (CM)	0.0											
SOIL DRAINAGE (CSSC, 1978)		w	w	r	w	w	w	w	r	r	w	w
COARSE FRAGMENTS >2CM (%)	9.9	8	9	5	9	0	14	15	12	15	10	12
THICKNESS OF HUM. HOR. (CM)	4.8	4	6	6	3	3	4	5	8	8	3	3
HUMUS FORM		HUR	HUR	MD	MD	MD	HUR	MD	UR	MD	HR	HUR
PH OF HUMUS	3.8	4.0	3.9	3.7	3.5	4.0	3.4	3.7	3.6	3.5	4.2	4.0
C/N OF HUMUS	43.9	38	42	41	55	40	55	35	47	47	38	45
PH OF MINERAL SOIL	4.2	4.3	4.0	4.1	4.3	4.5	4.0	4.4	4.1	4.2	4.5	4.2
VEGETATION :												
AGE (YEARS)	62.1	70	50	54	46	82	74	48	53	61	76	69
GC AND SI OF DOUGLAS-FIR	4-43.6	4-45	5-39	3-49	4-41	4-43	4-42	3-47	3-47	4-45	3-47	5-35
NS/HA	995.9	687	1292	482	1595	849	543	1025	751	795	585	2351
BA/HA (SQ.M)	59.5	57	54	60	64	56	48	64	70	75	38	69
DBH (CM)	29.7	33	23	40	23	29	34	28	34	35	29	19
VOL/HA (CU.M)	591.0	650	402	704	509	591	542	597	736	845	410	515
MAI (CU.M/HA/YR)	9.7	9	8	13	11	7	7	12	14	14	5	7
STRATA A LAYER	78.1	85	85	70	65	60	85	85	70	70	85	99
COVERAGE B LAYER	55.1	81	75	30	60	20	90	40	40	80	60	30
(%) C LAYER	15.5	8	4	40	25	15	6	15	10	8	30	10
D LAYER	71.4	80	70	90	20	50	90	50	80	80	80	95
GROUND H	75.7	85	80	80	80	60	65	90	73	65	85	70
COVERAGE MS	0.9	0	0	0	3	0	5	0	2	0	0	0
(%) DW	22.9	15	20	20	12	40	30	10	25	35	15	30
R & S	0.5	0	0	0	5	0	0	0	0	0	0	0

Environment table for biogeocoenotic association 3.11 ($PM-HS)

FOREST COVER TYPE		PM							PM-TH		
PLOT NUMBER	MEAN	05	10	14	17	20	24	26	21	22	45
BIOGEOCLIMATIC UNIT		CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa
ENVIRONMENT :											
ELEVATION (M)	193.0	170	170	200	210	170	210	200	200	170	230
SLOPE GRADIENT (%)	6.7	5	0	10	18	0	2	2	10	3	17
ASPECT		180	F	180	200	F	70	360	60	30	300
SOIL		s/O	s/O	s/O	s/O	s/O	s/O	s/O	O	s/O	O
SUBGROUP (CSSC, 1978)		.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP
SOIL FAMILY (PARTICLE SIZE)		LS	CLLS	CLLS	LS	CL	CL	CL	CL	CL	CL
DEPTH TO RESTR. HOR./LAYER	0.0										
COARSE FRAGMENTS >2MM (%)	23.0	48	5	25	41	0	25	25	30	7	24
SOIL MOIST.REGIME(HYGROTOPE)		5	5	5	5	6	5	5	5	6	5
SOIL NUTR.REGIME(TROPHOTOPE)		D	D	D	D	D	D	D	C	D	D
PARENT MATERIALS		Cb	Fb	Cb	Cb	Fb	Fb	Fb	Mb	Fb	Mb
THICKNESS OF MIN. SOIL (CM)		+80	61	+80	+90	+95	+100	+85	+80	+100	112
ROOTING DEPTH (CM)	78.2	37	60	50	100	90	100	90	90	90	75
SEEPAGE WATER DEPTH (CM)	0.0										
SOIL DRAINAGE (CSSC, 1978)		w	w	w	w	w	w	w	w	w	w
COARSE FRAGMENTS >2CM (%) *	13.6	33	0	27	23	0	4	15	17	6	11
THICKNESS OF HUM. HOR. (CM)	1.9	1	1	1	1	1	1	1	6	1	5
HUMUS FORM		VL	VL	VL	VL	VL	VL	VL	MD	VL	MD
PH OF HUMUS	3.6								3.1		4.2
C/N OF HUMUS	34.5								38		31
PH OF MINERAL SOIL	4.5	4.3	4.4	3.8	5.7	4.6	4.5	4.4	4.5	4.6	4.4
VEGETATION :											
AGE (YEARS)	64.8	54	79	58	65	78	53	69	62	62	68
GC AND SI OF DOUGLAS-FIR	2-53.9	2-54	2-55	2-57	2-57	1-59	1-58	2-53	3-51	2-54	4-41
NS/HA	556.3	680	595	448	238	501	309	822	753	323	894
BA/HA (SQ.M)	69.9	68	75	65	48	65	70	70	100	70	68
DBH (CM)	42.3	36	40	43	51	41	54	33	41	53	31
VOL/HA (CU.M)	878.0	821	1011	833	671	875	906	871	1168	918	706
MAI (CU.M/HA/YR)	13.7	15	13	14	10	11	17	13	19	15	10
STRATA COVERAGE (%) A LAYER	75.5	70	80	65	65	75	70	65	90	80	95
B LAYER	33.3	8	70	18	25	40	30	80	25	15	22
C LAYER	65.5	90	30	95	85	70	70	30	60	95	30
D LAYER	43.0	10	65	10	50	30	35	50	80	30	70
GROUND COVERAGE (%) H	82.6	89	80	85	85	70	90	79	85	88	75
MS	0.1	0	0	1	0	0	0	0	0	0	0
DW	16.9	10	20	12	15	30	10	20	15	12	25
R & S	0.4	1	0	2	0	0	0	1	0	0	0

Environment table for biogeocoenotic association 3.12 ($PM-PI)

FOREST COVER TYPE		CON.-DEC.			CON.						
PLOT NUMBER	MEAN	02	09	27	15	16	25	29	30	36	41
BIOGEOCLIMATIC UNIT		CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa	CWHa
ENVIRONMENT :											
ELEVATION (M)	181.0	170	170	180	200	180	200	170	170	170	200
SLOPE GRADIENT (%)	3.4	0	0	0	15	5	2	0	0	2	10
ASPECT		F	F	F	225	225	30	F	F	230	290
SOIL		SM	s/O	sgDU	s/O	s/O	st/O	s/O	SM	s/O	s/DU
SUBGROUP (CSSC, 1978)		.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP	.HFP
SOIL FAMILY (PARTICLE SIZE)		CL	CL	CLLS	LS	CL	CLLS	CL	CL	LSCL	CL
DEPTH TO RESTR. HOR./LAYER	63.0			K 51							K 75
COARSE FRAGMENTS >2MM (%)	15.7	0	0	9	50	25	0	2	1	49	21
SOIL MOIST.REGIME(HYGROTOPE)		5	6	6	5	6	6	6	6	6	6
SOIL NUTR.REGIME(TROPHOTOPE)		D	E	D	D	E	D	E	E	E	D
PARENT MATERIALS		Fb	Fb	Fb	Cb	Fb	Fb	Fb	Fb	Fb	Mb
THICKNESS OF MIN. SOIL (CM)		100	+90	50	+80	+85	+95	+100	100	+90	74
ROOTING DEPTH (CM)	85.5	75	80	45	70	80	80	120	120	110	75
SEEPAGE WATER DEPTH (CM)	57.5			40							75
SOIL DRAINAGE (CSSC, 1978)		w	w	i	w	w	w	w	w	w	w
COARSE FRAGMENTS >2CM (%)	9.3	0	0	11	36	13	12	0	0	15	6
THICKNESS OF HUM. HOR. (CM)	1.0	1	1	1	1	1	1	1	1	1	1
HUMUS FORM		VL	VL	VL	VL	VL	VL	VL	VL	VL	VL
PH OF HUMUS	0.0										
C/N OF HUMUS	0.0										
PH OF MINERAL SOIL	4.5	4.7	4.6	4.3	4.2	4.4	4.7	4.6	4.5	4.3	4.4
VEGETATION :											
AGE (YEARS)	68.0	49	84	66	65	66	51	77	82	69	71
GC AND SI OF DOUGLAS-FIR	2-55.0	3-48	2-53	2-53	2-56	1-60	2-52	2-56	1-58	1-58	2-56
NS/HA	483.6	525	491	675	575	679	242	377	293	485	494
BA/HA (SQ.M)	73.4	54	75	70	65	90	48	80	90	90	72
DBH (CM)	45.2	36	44	36	38	41	50	52	63	49	43
VOL/HA (CU.M)	963.8	472	965	862	821	1123	547	1176	1374	1326	972
MAI (CU.M/HA/YR)	14.0	10	11	13	13	17	11	15	17	19	14
STRATA A LAYER	77.5	70	75	80	80	75	60	85	80	90	80
COVERAGE B LAYER	20.3	25	25	40	5	8	10	30	15	15	30
(%) C LAYER	84.0	80	60	80	80	90	90	95	95	80	90
D LAYER	16.6	12	5	20	30	4	40	5	5	10	35
GROUND H	83.2	85	80	88	82	80	92	90	90	75	70
COVERAGE MS	0.9	0	5	2	2	0	0	0	0	0	0
(%) DW	15.8	15	15	10	15	20	8	10	10	25	30
R & S	0.1	0	0	0	1	0	0	0	0	0	0

Environment table for biogeocoenotic association 3.21 ($AR-LA)

FOREST COVER TYPE			CLOSED				OPEN
PLOT NUMBER		MEAN	13	18	31	39	40
BIOGEOCLIMATIC UNIT			CWHa	CWHa	CWHa	CWHa	CWHa
ENVIRONMENT :							
ELEVATION (M)		180.0	180	170	180	170	200
SLOPE GRADIENT (%)		2.4	12	0	0	0	0
ASPECT			210	F	F	F	F
SOIL			T	T	O	O	T
SUBGROUP (CSSC, 1978)			.H	.H	.HG	.HG	.H
SOIL FAMILY (PARTICLE SIZE)			O/LS	O	O/FL	O/FL	O/FL
DEPTH TO RESTR. HOR./LAYER		46.0	K 50		K 38		K 50
COARSE FRAGMENTS >2MM (%)		0.0	0	0	0	0	0
SOIL MOIST.REGIME(HYGROTOPE)			7	7	7	7	7
SOIL NUTR.REGIME(TROPHOTOPE)			E	E	E	E	E
PARENT MATERIALS			OvMb	Ob	OvMb	OvFb	OvMb
THICKNESS OF MIN. SOIL (CM)					27	25	
ROOTING DEPTH (CM)		42.6	50	40	38	45	40
SEEPAGE WATER DEPTH (CM)		15.4	30	16	6	15	10
SOIL DRAINAGE (CSSC, 1978)			vp	vp	vp	vp	vp
COARSE FRAGMENTS >2CM (%) •		0.0	0	0	0	0	0
THICKNESS OF HUM. HOR. (CM)		7.8	1	1	11	25	1
HUMUS FORM			SL	SL	YL	SL	SL
PH OF HUMUS		0.0					
C/N OF HUMUS		0.0					
PH OF MINERAL SOIL		4.8	5.5	5.3	3.5	4.8	4.9
VEGETATION :							
AGE (YEARS)		54.8	41	54	53	58	68
GC AND SI OF DOUGLAS-FIR		0- 0.0	-	-	-	-	-
NS/HA		579.6	475	400	950	668	405
BA/HA (SQ.M)		36.2	30	33	33	52	33
DBH (CM)		28.8	28	32	21	31	32
VOL/HA (CU.M)		279.4	249	191	174	514	269
MAI (CU.M/HA/YR)		5.2	6	4	3	9	4
STRATA	A LAYER	75.4	72	85	80	90	50
COVERAGE	B LAYER	18.4	5	4	8	25	50
(%)	C LAYER	92.0	90	95	95	90	90
	D LAYER	10.8	15	5	4	5	25
GROUND	H	75.0	83	70	85	92	45
COVERAGE	MS	0.0	0	0	0	0	0
(%)	DW	13.0	15	5	5	5	35
	R & S	0.0	0	0	0	0	0

APPENDIX H - LONG VEGETATION TABLES

In this appendix, a long vegetation table is shown for each biogeocoenotic association. These tables were produced by the F405:VTAB program (Emanuel and Wong, 1983). In these tables, several abbreviations are used. These abbreviations indicate the following:

1. FOREST COVER TYPE: Con.= coniferous, Dec.= Deciduous, PC = lodgepole pine, PM = Douglas-fir, TH = western hemlock
2. ST: stratum
3. P: presence
4. MS: mean species significance
5. RS: range of species significance
6. A1: dominant trees
7. A2: main tree canopy (codominant and intermediate trees)
8. A3: suppressed trees over 10 m tall
9. B1: tall shrubs (woody plants between 2 and 10 m tall)
10. B2: low shrubs (woody plants less than 2 m tall)
11. C: herbaceous species, species of doubtful lifeform, and some low shrubs
12. DH: bryophytes, lichens, and seedlings growing on the humus layer

Vegetation table for biogeocoenotic association 1.11 ($PC-PJ)

FOREST COVER TYPE					PC								PM	
PLOT NUMBER					35		49		50		51		47	
ST	SPECIES	P	MS	RS	SIGNIFICANCE AND VIGOR									
A1														
	Pinus contorta	80.0	4.4	0-5	3	2	4	2	5	2	4	2		
	Pseudotsuga menziesii	20.0	4.1	0-6									6	2
A2														
	Pinus contorta	80.0	6.9	0-8	6	2	6	2	7	2	8	2		
	Pseudotsuga menziesii	60.0	4.6	0-6	3	2	4	2					6	2
	Arbutus menziesii	20.0	1.6	0-3									3	1
A3														
	Pinus contorta	100.0	5.4	3-6	6	2	5	2	3	2	6	2	4	1
	Pseudotsuga menziesii	60.0	4.3	0-5			5	2			4	2	4	2
	Arbutus menziesii	40.0	3.7	0-5	3	2			5	2				
	Salix sitchensis	20.0	1.6	0-3	3	2								
B1														
	Holodiscus discolor	80.0	4.9	0-6	1	2	6	2	5	2	1	2		
	Pseudotsuga menziesii	60.0	2.7	0-4	+	2	4	2			2	2		
	Arbutus menziesii	40.0	4.1	0-6			6	2			+	2		
	Pinus contorta	40.0	2.4	0-4			4	2	+	2				
	Juniperus scopulorum	20.0	+.1	0-1	1	2								
B2														
	Mahonia nervosa	100.0	4.5	+-5	1	2	5	2	+	1	3	2	5	2
	Rosa gymnocarpa	100.0	2.1	+-3	1	2	1	2	+	1	1	2	3	1
	Gaultheria shallon	80.0	5.1	0-7	1	2	5	2			3	2	7	1
	Holodiscus discolor	80.0	4.7	0-7			1	2	1	2	2	2	7	2
	Symphoricarpos albus	60.0	1.1	0-2			+	2			+	2	2	1
	Pinus contorta	40.0	+.0	0-+	+	2			+	2				
	Cytisus scoparius	20.0	1.0	0-2									2	1
	Amelanchier alnifolia	20.0	+.0	0-+					+	1				
	Arbutus menziesii	20.0	+.0	0-+	+	2								
	Juniperus communis	20.0	+.0	0-+			+	2						
	Lonicera ciliosa	20.0	+.0	0-+	+	2								
	Mahonia aquifolium	20.0	+.0	0-+					+	1				
	Salix sitchensis	20.0	+.0	0-+					+	1				
	Vaccinium parvifolium	20.0	+.0	0-+			+	2						
C														
	Hieracium albiflorum	100.0	2.6	+-3	3	2	+	2	1	2	1	2	3	2
	Festuca occidentalis	100.0	2.5	+-3	3	2	1	2	+	2	+	2	3	2
	Goodyera oblongifolia	100.0	1.6	+-2	+	2	1	2	1	2	1	2	2	1
	Listera cordata	100.0	1.4	+-2	+	2	+	2	+	2	1	2	2	2
	Rubus ursinus	100.0	1.1	+-1	1	2	+	2	+	2	+	1	1	1
	Arctostaphylos uva-ursi	80.0	3.1	0-4	3	2			4	2	1	2	2	1
	Fragaria virginiana	80.0	1.4	0-2	2	2	+	2	1	2	1	2		
	Trientalis latifolia	60.0	1.8	0-3			1	2			+	1	3	2
	Achillea millefolium	60.0	1.4	0-2	2	2			1	2			1	1
	Hypochoeris radicata	60.0	+.5	0-1	+	2			1	2	+	2		
	Platanthera unalascensis	60.0	+.1	0-+	+	2			+	2	+	2		
	Melica subulata	40.0	2.5	0-4			1	2					4	2
	Lilium columbianum	40.0	1.1	0-2					+	2			2	2
	Polystichum munitum	40.0	1.1	0-2					+	2			2	1
	Linnaea borealis	40.0	+.3	0-1			+	2					1	2
	Montia parvifolia	40.0	+.3	0-1			+	2	1	2				
	Selaginella wallacei	40.0	+.3	0-1	1	2			+	1				
	Viola adunca	40.0	+.3	0-1					+	2			1	2
	Viola orbiculata	40.0	+.3	0-1			+	2					1	2
	Collomia heterophylla	40.0	+.0	0-+	+	2			+	2				
	Elymus glaucus	40.0	+.0	0-+	+	2					+	2		
	Prunella vulgaris	40.0	+.0	0-+			+	2	+	2				
	Viola sempervirens	20.0	1.6	0-3									3	2
	Anemone lyallii	20.0	1.0	0-2									2	2
	Circaea alpina	20.0	1.0	0-2									2	2
	Boykinia elata	20.0	+.1	0-1									1	1
	Danthonia spicata	20.0	+.1	0-1					1	2				
	Fragaria vesca	20.0	+.1	0-1									1	2
	Lupinus polyphyllus	20.0	+.1	0-1									1	2
	Platanthera chorisiana	20.0	+.1	0-1									1	2
	Achlys triphylla	20.0	+.0	0-+					+	2				
	Apocynum androsaemifolium	20.0	+.0	0-+							+	2		
	Boschniakia hookeri	20.0	+.0	0-+									+	2
	Bromus sitchensis	20.0	+.0	0-+							+	2		
	Camassia quamash	20.0	+.0	0-+					+	2				
	Heuchera micrantha	20.0	+.0	0-+			+	2						
	Lotus micranthus	20.0	+.0	0-+					+	2				
	Mycelis muralis	20.0	+.0	0-+					+	2				
	Polypodium glycyrrhiza	20.0	+.0	0-+					+	2				
	Tiarella laciniata	20.0	+.0	0-+			+	1						
DH														
	Hylocomium splendens	100.0	5.2	1-7	3	2	5	2	1	2	4	1	7	2
	Polytrichum juniperinum	100.0	4.3	1-5	5	2	1	2	4	2	1	2	4	2
	Kindbergia oregana	80.0	5.3	0-7	5	2	5	2			+	1	7	2
	Rhytidiadelphus triquetrus	80.0	3.7	0-5	+	2	5	2	+	2			3	2
	Dicranum scoparium	80.0	3.6	0-4	3	2	1	2	4	2	4	2		
	Peltigera aphthosa	80.0	+.3	0-+	+	2	+	2	+	1	+	1		
	Homalothecium megaptilum	60.0	2.6	0-4			1	2	1	2	4	1		
	Cladonia gracilis	60.0	1.1	0-2					+	1	+	2	2	2
	Cladina rangiferina	60.0	1.1	0-2					+	1	+	1	2	2
	Rhytidiadelphus loreus	40.0	1.6	0-3							+	1	3	2
	Cladonia furcata	40.0	1.1	0-2			+	2					2	2
	Plagiothecium undulatum	40.0	1.1	0-2							+	1	2	2
	Polytrichum commune	40.0	+.8	0-1	1	2			1	2				
	Dicranum howellii	20.0	3.4	0-5									5	2
	Rhacomitrium canescens	20.0	2.4	0-4					4	2				
	Leptogium palmatum	20.0	1.0	0-2									2	2
	Pseudotsuga menziesii	20.0	1.0	0-2									2	2
	Pleurozium schreberi	20.0	+.1	0-1									1	1
	Pogonatum alpinum	20.0	+.1	0-1							1	1		
	Cladonia coniocraea	20.0	+.0	0-+			+	2						
	Cladonia multiformis	20.0	+.0	0-+	+	2								
	Cladonia squamosa	20.0	+.0	0-+					+	1				
	Cladonia uncialis	20.0	+.0	0-+					+	1				
	Peltigera membranacea	20.0	+.0	0-+			+	2						
	Polytrichum piliferum	20.0	+.0	0-+							+	2		
	Rhytidiopsis robusta	20.0	+.0	0-+							+	1		

Vegetation table for biogeocoenotic association 1.21 ($PM-GS)

	FOREST COVER TYPE				PM-PC		PM-TH							
	PLOT NUMBER				37	11	12	32	33	34	38	44	46	48
ST	SPECIES	P	MS	RS	SPECIES SIGNIFICANCE AND VIGOR									
A1														
	Pseudotsuga menziesii	90.0	4.4	0-5		3 2	4 2	3 2	3 2	3 2	5 2	4 2	5 1	4 2
	Arbutus menziesii	10.0	2.6	0-5	5 2									
	Thuja plicata	10.0	1.6	0-4								4 1		
	Pinus contorta	10.0	+.3	0-2		2 2								
	Tsuga heterophylla	10.0	+.3	0-2							2 2			
A2														
	Pseudotsuga menziesii	100.0	7.9	6-9	6 2	7 2	8 2	7 2	7 2	7 2	8 2	9 2	8 2	6 2
	Pinus contorta	40.0	3.1	0-5	5 2	4 2	+ 2							2 2
	Tsuga heterophylla	30.0	2.1	0-4				3 2		1 2				4 2
	Arbutus menziesii	20.0	+.4	0-2			+ 2				2 2			
A3														
	Pseudotsuga menziesii	100.0	6.2	5-6	6 2	6 2	6 2	6 2	6 2	6 2	5 2	5 2	6 1	6 2
	Tsuga heterophylla	40.0	2.7	0-4				3 2	1 2	4 2				4 2
	Pinus contorta	10.0	2.6	0-5	5 2									
B1														
	Tsuga heterophylla	70.0	3.9	0-5			1 2	3 2	5 2	3 2	2 2	5 1		3 1
	Holodiscus discolor	70.0	2.7	0-4	4 2	3 2		3 2	1 2	1 2	2 2			2 2
	Pseudotsuga menziesii	60.0	3.4	0-5		2 1		5 2	4 2	3 2	2 2	3 1		
	Thuja plicata	40.0	2.1	0-4	2 2				1 2		2 2			4 2
	Arbutus menziesii	30.0	+.0	0-1				1 1	+ 0	+ 0				
	Salix sitchensis	20.0	+.1	0-1							1 2			1 2
	Vaccinium parvifolium	20.0	+.0	0-+					+ 2					+ 2
	Rhamnus purshianus	10.0	+.0	0-1	1 2									
B2														
	Gaultheria shallon	100.0	8.8	5-9	5 2	9 2	8 2	9 2	9 2	9 2	7 2	9 2	8 2	9 2
	Mahonia nervosa	100.0	4.9	2-6	6 2	3 2	6 2	2 2	3 2	2 2	5 2	3 1	4 2	2 2
	Vaccinium parvifolium	90.0	3.1	0-5	+ 2	2 2		1 2	2 2	1 2	1 2	5 2	3 2	+ 2
	Rosa gymnocarpa	90.0	2.5	0-3	2 2	3 2	1 2	2 2	+ 2	2 2	2 2		3 2	2 2
	Holodiscus discolor	80.0	2.3	0-4	2 2	2 2	2 2	1 2		1 2	1 2		4 2	+ 2
	Symphoricarpos albus	70.0	1.7	0-3	2 2	3 2	1 2	1 2	1 2	+ 2	1 2			
	Tsuga heterophylla	60.0	2.0	0-4				1 2	1 2	+ 1	+ 2	4 2	2 2	
	Thuja plicata	50.0	1.8	0-3			1 2	1 2	+ 2				3 2	3 2
	Amelanchier alnifolia	40.0	+.0	0-+			+ 2	+ 2	+ 2	+ 2				
	Lonicera ciliosa	30.0	1.1	0-3	+ 2			+ 2					3 2	
	Symphoricarpos hesperius	10.0	+.3	0-2									2 2	
	Malus fusca	10.0	+.0	0-+			+ 2							
	Pseudotsuga menziesii	10.0	+.0	0-1					1 2					
C														
	Achlys triphylla	90.0	1.5	0-3	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1		3 2	2 1
	Rubus ursinus	90.0	1.4	0-2	1 2	1 2	1 2	1 2	1 2	+ 2	1 2		2 1	1 2
	Polystichum munitum	80.0	2.1	0-3		3 2	2 2	+ 2	1 1	1 2	+ 1		3 1	2 1
	Pteridium aquilinum	80.0	1.5	0-2		1 2	2 2	1 2	1 2	1 2	+ 2	2 0		1 2
	Trientalis latifolia	80.0	1.1	0-2	+ 2	+ 2	1 2	+ 2		+ 2	+ 2		2 2	1 2
	Listera cordata	70.0	+.6	0-1		+ 2	1 2	+ 2		+ 2	+ 2	1 1		+ 2
	Goodyera oblongifolia	50.0	1.0	0-2	1 2	+ 2	1 2				+ 1		2 1	
	Bromus vulgaris	40.0	+.0	0-+	+ 2	+ 2				+ 2	+ 2			
	Hemitomes congestum	40.0	+.0	0-+	+ 2	+ 2			+ 2					+ 2
	Mycelis muralis	40.0	+.0	0-+				+ 1	+ 1	+ 1	+ 1			
	Linnaea borealis	30.0	+.9	0-2			1 2						2 2	1 2
	Viola sempervirens	30.0	+.7	0-2		+ 2	1 2						2 2	
	Trillium ovatum	30.0	+.5	0-2			+ 1						2 1	+ 2
	Anemone lyallii	30.0	+.0	0-1		+ 2							1 2	+ 2
	Chimaphila menziesii	30.0	+.0	0-+	+ 2		+ 2	+ 2						
	Melica subulata	20.0	1.1	0-3							+ 2		3 2	
	Viola orbiculata	20.0	+.0	0-1				+ 2					1 2	
	Circaea alpina	10.0	+.3	0-2									2 2	
	Erythronium revolutum	10.0	+.3	0-2									2 2	
	Festuca occidentalis	10.0	+.3	0-2									2 2	
	Boschniakia hookeri	10.0	+.0	0-1									1 2	
	Calypso bulbosa	10.0	+.0	0-+		+ 2								
	Chimaphila umbellata	10.0	+.0	0-+		+ 2								
	Corallorhiza mertensiana	10.0	+.0	0-+							+ 2			
	Cystopteris fragilis	10.0	+.0	0-+									+ 2	
	Disporum smithii	10.0	+.0	0-+									+ 2	
	Festuca subuliflora	10.0	+.0	0-+										+ 2
	Hieracium albiflorum	10.0	+.0	0-+			+ 2							
	Lilium columbianum	10.0	+.0	0-+		+ 2								
	Polypodium glycyrrhiza	10.0	+.0	0-+					+ 1					
DH														
	Kindbergia oregana	100.0	5.7	3-7	5 1	6 2	4 2	6 2	3 2	4 2	5 2	6 3	7 2	6 2
	Hylocomium splendens	80.0	4.3	0-6	+ 1	6 2	4 2			+ 2	+ 2	1 2	6 2	2 2
	Rhytidiadelphus loreus	40.0	2.8	0-5		2 2	1 2						5 2	+ 2
	Rhytidiadelphus triquetrus	40.0	2.8	0-5		2 2	1 2						5 2	+ 2
	Plagiothecium undulatum	40.0	+.1	0-1		+ 2	+ 2			+ 2		1 2		
	Rhizomnium glabrescens	30.0	+.0	0-+		+ 2			+ 2	+ 2				
	Leucolepis menziesii	20.0	+.6	0-2									2 2	1 2
	Pseudotsuga menziesii	20.0	+.4	0-2			+ 2						2 2	
	Tsuga heterophylla	20.0	+.4	0-2							+ 2		2 2	
	Dicranum scoparium	20.0	+.0	0-+		+ 2				+ 2				
	Peltigera polydactyla	20.0	+.0	0-+			+ 2			+ 1				
	Thuja plicata	10.0	+.3	0-2									2 2	
	Isothecium stoloniferum	10.0	+.0	0-1								1 2		
	Peltigera canina	10.0	+.0	0-1									1 2	
	Peltigera membranacea	10.0	+.0	0-+			+ 2							
	Polytrichum juniperinum	10.0	+.0	0-1			1 2							

Vegetation table for biogeocoenotic association 2.11 ($PM-KO)

ST	FOREST COVER TYPE				PM							PM-TH			
	PLOT NUMBER				01	03	04	06	08	19	28	07	23	42	43
ST	SPECIES	P	MS	RS	SPECIES SIGNIFICANCE AND VIGOR										
A1															
	Pseudotsuga menziesii	100.0	4.9	3-6	4 2	4 2	4 2	4 2	4 2	4 2	4 2	3 2	3 2	5 3	6 2
	Tsuga heterophylla	9.1	1.0	0-3				3 1							
A2															
	Pseudotsuga menziesii	100.0	8.3	7-9	9 2	8 2	8 2	8 2	8 2	8 2	8 2	7 2	7 2	7 2	8 2
	Tsuga heterophylla	63.6	4.2	0-6			3 2		3 2	2 2		6 1	4 2	5 2	4 2
A3															
	Tsuga heterophylla	100.0	4.9	1-6	1 1	2 2	2 2	4 1	4 2	6 2	6 2	5 1	4 2	3 2	3 2
	Pseudotsuga menziesii	90.9	4.9	0-5	3 1	5 2		3 1	3 2	5 2	3 2	4 2	5 2	5 2	5 1
	Thuja plicata	18.2	2.0	0-4					4 2					3 2	
	Abies grandis	9.1	1.0	0-3										3 2	
B1															
	Tsuga heterophylla	100.0	4.4	2-5	2 1	3 2	2 2	2 1	4 2	4 2	5 2	2 1	3 2	5 2	5 1
	Thuja plicata	36.4	3.5	0-5		2 2			5 2	5 2				3 2	
	Vaccinium parvifolium	18.2	+.3	0-2			+ 2						2 2		
	Cornus nuttallii	9.1	1.0	0-3				3 2							
	Acer macrophyllum	9.1	+.0	0-1							1 2				
	Amelanchier alnifolia	9.1	+.0	0-1									1 2		
	Pseudotsuga menziesii	9.1	+.0	0-1		1 0									
	Rubus spectabilis	9.1	+.0	0-+			+ 2								
B2															
	Gaultheria shallon	100.0	5.8	2-8	8 2	8 2	2 2	5 2	4 2	5 2	4 2	5 2	6 2	5 2	4 2
	Mahonia nervosa	100.0	4.5	+-5	3 2	5 2	2 2	4 2	2 2	4 2	5 2	4 2	+ 2	5 2	3 2
	Tsuga heterophylla	100.0	2.0	+-3	1 1	1 2	1 2	1 1	1 2	1 2	1 2	+ 1	+ 2	3 3	3 1
	Vaccinium parvifolium	90.9	4.4	0-6	4 2	4 2	4 2	1 2		5 2	1 2	2 2	2 2	6 2	4 2
	Thuja plicata	54.5	1.7	0-3		1 2			1 2	1 2		+ 2		3 2	3 1
	Rosa gymnocarpa	54.5	1.3	0-3		+ 2	1 2	1 2	3 2	1 2			+ 2		
	Amelanchier alnifolia	45.4	+.1	0-1			1 2	+ 1		+ 2		+ 1	+ 2		
	Holodiscus discolor	27.3	+.0	0-1	+ 1		+ 2	1 2							
	Symphoricarpos albus	27.3	+.0	0-+			+ 2	+ 1	+ 1						
	Acer macrophyllum	18.2	+.0	0-1		1 2			+ 1						
	Abies grandis	9.1	1.5	0-4										4 2	
	Cornus nuttallii	9.1	+.0	0-+				+ 2							
	Physocarpus capitatus	9.1	+.0	0-+										+ 2	
	Pinus monticola	9.1	+.0	0-1										1 2	
	Pseudotsuga menziesii	9.1	+.0	0-1										1 1	
	Rubus parviflorus	9.1	+.0	0-+						+ 2					
	Rubus spectabilis	9.1	+.0	0-+			+ 2								
	Vaccinium alaskaense	9.1	+.0	0-+			+ 2								
	Vaccinium ovalifolium	9.1	+.0	0-+			+ 2								
C															
	Polystichum munitum	100.0	4.4	2-6	2 1	2 1	6 2	5 2	4 2	2 2	4 2	3 2	2 2	3 2	2 1
	Achlys triphylla	100.0	3.1	+-4	1 2	+ 1	2 2	1 1	2 1	2 1	4 2	2 1	1 1	4 2	3 1
	Pteridium aquilinum	100.0	3.0	1-3	3 2	1 1	3 2	3 2	3 2	2 2	1 2	2 1	2 2	2 2	3 2
	Linnaea borealis	90.9	2.7	0-4	2 2		3 2	1 2	3 2	1 2	+ 2	1 2	1 2	4 3	2 2
	Listera cordata	81.8	1.1	0-2	+ 2		+ 2	+ 2	+ 2	1 2	1 2	+ 2		2 3	1 1
	Trillium ovatum	81.8	+.7	0-1		+ 1	1 2	+ 1	+ 2	+ 1	+ 1	+ 1	+ 1	1 2	
	Rubus ursinus	72.7	1.1	0-1		1 2	1 2	1 2	1 2	1 2	1 2	1 2	+ 2		
	Trientalis latifolia	72.7	1.0	0-2		+ 1	1 2	1 2	+ 2	+ 1	+ 2			2 1	+ 1
	Goodyera oblongifolia	63.6	+.3	0-1	+ 2	+ 2	+ 2				+ 2	+ 2		1 2	+ 1
	Tiarella trifoliata	45.4	+.3	0-1			+ 2		1 2	+ 2			+ 2	1 2	
	Viola sempervirens	36.4	1.1	0-3			+ 2	+ 2			1 2			3 3	
	Mycelis muralis	36.4	+.5	0-2	+ 1		+ 2				+ 1			2 2	
	Chimaphila menziesii	36.4	+.0	0-+		+ 1	+ 2			+ 2		+ 2			
	Disporum hookeri	36.4	+.0	0-+					+ 1	+ 2		+ 2	+ 2		
	Maianthemum dilatatum,	36.4	+.0	0-1			+ 2	+ 1		1 1	+ 1				
	Adenocaulon bicolor	27.3	+.0	0-+	+ 1					+ 1					+ 1
	Hypopithys lanuginosa	27.3	+.0	0-+				+ 2		+ 2					+ 2
	Festuca subuliflora	18.2	1.0	0-3	+ 1									3 2	
	Chimaphila umbellata	18.2	+.0	0-+	+ 1							+ 2			
	Corallorhiza mertensiana	18.2	+.0	0-+						+ 2		+ 2			
	Festuca occidentalis	18.2	+.0	0-+	+ 1										+ 1
	Galium triflorum	18.2	+.0	0-+	+ 1		+ 2								
	Pterospora andromedea	18.2	+.0	0-+		+ 1									+ 1
	Viola orbiculata	18.2	+.0	0-1				+ 2			1 2				
	Bromus sitchensis	9.1	+.0	0-+			+ 2								
	Carex hendersonii	9.1	+.0	0-+							+ 2				
	Hemitomes congestum	9.1	+.0	0-+											+ 2
	Hieracium albiflorum	9.1	+.0	0-+							+ 2				
	Listera banksiana	9.1	+.0	0-+									+ 2		
	Lycopodium clavatum	9.1	+.0	0-1			1 +								
	Pyrola dentata	9.1	+.0	0-+				+ 2							
	Pyrola picta	9.1	+.0	0-+											+ +
	Smilacina stellata	9.1	+.0	0-+							+ 2				
	Streptopus amplexifolius	9.1	+.0	0-+			+ 2								
	Tiarella laciniata	9.1	+.0	0-+					+ 2						
	Trisetum cernuum	9.1	+.0	0-+			+ 2								
DH															
	Kindbergia oregana	100.0	7.9	5-9	8 2	8 2	8 2	5 2	5 2	9 2	7 2	8 2	6 2	7 3	8 2
	Hylocomium splendens	90.9	5.3	0-8	2 2	4 2	6 2		6 2	1 2	+ 2	2 2	8 2	6 3	4 2
	Rhytidiadelphus loreus	72.7	1.4	0-3	1 2	+ 1	+ 2		1 2	+ 2	+ 2			3 2	1 3
	Plagiothecium undulatum	54.5	1.4	0-3	1 2					+ 2	+ 2	+ 2		3 3	2 2
	Rhytidiadelphus triquetrus	45.4	1.4	0-3	2 2		+ 2		1 2					3 3	1 3
	Tsuga heterophylla	27.3	+.4	0-2	+ 1					+ 2					2 1
	Acer macrophyllum	18.2	+.0	0-+		+ 2					+ 2				
	Dicranum fuscescens	18.2	+.0	0-+	+ 2			+ 1							
	Peltigera canina	18.2	+.0	0-1								+ 2		1 2	
	Peltigera membranacea	9.1	1.0	0-3										3 2	
	Peltigera polydactyla	9.1	+.2	0-2										2 2	
	Isopterygium elegans	9.1	+.0	0-+				+ 2							
	Pseudotsuga menziesii	9.1	+.0	0-1	1 1										
	Rhizomnium glabrescens	9.1	+.0	0-+									+ 2		
	Rhytidiopsis robusta	9.1	+.0	0-+	+ 2										
	Thuja plicata	9.1	+.0	0-1											1 1
	Vaccinium parvifolium	9.1	+.0	0-+											+ 2

Vegetation table for biogeocoenotic association 3.11 ($PM-HS)

FOREST COVER TYPE					PM							PM-TH		
PLOT NUMBER					05	10	14	17	20	24	26	21	22	45
ST	SPECIES	P	MS	RS	SPECIES SIGNIFICANCE AND VIGOR									
A1														
	Pseudotsuga menziesii	100.0	5.0	3-6	4 2	4 2	3 2	3 2	6 2	3 2	4 2	5 2	4 2	5 2
	Tsuga heterophylla	20.0	2.4	0-4								4 2		4 2
A2														
	Pseudotsuga menziesii	100.0	7.8	6-8	8 2	8 2	7 2	7 2	7 2	7 2	8 2	6 2	8 2	6 2
	Tsuga heterophylla	40.0	5.0	0-8				2 +				8 2	4 2	7 1
	Thuja plicata	10.0	1.0	0-3										3 1
	Abies grandis	10.0	+.3	0-2				2 2						
A3														
	Pseudotsuga menziesii	80.0	5.1	0-6	5 1	6 2	5 2	5 2	3 2	4 2			4 2	5 1
	Tsuga heterophylla	80.0	4.9	0-6	4 2	4 2			5 2	6 2	4 2	5 2	4 2	3 1
	Acer macrophyllum	30.0	1.9	0-4					4 2				1 2	2 1
	Alnus rubra	20.0	3.1	0-5	4 1		5 1							
	Thuja plicata	10.0	1.6	0-4										4 1
	Abies grandis	10.0	+.0	0-1										1 0
B1														
	Tsuga heterophylla	90.0	5.4	0-7	2 2	7 2	5 2	5 2	6 2	5 2	6 2	5 2		2 1
	Thuja plicata	30.0	2.7	0-5		+ 2				5 2	2 2			
	Abies grandis	20.0	1.0	0-2		2 2		2 2						
	Vaccinium parvifolium	20.0	+.1	0-1		1 2				1 2				
	Acer macrophyllum	20.0	+.0	0-1		+ 2					1 2			
	Cornus nuttallii	10.0	+.0	0-1				1 2						
B2														
	Vaccinium parvifolium	80.0	3.8	0-5	3 2	2 2			3 2	2 2	5 2	4 2	4 2	2 2
	Tsuga heterophylla	80.0	3.0	0-5		5 2	1 2	+ 2	1 2	+ 2	1 2	1 2		3 2
	Mahonia nervosa	60.0	1.9	0-4		1 2		+ 2	+ 2	1 2	1 2			4 2
	Rubus spectabilis	60.0	1.0	0-2		1 2		+ 2	+ 2	+ 2		+ 2	2 2	
	Gaultheria shallon	40.0	1.0	0-2	1 1	1 2				1 2				2 1
	Amelanchier alnifolia	40.0	+.0	0-+	+ 2			+ 1			+ 2	+ 2		
	Acer macrophyllum	30.0	+.0	0-1				+ 2			1 2		+ 2	
	Rosa gymnocarpa	20.0	+.0	0-+					+ 2		+ 2			
	Symphoricarpos albus	20.0	+.0	0-1	1 2				+ 2					
	Thuja plicata	20.0	+.0	0-1					+ 2					1 1
	Abies grandis	10.0	2.6	0-5		5 2								
	Holodiscus discolor	10.0	+.3	0-2				2 2						
	Oplopanax horridus	10.0	+.0	0-+					+ 2					
	Rhamnus purshianus	10.0	+.0	0-+					+ 2					
	Rubus parviflorus	10.0	+.0	0-+							+ 2			
	Sorbus aucuparia	10.0	+.0	0-+		+ 2								
	Sorbus sitchensis	10.0	+.0	0-+							+ 2			
C														
	Polystichum munitum	100.0	7.8	3-9	9 2	3 2	9 2	7 2	7 2	8 2	4 2	8 2	8 2	5 2
	Achlys triphylla	100.0	5.0	1-7	3 2	4 2	3 2	7 2	4 2	4 2	4 2	1 2	5 2	4 2
	Tiarella trifoliata	100.0	3.8	+-5	3 2	2 2	1 2	3 2	4 2	1 2	2 2	+ 2	5 2	4 2
	Tiarella laciniata	100.0	1.4	+-2	1 2	2 1	+ 2	+ 2	+ 2	+ 2	+ 2	+ 2	1 2	2 2
	Galium triflorum	90.0	2.1	0-3	2 2	2 2	1 2	3 2	+ 2	1 2	1 2		1 2	2 2
	Trillium ovatum	90.0	1.2	0-1	1 2	1 2		+ 2	1 2	1 2	1 2	+ 2	1 2	1 2
	Mycelis muralis	80.0	2.5	0-3	3 2	3 2	+ 2	3 2	+ 2	+ 2	2 2			3 2
	Disporum hookeri	80.0	1.6	0-2	1 2	2 2	+ 2		2 2		1 2	1 2	2 2	1 2
	Pteridium aquilinum	80.0	1.3	0-2	1 2	1 2		2 2	1 2	1 2	1 2	+ 2		1 2
	Blechnum spicant	80.0	1.2	0-2	+ 2	+ 2	+ 2	+ 2		2 2		+ 2	+ 2	2 2
	Rubus ursinus	80.0	+.5	0-1	1 2	+ 2		+ 2	+ 2	+ 2	+ 2	+ 2		+ 1
	Trientalis latifolia	70.0	1.5	0-3	1 2	2 2		+ 2		+ 2	+ 2		+ 2	3 2
	Dryopteris expansa	70.0	1.0	0-2	1 2		+ 2		+ 2	+ 2	+ 2	+ 2	2 2	
	Adenocaulon bicolor	70.0	+.8	0-1	+ 2	+ 2		1 2	+ 2	+ 2	1 2			1 2
	Linnaea borealis	60.0	1.6	0-3	1 2	3 2			+ 2	1 2	1 2			2 2
	Streptopus amplexifolius	50.0	1.3	0-2		2 1			2 2	2 2		+ 2	+ 2	
	Goodyera oblongifolia	50.0	+.2	0-1		+ 1		+ 2		+ 2	+ 2			1 1
	Maianthemum dilatatum	40.0	+.6	0-2		+ 1			2 2		+ 2		+ 2	
	Athyrium filix-femina	40.0	+.3	0-1	1 2		+ 2		+ 2				1 2	
	Bromus vulgaris	40.0	+.3	0-1		+ 2		1 2		+ 2	1 2			
	Claytonia sibirica	40.0	+.0	0-+			+ 2	+ 2					+ 2	+ 1
	Festuca subuliflora	30.0	+.5	0-2	+ 2								+ 2	2 2
	Viola sempervirens	30.0	+.0	0-+	+ 2					+ 2	+ 2			
	Viola orbiculata	20.0	1.1	0-3		+ 2								3 2
	Bromus sitchensis	20.0	+.0	0-+				+ 2			+ 2			
	Luzula parviflora	20.0	+.0	0-1	+ 2									1 2
	Monotropa uniflora	20.0	+.0	0-+				+ 2					+ 2	
	Osmorhiza chilensis	20.0	+.0	0-+				+ 2			+ 2			
	Streptopus roseus	10.0	+.3	0-2					2 2					
	Trautvetteria caroliniensis	10.0	+.3	0-2					2 2					
	Carex deweyana	10.0	+.0	0-+	+ 2									
	Carex hendersonii	10.0	+.0	0-+	+ 2									
	Circaea alpina	10.0	+.0	0-1										1 2
	Corallorhiza mertensiana	10.0	+.0	0-+							+ 2			
	Disporum smithii	10.0	+.0	0-+										+ 1
	Festuca occidentalis	10.0	+.0	0-+				+ 2						
	Gymnocarpium dryopteris	10.0	+.0	0-+									+ 2	
	Listera banksiana	10.0	+.0	0-+	+ 2									
	Listera cordata	10.0	+.0	0-+							+ 2			
	Lycopodium clavatum	10.0	+.0	0-+		+ 2								
	Ranunculus uncinatus	10.0	+.0	0-+	+ 2									
	Stellaria crispa	10.0	+.0	0-+	+ 2									
DH														
	Kindbergia oregana	100.0	6.3	3-8	3 2	7 2	3 2	7 2	6 2	6 2	5 2	6 2	5 2	8 2
	Hylocomium splendens	90.0	5.1	0-7	2 2	4 2	+ 2		+ 2	2 2	6 2	7 2	5 2	5 2
	Rhizomnium glabrescens	80.0	2.5	0-4		3 2	3 2	+ 2	+ 2	+ 2		+ 2	1 2	4 3
	Rhytidiadelphus loreus	70.0	1.3	0-3	+ 2	1 2	+ 2			+ 2		1 2	+ 2	3 2
	Plagiomnium insigne	70.0	+.6	0-1	1 2		+ 2	+ 2	+ 2	+ 2	+ 2		1 2	
	Plagiothecium undulatum	40.0	1.1	0-2	2 1	+ 1						+ 2		2 2
	Acer macrophyllum	30.0	+.0	0-+		+ 2		+ 2						+ 1
	Rhytidiadelphus triquetrus	20.0	+.4	0-2							+ 2			2 2
	Tsuga heterophylla	20.0	+.1	0-1		1 2								1 2
	Leucolepis menziesii	20.0	+.0	0-+				+ 2			+ 2			
	Abies grandis	10.0	+.0	0-+										+ 1
	Mnium spinulosum	10.0	+.0	0-+										+ 2
	Peltigera membranacea	10.0	+.0	0-+		+ 2								
	Plagiochila asplenioides	10.0	+.0	0-+								+ 2		
	Pseudotsuga menziesii	10.0	+.0	0-+										+ 1

Vegetation table for biogeocoenotic association 3.12 ($PM-PI)

ST	SPECIES	P	MS	RS	02	09	27	15	16	25	29	30	36	41
FOREST COVER TYPE					CON.-DEC.			CON.						
PLOT NUMBER					02	09	27	15	16	25	29	30	36	41
					SPECIES SIGNIFICANCE AND VIGOR									
A1														
	Pseudotsuga menziesii	100.0	5.0	3-7	5 2	4 2	7 2	4 2	4 2	3 2	4 2	4 2	4 2	3 2
	Abies grandis	20.0	2.9	0-5		3 2								5 3
	Alnus rubra	10.0	1.0	0-3			3 2							
	Populus trichocarpa	10.0	+.0	0-1	1 2									
A2														
	Pseudotsuga menziesii	100.0	7.5	3-8	3 2	5 2	4 2	8 2	8 2	7 2	8 2	8 2	8 2	7 2
	Alnus rubra	20.0	3.7	0-7		1 0	7 2							
	Abies grandis	20.0	2.9	0-5		5 2					3 2			
	Tsuga heterophylla	20.0	2.1	0-4		3 2				4 2				
	Populus trichocarpa	10.0	2.6	0-5	5 2									
	Acer macrophyllum	10.0	1.6	0-4	4 2									
A3														
	Acer macrophyllum	70.0	5.1	0-6	5 2	6 2		5 2	5 2		5 2	3 2	5 2	
	Pseudotsuga menziesii	60.0	4.8	0-5				5 2	5 2		5 2	5 2	3 2	5 2
	Tsuga heterophylla	40.0	3.6	0-6		3 2			1 2	6 2			4 2	
	Abies grandis	20.0	1.3	0-3	2 2									3 2
	Thuja plicata	20.0	1.1	0-3		3 2						+ 2		
	Alnus rubra	10.0	1.6	0-4										4 1
	Populus trichocarpa	10.0	+.0	0-+	+ 1									
B1														
	Tsuga heterophylla	90.0	4.1	0-5	2 2	5 2	4 2		+ 2	2 2	4 2	2 2	3 2	5 2
	Thuja plicata	60.0	4.0	0-5	4 2	3 2			3 2		5 2	3 2	5 2	
	Acer macrophyllum	30.0	1.7	0-4			4 2				1 2	+ 2		
	Rubus spectabilis	30.0	1.1	0-2			1 2				2 2	2 2		
	Abies grandis	20.0	+.1	0-1							1 2	1 2		
	Oplopanax horridus	20.0	+.1	0-1			1 2			1 2				
	Ilex aquifolium	20.0	+.0	0-+							+ 2	+ 2		
	Sambucus racemosa	10.0	+.0	0-1			1 2							
B2														
	Rubus spectabilis	90.0	1.9	0-3	+ 2	2 2	3 2	1 2	1 2	+ 2	2 2	1 2	+ 2	
	Vaccinium parvifolium	70.0	2.8	0-5	+ 2	+ 1	1 2			1 2		+ 2	+ 2	5 1
	Abies grandis	60.0	1.4	0-2	2 +	2 2					1 2	2 2	+ 2	1 2
	Tsuga heterophylla	60.0	1.3	0-3		+ 2			1 2		+ 2	+ 2	+ 2	3 2
	Acer macrophyllum	60.0	+.7	0-1		1 2	1 2	1 2			+ 2	+ 2	+ 2	
	Thuja plicata	40.0	+.8	0-2	2 2				1 2			+ 2	+ 2	
	Oplopanax horridus	30.0	+.5	0-2		+ 2	+ 2			2 2				
	Mahonia nervosa	20.0	1.1	0-3	3 2		1 2							
	Amelanchier alnifolia	20.0	+.0	0-+	+ 1			+ 2						
	Ilex aquifolium	20.0	+.0	0-+							+ 2	+ 2		
	Rhamnus purshianus	20.0	+.0	0-+	+ 1									+ 2
	Symphoricarpos albus	10.0	+.3	0-2	2 2									
	Gaultheria shallon	10.0	+.0	0-1										1 1
	Mahonia aquifolium	10.0	+.0	0-+	+ 1									
	Malus fusca	10.0	+:0	0-+	+ 1									
	Ribes divaricatum	10.0	+.0	0-+								+ 2		
	Rosa gymnocarpa	10.0	+.0	0-+	+ 1									
	Rubus parviflorus	10.0	+.0	0-+			+ 2							
	Taxus brevifolia	10.0	+.0	0-+	+ 1									
C														
	Polystichum munitum	100.0	8.7	6-9	6 2	8 2	8 2	7 2	9 2	9 2	9 2	9 2	7 2	9 3
	Achlys triphylla	100.0	5.3	2-7	4 2	3 2	3 2	7 2	2 2	3 2	5 2	7 2	2 2	6 3
	Tiarella trifoliata	100.0	4.3	1-6	2 2	2 2	3 2	1 2	4 2	2 2	2 2	2 2	6 2	5 2
	Mycelis muralis	100.0	3.1	1-4	1 2	1 2	2 2	4 2	2 2	1 2	1 2	2 2	4 2	3 3
	Galium triflorum	100.0	2.5	1-3	1 2	2 2	2 2	2 2	1 2	3 2	1 2	2 2	1 2	3 3
	Trillium ovatum	100.0	1.7	+-2	2 2	1 2	1 2	+ 2	1 2	1 2	1 2	1 2	1 2	2 2
	Tiarella laciniata •	90.0	1.7	0-3	+ 2	1 2		1 2	2 2	1 2	+ 2	+ 2	1 2	3 2
	Adenocaulon bicolor	90.0	1.3	0-2	2 2	+ 2	1 2	+ 2	+ 2	1 2	1 2	1 2	1 2	
	Trientalis latifolia	90.0	1.1	0-1	1 2	1 2	+ 2	1 2	+ 2	+ 2	1 2	1 2	+ 2	
	Dryopteris expansa	80.0	1.6	0-2		2 2	1 2	1 2	2 2		+ 2	+ 2	1 2	2 2
	Claytonia sibirica	80.0	1.4	0-3	+ 2	+ 2	1 2	+ 2	+ 2		1 2	1 2		3 3
	Athyrium filix-femina	70.0	2.3	0-4			4 2		2 2	1 2	+ 2	+ 2	1 2	3 2
	Disporum hookeri	70.0	1.4	0-2	1 2	1 2	1 2			+ 2	2 2	1 2		2 2
	Streptopus amplexifolius	70.0	+.6	0-1	+ 2	+ 2		+ 2	+ 2	1 2	+ 2		1 2	
	Carex hendersonii	60.0	1.0	0-2				1 2	1 2		+ 2	+ 2	+ 2	2 3
	Bromus vulgaris	60.0	+.5	0-1		1 2	+ 2	1 2			+ 2	+ 2	+ 2	
	Pteridium aquilinum	60.0	+.5	0-1	1 2		+ 2			+ 2		+ 2	+ 2	1 2
	Trautvetteria caroliniensis	50.0	2.1	0-4	3 2		4 2			1 2	+ 2	+ 2		
	Blechnum spicant	50.0	1.5	0-3		2 2		1 2	3 2				+ 2	1 1
	Stachys cooleyae	50.0	1.1	0-2	+ 2		+ 2				1 2	2 2		2 2
	Gymnocarpium dryopteris	50.0	1.0	0-2	1 2		+ 2			1 2	2 2	+ 2		
	Bromus sitchensis	40.0	1.8	0-4	+ 2		1 2	+ 2						4 3
	Maianthemum dilatatum	40.0	+.3	0-1	1 2		1 2				+ 2	+ 2		
	Osmorhiza chilensis	40.0	+.3	0-1	1 2		1 2				+ 2	+ 2		
	Luzula parviflora	40.0	+.1	0-1	+ 1		+ 2						+ 2	1 2
	Rubus ursinus	40.0	+.0	0-+			+ 2	+ 2	+ 2	+ 2				
	Viola glabella	40.0	+.0	0-+			+ 2			+ 2	+ 2	+ 2		
	Dicentra formosa	30.0	+.5	0-2			+ 2				2 2	+ 2		
	Melica subulata	30.0	+.0	0-1	+ 2		+ 2			1 2				
	Adiantum pedatum	20.0	+.1	0-1	1 2					1 2				
	Geranium robertianum	20.0	+.1	0-1				1 2	1 2					
	Carex deweyana	20.0	+.0	0-+	+ 2					+ 2				
	Linnaea borealis	20.0	+.0	0-+			+ 2			+ 2				
	Polypodium glycyrrhiza	20.0	+.0	0-1									+ 2	1 2
	Elymus glaucus	10.0	1.0	0-3										3 3
	Cinna latifolia	10.0	+.3	0-2										2 3
	Asarum caudatum	10.0	+.0	0-+	+ 2									
	Botrychium virginianum	10.0	+.0	0-+	+ 2									
	Festuca subuliflora	10.0	+.0	0-+			+ 2							
	Goodyera oblongifolia	10.0	+.0	0-+				+ 2						
	Mitella ovalis	10.0	+.0	0-+								+ 2		
	Monotropa uniflora	10.0	+.0	0-+				+ 2						
	Nemophila parviflora	10.0	+.0	0-+								+ 2		
	Poa marcida	10.0	+.0	0-1						1 2				
	Ranunculus uncinatus	10.0	+.0	0-+				+ 2						
	Smilacina stellata	10.0	+.0	0-1	1 2									
	Veratrum viride	10.0	+.0	0-+			+ 2							
	Viola orbiculata	10.0	+.0	0-+			+ 2							
DH														
	Kindbergia oregana	100.0	3.8	+-5	4 2	2 2	1 2	5 2	1 2	4 2	+ 2	+ 2	2 2	4 2
	Plagiomnium insigne	90.0	4.4	0-6	3 2		5 2	3 2	2 2	2 2	3 2	3 2	4 2	6 3
	Hylocomium splendens	70.0	3.0	0-5		1 2	+ 2	+ 2	+ 2	3 2			1 2	5 3
	Leucolepis menziesii	70.0	2.9	0-5	2 1		+ 2		1 2	5 2	+ 2	1 2	+ 2	
	Acer macrophyllum	70.0	1.5	0-2	2 +	2 1		+ 2	1 2		2 2	1 2	+ 2	
	Rhizomnium glabrescens	40.0	1.0	0-2	1 2			1 2		2 2			+ 2	
	Kindbergia praelonga	30.0	+.0	0-+	+ 1		+ 2			+ 2				
	Rhytidiadelphus triquetrus	20.0	1.1	0-3	+ 2									3 3
	Plagiothecium undulatum	20.0	+.4	0-2		+ 1								2 3
	Rhytidiadelphus loreus	20.0	+.0	0-1		1 2				+ 2				
	Abies grandis	10.0	+.0	0-+									+ 2	
	Brachythecium frigidum	10.0	+.0	0-1										1 2
	Hookeria lucens	10.0	+.0	0-+			+ 2							
	Hylocomium umbratum	10.0	+.0	0-+			+ 2							
	Plagiochila porelloides	10.0	+.0	0-+			+ 2							

Vegetation table for biogeocoenotic association 3.21 ($AR-LA)

ST	SPECIES	P	MS	RS	13		18		31		39		40	
FOREST COVER TYPE					CLOSED								OPEN	
PLOT NUMBER					13		18		31		39		40	
					SIGNIFICANCE AND VIGOR									
A1														
	Alnus rubra	100.0	4.3	3-4	4	2	4	2	3	2	4	2	4	1
	Thuja plicata	20.0	2.4	0-4					4	2				
A2														
	Alnus rubra	100.0	8.2	6-9	8	2	8	2	7	2	9	2	6	2
	Thuja plicata	20.0	3.4	0-5					5	2				
	Acer macrophyllum	20.0	+.0	0-+	+	2								
A3														
	Alnus rubra	100.0	5.2	4-6	4	2	5	2	6	2	4	2	4	1
	Picea sitchensis	40.0	4.4	0-5							5	2	5	2
	Thuja plicata	40.0	2.4	0-4							+	0	4	2
	Tsuga heterophylla	20.0	2.4	0-4									4	2
B1														
	Rubus spectabilis	60.0	3.9	0-5	3	2	3	2			5	2		
	Tsuga heterophylla	40.0	2.5	0-4							1	2	4	2
	Malus fusca	40.0	1.8	0-3					3	2	1	2		
	Thuja plicata	20.0	1.6	0-3									3	2
	Sambucus racemosa	20.0	1.0	0-2							2	2		
	Rhamnus purshianus	20.0	+.1	0-1					1	2				
B2														
	Rubus spectabilis	80.0	3.6	0-5	1	2			1	2	1	2	5	2
	Vaccinium parvifolium	40.0	4.1	0-6					1	2			6	1
	Sambucus racemosa	40.0	+.8	0-1							1	2	1	2
	Oplopanax horridus	20.0	1.6	0-3									3	2
	Alnus rubra	20.0	+.1	0-1			1	2						
	Gaultheria shallon	20.0	+.1	0-1									1	2
	Malus fusca	20.0	+.0	0-+							+	2		
	Spiraea menziesii	20.0	+.0	0-+					+	2				
	Tsuga heterophylla	20.0	+.0	0-+							+	2		
C														
	Lysichitum americanum	100.0	8.5	7-9	8	2	8	2	9	2	8	2	7	2
	Athyrium filix-femina	100.0	5.7	+-8	7	2	8	2	+	2	3	2	2	2
	Stachys cooleyae	100.0	2.9	+-4	2	2	1	2	+	2	1	2	4	3
	Equisetum telmateia	80.0	3.7	0-5	+	1	3	2			+	2	5	2
	Polystichum munitum	80.0	3.1	0-4	4	2			1	2	2	2	3	2
	Claytonia sibirica	80.0	2.8	0-4	+	1	1	2			2	2	4	3
	Tiarella trifoliata	80.0	2.8	0-4	2	2	+	2			1	2	4	2
	Mycelis muralis	80.0	1.7	0-2	2	2	+	2	1	2			2	2
	Trautvetteria caroliniensis	60.0	4.9	0-6	2	2					6	2	5	2
	Oenanthe sarmentosa	60.0	4.4	0-6			4	2	1	2			6	3
	Achlys triphylla	60.0	1.2	0-2	1	2			+	2			2	2
	Rubus ursinus	60.0	+.5	0-1	+	1			+	2			1	2
	Streptopus amplexifolius	60.0	+.5	0-1			+	2			+	2	1	2
	Tiarella laciniata	60.0	+.5	0-1	+	1					+	2	1	2
	Trillium ovatum	60.0	+.1	0-+	+	1					+	2	+	1
	Carex obnupta	40.0	4.6	0-7			1	2	7	2				
	Mitella ovalis	40.0	4.2	0-6			2	2					6	3
	Blechnum spicant	40.0	3.5	0-5	1	2							5	2
	Galium triflorum	40.0	3.4	0-5	+	1							5	3
	Glyceria elata	40.0	2.4	0-4	+	2							4	3
	Veratrum viride	40.0	2.0	0-3							2	2	3	2
	Dryopteris expansa	40.0	1.5	0-2							2	2	2	2
	Ranunculus uncinatus	40.0	1.5	0-2			2	2					2	2
	Bromus vulgaris	40.0	+.8	0-1	1	2							1	2
	Carex deweyana	40.0	+.8	0-1	1	2	1	2						
	Bromus sitchensis	40.0	+.3	0-1	+	2	1	2						
	Osmorhiza chilensis	40.0	+.3	0-1	+	2					1	2		
	Cinna latifolia	40.0	+.0	0-+			+	2			+	2		
	Circaea alpina	40.0	+.0	0-+	+	1	+	2						
	Disporum hookeri	40.0	+.0	0-+	+	1							+	1
	Maianthemum dilatatum	40.0	+.0	0-+	+	1					+	2		
	Streptopus streptopoides	20.0	1.6	0-3									3	3
	Urtica dioica	20.0	1.6	0-3			3	2						
	Linnaea borealis	20.0	1.0	0-2									2	2
	Luzula parviflora	20.0	+.1	0-1									1	2
	Adiantum pedatum	20.0	+.0	0-+	+	1								
	Cardamine breweri	20.0	+.0	0-+			+	2						
	Cardamine oligosperma	20.0	+.0	0-+			+	2						
	Equisetum arvense	20.0	+.0	0-+	+	1								
	Pteridium aquilinum	20.0	+.0	0-+					+	2				
	Tellima grandiflora	20.0	+.0	0-+	+	2								
	Trisetum cernuum	20.0	+.0	0-+							+	2		
DH														
	Kindbergia praelonga	100.0	4.3	+-6	3	1	1	2	+	2	1	2	6	3
	Plagiomnium insigne	80.0	3.6	0-5	1	2	1	2			2	2	5	2
	Conocephalum conicum	60.0	4.1	0-6	+	1	+	2					6	3
	Leucolepis menziesii	60.0	1.7	0-3	3	2	+	2			+	2		
	Hylocomium splendens	40.0	+.3	0-1					+	2			1	2
	Rhizomnium glabrescens	40.0	+.3	0-1					+	2	1	2		
	Brachythecium frigidum	40.0	+.0	0-+			+	2			+	2		
	Kindbergia oregana	40.0	+.0	0-+	+	2			+	2				
	Aulacomnium androgynum	20.0	+.1	0-1									1	2
	Rhizomnium nudum	20.0	+.1	0-1									1	2
	Chiloscyphus pallescens	20.0	+.0	0-+									+	3
	Claopodium bolanderi	20.0	+.0	0-+					+	2				
	Plagiothecium cavifolium	20.0	+.0	0-+	+	1								
	Rhytidiadelphus loreus	20.0	+.0	0-+					+	2				

APPENDIX I - RELATIVE SPECIES IMPORTANCE OF EISG'S

The relative species importance (RSI) of each edatopic indicator species group (EISG) in each plot is shown in this appendix. Also shown is the biogeocoenotic association (BA) to which each plot belongs.

EISG codes are as follows:

1.1 (vdvp): very dry, nutrient-very poor to poor sites
1.2 (dpm) : very dry to dry, nutrient-very poor to medium sites
1.3 (dfpm): dry to fresh, nutrient-very poor to medium sites
1.4 (dmpm): dry to moist, nutrient-very poor to medium sites
1.5 (fmpm): fresh to moist, nutrient-very poor to medium sites
1.6 (mwpm): moist to wet, nutrient-very poor to medium sites
1.7 (wpm) : wet, nutrient-very poor to medium sites
2.1 (vdm) : very dry to dry, nutrient-poor to medium sites
2.2 (dfm) : dry to fresh, nutrient-medium sites
2.3 (dmm) : dry to moist, nutrient-medium sites
2.4 (fmm) : fresh to moist, nutrient-medium sites
3.1 (vdmr): very dry, nutrient-medium (to rich) sites
3.2 (dmr) : very dry to dry, nutrient-medium to very rich sites
3.3 (dfmr): dry to fresh, nutrient-medium to very rich sites
3.4 (dmmr): dry to moist, nutrient-medium to very rich sites
3.5 (fmmr): fresh to moist, nutrient-medium to very rich sites
3.6 (mwmr): moist to wet, nutrient-medium to very rich sites
3.7 (wmr) : wet, nutrient-medium to very rich sites

PLOT	BA	1.1 vdvp	1.2 dpm	1.3 dfpm	1.4 dmpm	1.5 fmpm	1.6 mwpm	1.7 wpm	2.1 vdm	2.2 dfm
1.	3.	0.0	0.2	5.2	43.9	0.9	0.0	0.0	0.1	43.9
2.	5.	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	10.3
3.	3.	0.0	0.0	4.8	43.1	0.1	0.0	0.0	0.1	49.5
4.	3.	0.0	0.0	6.3	23.4	0.2	0.0	0.0	0.1	44.3
5.	4.	0.0	0.0	2.7	2.3	1.9	0.1	0.0	0.0	3.4
6.	3.	0.0	0.2	2.4	24.7	0.2	0.0	0.0	1.2	34.8
7.	3.	0.0	0.1	1.7	20.2	0.1	0.0	0.0	0.0	70.4
8.	3.	0.0	0.0	4.5	50.5	0.8	0.0	0.0	0.0	24.8
9.	5.	0.0	0.0	0.1	0.6	2.2	1.4	0.0	0.0	1.4
10.	4.	0.0	0.0	2.7	13.4	1.0	0.2	0.0	0.0	47.6
11.	2.	0.0	0.1	3.1	67.8	1.0	0.0	0.0	2.0	19.4
12.	2.	0.0	0.1	2.0	59.2	0.7	0.0	0.0	1.3	30.9
13.	6.	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.2
14.	4.	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.0	3.0
15.	5.	0.0	0.0	0.1	0.1	0.5	0.5	0.0	0.0	12.9
16.	5.	0.0	0.0	0.0	0.1	1.2	2.7	0.0	0.0	0.6
17.	4.	0.0	0.0	0.2	0.0	0.0	0.1	0.0	1.1	29.1
18.	6.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19.	3.	0.0	0.0	13.0	14.1	0.2	0.0	0.0	0.0	67.8
20.	4.	0.0	0.0	3.4	0.3	0.1	0.0	0.0	0.0	26.9
21.	4.	0.0	0.0	5.1	28.3	0.7	0.1	0.0	0.0	20.3
22.	4.	0.0	0.0	4.9	11.5	1.1	0.1	0.0	0.0	11.5
23.	3.	0.0	0.0	2.9	70.3	0.0	0.0	0.0	0.0	22.9
24.	4.	0.0	0.0	1.5	2.6	0.3	1.4	0.0	0.0	26.4
25.	5.	0.0	0.0	0.5	2.7	0.1	0.0	0.0	0.0	5.5
26.	4.	0.0	0.0	19.5	32.4	0.2	0.0	0.0	0.0	20.0
27.	5.	0.0	0.0	0.5	0.2	0.4	0.1	0.0	0.0	0.9
28.	3.	0.0	0.0	2.0	9.7	0.4	0.0	0.0	0.0	67.0
29.	5.	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
30.	5.	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1
31.	6.	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.1
32.	2.	0.0	0.5	1.9	68.3	0.0	0.0	0.0	2.7	24.4
33.	2.	0.0	0.1	1.7	86.2	0.0	0.0	0.0	0.6	7.9
34.	2.	0.0	0.1	2.2	84.2	0.1	0.0	0.0	1.5	9.1
35.	1.	0.0	6.4	43.5	7.5	0.0	0.0	0.0	7.2	31.8
36.	5.	0.0	0.0	0.1	0.6	0.6	0.1	0.0	0.0	1.4
37.	2.	0.0	18.2	2.6	18.6	0.0	0.0	0.0	7.8	49.2
38.	2.	0.0	1.8	2.9	48.8	0.0	0.0	0.0	1.8	41.9
39.	6.	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
40.	6.	0.0	0.0	7.5	0.7	1.3	4.5	0.0	0.0	0.1
41.	5.	0.0	0.0	6.9	7.1	1.2	0.2	0.0	0.0	2.9
42.	3.	0.0	0.0	18.2	30.3	3.9	0.0	0.0	0.0	31.9
43.	3.	0.0	0.0	7.7	16.5	2.2	0.0	0.0	0.1	63.3
44.	2.	0.0	0.0	12.3	62.9	0.4	0.0	0.0	0.0	23.0
45.	4.	0.0	0.0	3.6	12.6	3.1	0.9	0.0	0.0	42.9
46.	2.	0.0	0.3	4.9	41.6	7.8	0.0	0.0	3.3	22.4
47.	1.	1.2	2.0	14.6	31.8	1.9	0.0	0.0	16.0	23.2
48.	2.	0.0	0.0	1.3	68.7	0.1	0.0	0.0	1.2	23.8
49.	1.	0.0	19.5	2.3	23.1	0.0	0.0	0.0	19.0	23.0
50.	1.	11.9	27.7	15.1	1.3	0.0	0.0	0.0	38.8	1.5
51.	1.	1.2	25.3	10.2	38.4	1.2	0.0	0.0	8.6	12.8

PLOT	BA	2.3 dmm	2.4 fmm	3.1 vdmr	3.2 dmr	3.3 dfmr	3.4 dmmr	3.5 fmmr	3.6 mwmr	3.7 wmr
1.	3.	0.0	0.0	0.0	0.0	3.5	1.5	0.3	0.0	0.0
2.	5.	0.0	0.8	0.0	0.1	2.9	36.7	38.3	10.0	0.1
3.	3.	0.0	0.0	0.0	0.0	0.5	1.1	0.5	0.0	0.0
4.	3.	0.0	0.0	0.0	0.1	3.0	20.8	1.1	0.2	0.0
5.	4.	0.0	0.3	0.0	0.1	1.2	71.9	8.0	7.5	0.0
6.	3.	0.0	0.0	0.0	0.2	10.6	24.7	0.2	0.2	0.0
7.	3.	0.0	0.0	0.0	0.0	1.5	5.3	0.1	0.0	0.0
8.	3.	0.0	0.0	0.0	0.0	5.6	11.9	1.6	0.0	0.0
9.	5.	0.0	0.0	0.0	0.0	0.8	59.5	31.5	2.2	0.0
10.	4.	0.0	4.0	0.0	0.0	2.8	14.4	12.6	1.0	0.0
11.	2.	0.1	0.2	0.0	0.1	1.4	4.2	0.1	0.0	0.0
12.	2.	0.0	0.0	0.0	0.5	2.4	2.0	0.1	0.0	0.1
13.	6.	0.0	0.1	0.0	0.0	0.0	6.0	2.6	58.7	31.7
14.	4.	0.0	3.0	0.0	0.0	0.0	76.5	1.6	15.0	0.0
15.	5.	0.0	0.6	0.0	0.0	0.6	59.4	21.2	3.7	0.0
16.	5.	0.0	0.0	0.0	0.0	0.3	67.9	22.8	4.0	0.0
17.	4.	0.0	0.2	0.0	0.0	2.2	57.5	8.7	0.4	0.0
18.	6.	0.0	0.0	0.0	0.0	0.0	0.2	0.5	67.5	31.5
19.	3.	0.0	0.0	0.0	0.0	1.4	2.5	0.2	0.4	0.0
20.	4.	0.0	0.1	0.0	0.0	0.8	46.1	17.9	3.8	0.0
21.	4.	0.0	0.2	0.0	0.0	0.1	44.1	0.5	0.1	0.0
22.	4.	0.0	0.5	0.0	0.0	0.1	53.8	13.9	2.1	0.0
23.	3.	0.0	0.3	0.0	0.0	1.2	1.9	0.3	0.0	0.0
24.	4.	0.0	0.1	0.0	0.1	0.9	62.0	3.8	0.3	0.0
25.	5.	0.0	1.1	0.0	0.0	0.7	66.1	6.2	16.7	0.0
26.	4.	0.0	0.0	0.0	0.2	1.9	17.1	7.8	0.6	0.0
27.	5.	0.0	0.2	0.0	0.0	0.6	40.0	10.1	46.6	0.0
28.	3.	0.0	0.0	0.0	0.7	1.0	17.2	1.2	0.4	0.0
29.	5.	0.0	0.0	0.0	0.0	0.9	74.3	18.0	6.3	0.0
30.	5.	0.0	0.0	0.0	0.0	1.0	85.6	7.1	5.7	0.0
31.	6.	0.0	0.0	0.0	0.0	0.0	0.5	0.3	32.0	66.0
32.	2.	0.0	0.0	0.0	0.1	0.6	0.8	0.1	0.0	0.0
33.	2.	0.0	0.3	0.0	0.0	0.8	1.5	0.1	0.0	0.0
34.	2.	0.0	0.1	0.0	0.0	0.8	1.0	0.3	0.0	0.0
35.	1.	0.0	0.0	2.3	0.3	0.6	0.0	0.0	0.0	0.0
36.	5.	0.0	0.3	0.0	0.0	1.1	37.5	50.2	7.7	0.0
37.	2.	0.0	0.2	0.0	0.2	0.2	1.8	0.2	0.7	0.0
38.	2.	0.0	0.0	0.0	0.0	0.4	1.5	0.4	0.0	0.0
39.	6.	0.0	0.3	0.0	0.0	0.0	1.8	1.7	65.9	29.4
40.	6.	0.0	0.1	0.0	0.0	0.0	9.1	9.4	44.1	22.7
41.	5.	0.0	0.2	0.0	0.0	3.3	46.6	13.2	17.8	0.0
42.	3.	0.0	0.0	0.0	1.9	3.7	6.0	3.6	0.1	0.0
43.	3.	0.1	0.1	0.0	0.0	4.5	4.9	0.0	0.0	0.0
44.	2.	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0
45.	4.	0.1	5.4	0.0	0.0	4.0	15.7	11.3	0.0	0.0
46.	2.	0.0	0.7	0.0	3.0	8.5	4.9	1.5	0.7	0.0
47.	1.	0.0	0.6	0.0	1.3	2.7	4.0	0.0	0.2	0.0
48.	2.	0.0	0.1	0.0	0.0	1.2	2.4	0.3	0.5	0.0
49.	1.	0.1	0.0	0.0	0.0	11.9	0.5	0.1	0.0	0.0
50.	1.	1.0	0.0	0.3	0.6	0.6	0.6	0.3	0.0	0.0
51.	1.	0.0	0.0	0.0	0.0	1.2	0.6	0.0	0.0	0.0

APPENDIX J - CANONICAL VARIABLES FOR EISG'S

In this appendix, canonical variables (CNVR) 1, 2, and 3 are given for the discriminant analysis of the edatopic indicator species groups (EISG) by plots matrix. Also shown is the biogeocoenotic association (BA) to which each plot belongs.

PLOT	BA	CNVR1	CNVR2	CNVR3
1.	3.	3.159	0.395	-2.883
2.	5.	-2.403	-4.344	2.866
3.	3.	3.146	0.384	-2.903
4.	3.	2.492	-1.058	-2.016
5.	4.	-0.554	-4.206	1.695
6.	3.	2.685	-0.615	-1.320
7.	3.	2.886	-0.395	-3.162
8.	3.	2.873	-0.065	-2.054
9.	5.	-2.578	-4.384	2.870
10.	4.	1.478	-2.443	0.325
11.	2.	3.241	0.623	-2.334
12.	2.	3.478	1.356	-2.014
13.	6.	-14.348	3.714	-0.729
14.	4.	-1.280	-4.469	2.776
15.	5.	-1.096	-4.381	2.195
16.	5.	-3.726	-3.554	2.507
17.	4.	1.004	-3.284	1.084
18.	6.	-15.114	4.252	-1.006
19.	3.	2.826	-0.401	-3.420
20.	4.	-0.083	-3.709	0.872
21.	4.	1.982	-2.063	-0.549
22.	4.	0.325	-3.677	1.260
23.	3.	3.353	0.895	-2.283
24.	4.	-0.223	-2.995	0.282
25.	5.	-1.621	-3.738	1.868
26.	4.	2.056	-1.075	-1.440
27.	5.	-6.262	-1.502	1.298
28.	3.	2.403	-1.264	-2.518
29.	5.	-1.095	-4.961	2.618
30.	5.	-0.419	-4.912	2.193
31.	6.	-17.350	5.916	-1.852
32.	2.	3.851	2.320	-1.248
33.	2.	3.611	1.606	-1.744
34.	2.	3.745	2.063	-1.450
35.	1.	5.808	7.731	4.797
36.	5.	-3.044	-4.954	3.795
37.	2.	4.243	3.587	0.457
38.	2.	3.496	1.353	-1.969
39.	6.	-14.493	3.813	-0.738
40.	6.	-14.859	4.206	-0.675
41.	5.	-2.110	-2.747	1.098
42.	3.	2.672	-0.378	-2.582
43.	3.	2.480	-1.562	-4.209
44.	2.	3.346	0.891	-2.699
45.	4.	0.618	-3.553	-0.216
46.	2.	3.469	1.570	-0.731
47.	1.	5.888	7.784	4.903
48.	2.	3.459	1.491	-1.780
49.	1.	6.022	8.226	4.664
50.	1.	5.875	7.965	5.098
51.	1.	4.689	4.551	1.001

APPENDIX K - DESCRIPTIVE STATISTICS FOR SITE AND SOIL PROPERTIES

In this appendix, means (MN), sample sizes (n), standard deviations (SD), and 95% confidence intervals (CI) are given for seven site morphological properties, thirteen soil physical, and fifty-seven soil chemical properties. Data is stratified according to biogeocoenotic association (BA). Correlation coefficients (r) for linear relationship between the site and soil properties and the BA codes are also given.

In the following tables, the codes used to indicate the site morphological, and the soil physical and chemical properties are defined as follows:

A. site morphological properties

- VCL - % volume of large (>2 cm) coarse fragments (whole pit)
- VCT - % volume of total (>2 mm) coarse fragments (weighted to rooting depth)
- THECT - thickness of ectorganic layer (cm)
- THAE - thickness of Ae horizon (cm)
- THAH - thickness of Ah horizon (cm)
- RTDPTH - depth (cm) from ground surface down to the bottom of the effective rooting zone (the level at which the majority of roots stop)
- SLOPE - slope gradient (%)

B. soil physical properties

- CFFBD - coarse fragment-free bulk density ($g\bullet cm^{-3}$)
- SBD - standard bulk density ($g\bullet cm^{-3}$)
- POR - porosity (%)

C. soil chemical properties

- PH - pH in calcium chloride
- TC - total C ($kg\bullet ha^{-1}$)
- TN - total N ($kg\bullet ha^{-1}$)
- MN - mineralizable N ($kg\bullet ha^{-1}$)
- CN - C:N ratio
- CA - exchangeable Ca ($kg\bullet ha^{-1}$)
- MG - exchangeable Mg ($kg\bullet ha^{-1}$)
- K - exchangeable K ($kg\bullet ha^{-1}$)
- NA - exchangeable Na ($kg\bullet ha^{-1}$)
- CAT - exchangeable cations ($kg\bullet ha^{-1}$)
- CEC - cation exchange capacity ($10^3 e\bullet ha^{-1}$)

In the following tables, the soil layer codes indicate the following:

layer 0 = the ectorganic layer
layer 1 = the upper mineral layer (0-30 cm)
layer 2 = the middle mineral layer (30-60 cm)
layer 3 = the lower mineral layer (60-90 cm)
layer 123 = the mineral soil (weighted to rooting depth)
layer 0123 = the whole soil including the ectorganic layer (weighted to rooting depth)

N.B. HF refers to the humus form

Site morphological properties

BA		VCL	VCT	THECT	THAE	THAH	RTDPTH	SLOPE
1	MN	4	17	3	0	0	19	6
	n	5	5	5	5	5	5	5
	SD	5	12	1	0	0	12	9
	CI	-3-10	1-32	2-4	0-1	--	4-33	-5-16
2	MN	11	24	4	2	0	55	21
	n	10	10	10	10	10	10	10
	SD	5	11	1	3	0	23	13
	CI	8-15	16-32	3-5	0-4	--	38-72	11-30
3	MN	10	33	5	2	0	64	10
	n	11	11	11	11	11	11	11
	SD	5	14	2	2	1	13	15
	CI	7-13	23-42	4-6	1-4	0-1	55-73	0-20
4	MN	14	23	2	0	5	78	7
	n	10	10	10	10	10	10	10
	SD	11	15	2	1	3	22	7
	CI	5-22	12-34	1-3	0-1	3-7	62-94	2-12
5	MN	9	16	1	0	9	86	3
	n	10	10	10	10	10	10	10
	SD	11	20	0	0	5	24	5
	CI	1-17	1-30	--	--	6-12	68-103	0-7
6	MN	0	0	8	0	5	43	2
	n	5	5	5	5	5	5	5
	SD	0	0	11	0	7	5	5
	CI	--	--	-5-21	--	-4-14	37-49	-4-9
1-6	MN	9	21	3	1	3	63	9
	n	51	51	51	51	51	51	51
	SD	9	16	4	2	5	27	12
	CI	7-12	16-26	2-5	0-1	2-5	55-70	6-12
	r	-.09	-.31*	-.01	-.29*	.62**	.41**	-.36*
2-5	MN	11	24	3	1	3	71	10
	n	41	41	41	41	41	41	41
	SD	8	16	2	2	5	23	13
	CI	8-14	19-29	2-4	0-2	2-5	63-78	6-14
	r	-.03	-.24	-.64**	-.41**	.77**	.51**	-.49**

Soil Physical Properties

BA		CFFBD.0	CFFBD.1	CFFBD.2	CFFBD.3
1	MN	0.15	0.43	--	--
	n	5	5	--	--
	SD	0.04	0.07	--	--
	CI	0.11-0.20	0.33-0.52	--	--
2	MN	0.13	0.49	0.63	0.61
	n	10	10	6	4
	SD	0.06	0.16	0.09	0.19
	CI	0.09-0.17	0.38-0.60	0.54-0.72	0.32-0.91
3	MN	0.13	0.60	0.77	0.79
	n	11	11	11	11
	SD	0.06	0.10	0.23	0.30
	CI	0.09-0.17	0.53-0.67	0.62-0.92	0.59-0.99
4	MN	0.08	0.59	0.71	0.70
	n	2	10	10	10
	SD	0.01	0.19	0.20	0.22
	CI	0.06-0.10	0.45-0.73	0.57-0.85	0.54-0.85
5	MN	--	0.52	0.76	0.90
	n	--	10	10	10
	SD	--	0.24	0.20	0.22
	CI	--	0.35-0.69	0.61-0.90	0.74-1.05
6	MN	--	0.14	0.25	0.43
	n	--	5	4	3
	SD	--	0.04	0.18	0.39
	CI	--	0.09-0.18	-0.04-0.54	-0.55-1.40
1-6	MN	0.13	0.50	0.68	0.75
	n	28	51	41	38
	SD	0.06	0.20	0.24	0.28
	CI	0.11-0.15	0.44-0.56	0.61-0.76	0.66-0.84
	r	-.23	-.21	-.26	.02
2-5	MN	0.13	0.55	0.73	0.77
	n	23	41	37	35
	SD	0.06	0.18	0.19	0.25
	CI	0.10-0.15	0.49-0.61	0.66-0.79	0.69-0.86
	r	-.14	.05	.14	.27

Soil Physical Properties

BA		SBD.0	SBD.1	SBD.2	SBD.3
1	MN	0.15	0.80	--	--
	n	5	5	--	--
	SD	0.04	0.25	--	--
	CI	0.11-0.20	0.49-1.11	--	--
2	MN	0.13	1.07	1.18	1.20
	n	10	10	6	4
	SD	0.06	0.22	0.16	0.08
	CI	0.09-0.17	0.91-1.23	1.01-1.35	1.07-1.33
3	MN	0.13	1.20	1.39	1.54
	n	11	11	11	11
	SD	0.06	0.24	0.30	0.25
	CI	0.09-0.17	1.04-1.36	1.19-1.59	1.37-1.70
4	MN	0.08	1.01	1.28	1.38
	n	2	10	10	10
	SD	0.01	0.19	0.39	0.35
	CI	0.06-0.10	0.87-1.14	1.00-1.56	1.13-1.63
5	MN	--	0.85	1.23	1.31
	n	--	10	10	10
	SD	--	0.39	0.41	0.37
	CI	--	0.57-1.12	0.93-1.53	1.05-1.58
6	MN	--	0.14	0.25	0.69
	n	--	5	4	3
	SD	--	0.04	0.18	0.84
	CI	--	0.09-0.18	-0.04-0.54	-1.40-2.77
1-6	MN	0.13	0.92	1.18	1.33
	n	28	51	41	38
	SD	0.06	0.38	0.45	0.41
	CI	0.11-0.15	0.82-1.03	1.04-1.32	1.20-1.47
	r	-.23	-.45**	-.42**	-.31
2-5	MN	0.13	1.04	1.28	1.39
	n	23	41	37	35
	SD	0.06	0.29	0.34	0.32
	CI	0.10-0.15	0.94-1.13	1.17-1.40	1.28-1.50
	r	-.14	-.34*	-.04	-.08

Soil Physical Properties

BA		POR.0	POR.1	POR.2	POR.3	POR.123
1	MN	92	69	--	--	69
	n	5	5	--	--	5
	SD	2	9	--	--	9
	CI	90-94	58-80	--	--	58-80
2	MN	93	59	55	54	59
	n	10	10	6	4	10
	SD	3	8	6	3	7
	CI	91-95	53-65	49-61	50-59	54-64
3	MN	93	54	47	42	50
	n	11	11	11	11	11
	SD	4	9	11	9	9
	CI	91-95	48-60	40-55	36-48	45-56
4	MN	96	61	51	48	56
	n	2	10	10	10	10
	SD	1	7	15	13	7
	CI	89-102	56-66	41-62	38-57	51-61
5	MN	--	67	53	50	59
	n	--	10	10	10	10
	SD	--	14	16	14	10
	CI	--	57-78	42-64	40-60	52-66
6	MN	--	92	88	73	91
	n	--	5	4	3	5
	SD	--	1	7	31	2
	CI	--	91-94	78-99	-4-149	89-94
1-6	MN	93	64	55	49	61
	n	28	51	41	38	51
	SD	3	14	17	15	14
	CI	92-94	60-68	50-60	44-54	57-65
	r	.22	.44**	.41**	.29	.31*
2-5	MN	93	60	51	47	56
	n	23	41	37	35	41
	SD	3	11	13	12	9
	CI	92-95	57-64	47-55	43-51	53-59
	r	.13	.33*	.03	.07	.08

Soil Chemical Properties

BA		PH.0	PH.1	PH.2	PH.3	PHHF	PH.123
1	MN	3.5	3.9	--	--	3.5	3.9
	n	5	5	--	--	5	5
	SD	0.3	0.3	--	--	0.3	0.3
	CI	3.1-3.9	3.5-4.4	--	--	3.1-3.9	3.5-4.4
2	MN	4.2	4.4	4.5	4.5	4.2	4.4
	n	10	10	6	4	10	10
	SD	0.3	0.2	0.1	0.2	0.3	0.2
	CI	4.0-4.4	4.2-4.5	4.4-4.6	4.1-4.8	4.0-4.4	4.3-4.5
3	MN	3.8	4.2	4.4	4.4	3.8	4.2
	n	11	11	11	11	11	11
	SD	0.3	0.2	0.2	0.2	0.3	0.2
	CI	3.6-3.9	4.1-4.3	4.3-4.5	4.2-4.5	3.6-3.9	4.1-4.4
4	MN	3.7	4.3	4.7	4.6	4.2	4.5
	n	2	10	10	10	10	10
	SD	0.8	0.5	0.4	0.4	0.6	0.5
	CI	-3.3-10.6	4.0-4.7	4.4-5.0	4.4-4.9	3.8-4.7	4.2-4.9
5	MN	--	4.5	4.5	4.5	4.5	4.5
	n	--	10	10	10	10	10
	SD	--	0.3	0.2	0.2	0.3	0.2
	CI	--	4.3-4.7	4.4-4.6	4.4-4.6	4.3-4.7	4.3-4.6
6	MN	--	4.8	4.9	5.2	4.8	4.8
	n	--	5	5	4	5	5
	SD	--	0.8	0.6	0.3	0.8	0.8
	CI	--	3.8-5.8	4.1-5.6	4.7-5.7	3.8-5.8	3.8-5.8
1-6	MN	3.9	4.3	4.6	4.6	4.2	4.4
	n	28	51	42	39	51	51
	SD	0.4	0.4	0.3	0.4	0.5	0.4
	CI	3.7-4.0	4.2-4.5	4.5-4.7	4.5-4.7	4.0-4.3	4.3-4.5
	r	-.03	.42**	.27	.51**	.55**	.44**
2-5	MN	3.9	4.3	4.5	4.5	4.2	4.4
	n	23	41	37	35	41	41
	SD	0.4	0.3	0.3	0.3	0.5	0.3
	CI	3.8-4.1	4.2-4.4	4.4-4.6	4.4-4.6	4.0-4.3	4.3-4.5
	r	-.58**	.17	.10	.23	.34*	.19

BA		TC.0	TC.1	TC.2	TC.3	TC.0123
1	MN	13989	29591	--	--	43580
	n	5	5	--	--	5
	SD	1410	12792	--	--	11870
	CI	12238-15740	13708-45474	--	--	28842-58318
2	MN	16962	28664	19274	22305	63882
	n	10	10	6	3	10
	SD	6270	12125	14172	4095	28381
	CI	12476-21447	19991-37338	4401-34147	12133-32478	43580-84184
3	MN	19803	26526	14140	3968	61348
	n	11	11	10	6	11
	SD	10681	12580	8778	2945	23433
	CI	12627-26978	18075-34978	7860-20419	878-7059	45605-77090
4	MN	12853	52945	19462	25959	93150
	n	2	10	10	7	10
	SD	9870	21631	10023	10937	39563
	CI	-75823-101530	37472-68419	12292-26633	15844-36074	64848-121450
5	MN	--	46670	24614	27688	96203
	n	--	10	10	9	10
	SD	--	21235	17193	24910	35916
	CI	--	31479-61860	12315-36914	8540-46835	70510-121900
6	MN	--	129270	60059	--	177310
	n	--	5	4	--	5
	SD	--	17186	16717	--	43390
	CI	--	107930-150610	33458-86659	--	123440-231190
1-6	MN	17253	46449	23451	20865	84542
	n	28	51	40	25	51
	SD	8084	33668	17978	18347	46956
	CI	14119-20388	36979-55918	17701-29201	13292-28438	71336-97749
	r	.14	.66**	.52**	.33	.66**
2-5	MN	17963	38404	19384	20865	78224
	n	23	41	36	25	41
	SD	8769	20294	12885	18347	35031
	CI	14171-21755	31999-44810	15024-23743	13292-28438	67167-89281
	r	-.01	.45**	.22	.33	.42**

Soil Chemical Properties

BA		TN.0	TN.1	TN.2	TN.3	TN.0123
1	MN	361	1317	--	--	1678
	n	5	5	--	--	5
	SD	92	575	--	--	497
	CI	247-475	603-2032	--	--	1061-2295
2	MN	421	1006	844	814	2178
	n	10	10	6	3	10
	SD	163	441	690	199	1320
	CI	304-538	691-1321	120-1568	320-1307	1234-3122
3	MN	446	1037	739	173	2250
	n	11	11	10	6	11
	SD	228	521	509	124	1095
	CI	293-600	687-1387	376-1103	43-303	1514-2986
4	MN	357	2468	1077	1371	4576
	n	2	10	10	7	10
	SD	239	1375	563	651	2516
	CI	-1792-2506	1485-3452	674-1480	769-1973	2777-6376
5	MN	--	2446	1470	1541	5302
	n	--	10	10	9	10
	SD	--	1302	988	1329	2228
	CI	--	1514-3377	764-2177	519-2562	3708-6896
6	MN	--	6392	2329	--	8255
	n	--	5	4	--	5
	SD	--	1761	933	--	860
	CI	--	4206-8578	844-3814	--	7188-9323
1-6	MN	416	2140	1181	1078	3823
	n	28	51	40	25	51
	SD	181	1857	844	1010	2594
	CI	345-486	1618-2663	911-1451	661-1495	3094-4553
	r	.09	.67**	.50**	.44*	.73**
2-5	MN	428	1722	1054	1078	3544
	n	23	41	36	25	41
	SD	195	1202	743	1010	2280
	CI	343-512	1343-2102	802-1305	661-1495	2825-4264
	r	-.03	.54**	.35*	.44*	.58**

Soil Chemical Properties

BA		MN.0	MN.1	MN.2	MN.3	MN.0123
1	MN	1	13	--	--	14
	n	5	5	--	--	5
	SD	1	12	--	--	12
	CI	0-2	-2-28	--	--	0-29
2	MN	0	3	-2	-4	1
	n	10	10	6	3	10
	SD	1	13	5	4	15
	CI	0-1	-7-12	-7-3	-14-7	-10-11
3	MN	0	9	-1	-1	9
	n	11	11	10	6	11
	SD	1	14	7	1	16
	CI	0-1	0-18	-6-4	-1-0	-3-20
4	MN	1	63	2	2	67
	n	2	10	10	7	10
	SD	2	57	11	19	57
	CI	-12-15	23-104	-6-9	-15-20	26-108
5	MN	--	49	9	5	63
	n	--	10	10	9	10
	SD	--	39	22	11	51
	CI	--	21-77	-7-24	-4-14	26-99
6	MN	--	1	13	--	12
	n	--	5	4	--	5
	SD	--	18	13	--	21
	CI	--	-21-23	-7-33	--	-15-38
1-6	MN	1	26	3	2	30
	n	28	51	40	25	51
	SD	1	40	14	12	45
	CI	0-1	15-37	-1-8	-3-7	17-43
	r	-.07	.28*	.35*	.25	.36*
2-5	MN	1	31	2	2	34
	n	23	41	36	25	41
	SD	1	43	14	12	49
	CI	0-1	17-44	-2-7	-3-7	19-49
	r	.20	.51**	.28	.25	.56**

Soil Chemical Properties

BA		CN.0	CN.1	CN.2	CN.3	CNHF	CN.123
1	MN	40	23	--	--	40	23
	n	5	5	--	--	5	5
	SD	7	4	--	--	7	4
	CI	32-49	17-28	--	--	32-49	17-28
2	MN	41	29	24	26	41	28
	n	10	10	6	4	10	10
	SD	5	5	4	6	5	5
	CI	38-44	25-32	20-28	17-36	38-44	25-32
3	MN	44	26	20	20	44	24
	n	11	11	11	11	11	11
	SD	7	3	4	4	7	4
	CI	40-48	24-28	17-23	17-23	40-48	21-26
4	MN	34	23	18	19	26	21
	n	2	10	10	10	10	10
	SD	5	5	3	4	7	4
	CI	-6-75	19-27	16-20	16-22	21-31	18-24
5	MN	--	20	17	18	20	18
	n	--	10	10	10	10	10
	SD	--	4	3	3	4	3
	CI	--	17-23	15-19	16-20	17-23	16-20
6	MN	--	21	25	18	21	22
	n	--	5	5	4	5	5
	SD	--	6	10	2	6	5
	CI	--	14-28	13-38	15-21	14-28	16-28
1-6	MN	42	24	20	20	33	23
	n	28	51	42	39	51	51
	SD	6	5	5	4	12	5
	CI	39-44	23-26	19-22	18-21	29-36	21-24
	r	.04	-.42**	-.10	-.45**	-.75**	-.44**
2-5	MN	42	25	20	20	33	23
	n	23	41	37	35	41	41
	SD	6	5	4	5	12	5
	CI	39-45	23-26	18-21	18-22	29-37	21-25
	r	-.07	-.61**	-.55**	-.45**	-.79**	-.68**

Soil Chemical Properties

BA		CA.0	CA.1	CA.2	CA.3	CA.0123
1	MN	143	115	--	--	258
	n	5	5	--	--	5
	SD	88	50	--	--	104
	CI	34-252	52-177	--	--	128-388
2	MN	282	268	55	77	607
	n	10	10	6	3	10
	SD	130	196	46	49	234
	CI	189-375	128-408	8-103	-44-198	439-774
3	MN	217	146	39	11	405
	n	11	11	10	6	11
	SD	116	125	26	9	149
	CI	140-295	63-230	20-58	2-20	305-505
4	MN	127	1073	264	656	1822
	n	2	10	10	7	10
	SD	2	1498	524	1211	3023
	CI	111-142	1-2145	-110-639	-464-1777	-340-3984
5	MN	--	1417	636	816	2787
	n	--	10	10	9	10
	SD	--	759	549	779	1279
	CI	--	874-1960	243-1029	217-1414	1872-3702
6	MN	--	5509	3408	--	8235
	n	--	5	4	--	5
	SD	--	3289	1270	--	4949
	CI	--	1425-9592	1387-5429	--	2090-14380
1-6	MN	221	1124	584	489	1943
	n	28	51	40	25	51
	SD	122	1945	1105	834	3030
	CI	174-268	577-1671	230-937	145-834	1090-2795
	r	-.01	.61**	.66**	.39	.62**
2-5	MN	238	712	270	489	1381
	n	23	41	36	25	41
	SD	123	970	458	834	1843
	CI	184-291	406-1018	115-425	145-834	799-1962
	r	-.38	.51**	.50**	.39	.49**

Soil Chemical Properties

BA		MG.0	MG.1	MG.2	MG.3	MG.0123
1	MN	16	17	--	--	33
	n	5	5	--	--	5
	SD	7	6	--	--	8
	CI	8-24	10-25	--	--	23-43
2	MN	25	34	14	12	70
	n	10	10	6	3	10
	SD	10	32	7	4	29
	CI	18-32	11-57	6-21	1-23	49-91
3	MN	27	25	12	4	65
	n	11	11	10	6	11
	SD	17	17	10	3	23
	CI	15-38	14-37	5-20	1-7	49-81
4	MN	18	93	17	30	135
	n	2	10	10	7	10
	SD	10	76	15	34	108
	CI	-68-105	39-148	6-28	-1-62	57-212
5	MN	--	146	65	84	287
	n	--	10	10	9	10
	SD	--	67	90	108	160
	CI	--	99-194	1-130	1-167	173-401
6	MN	--	319	171	--	455
	n	--	5	4	--	5
	SD	--	128	52	--	186
	CI	--	161-477	87-254	--	224-687
1-6	MN	23	92	43	41	158
	n	28	51	40	25	51
	SD	13	107	67	73	164
	CI	18-28	62-122	21-64	11-71	112-205
	r	.17	.73**	.59**	.43*	.72**
2-5	MN	25	73	29	41	138
	n	23	41	36	25	41
	SD	14	71	52	73	130
	CI	19-31	51-96	11-46	11-71	97-179
	r	-.05	.64**	.36*	.43*	.63**

Soil Chemical Properties

BA		K.0	K.1	K.2	K.3	K.0123
1	MN	18	35	--	--	53
	n	5	5	--	--	5
	SD	6	12	--	--	10
	CI	11-25	19-50	--	--	41-65
2	MN	39	61	35	24	128
	n	10	10	6	3	10
	SD	14	32	13	7	44
	CI	29-49	37-84	21-49	7-40	96-159
3	MN	37	57	41	10	137
	n	11	11	10	6	11
	SD	19	22	25	7	42
	CI	25-50	42-72	23-59	3-17	109-166
4	MN	25	86	40	48	164
	n	2	10	10	7	10
	SD	15	50	29	30	90
	CI	-110-159	50-122	19-61	20-75	99-229
5	MN	--	78	52	74	196
	n	--	10	10	9	10
	SD	--	27	38	69	99
	CI	--	59-97	24-79	21-127	125-267
6	MN	--	125	12	--	135
	n	--	5	4	--	5
	SD	--	141	6	--	146
	CI	--	-50-300	2-22	--	-46-315
1-6	MN	34	72	39	45	144
	n	28	51	40	25	51
	SD	16	55	29	50	85
	CI	27-40	57-87	30-49	25-66	120-167
	r	.21	.37**	-.04	.47*	.34*
2-5	MN	37	70	43	45	156
	n	23	41	36	25	41
	SD	16	35	29	50	75
	CI	30-44	59-81	33-52	25-66	132-179
	r	-.20	.26	.19	.47*	.35*

Soil Chemical Properties

BA		NA.0	NA.1	NA.2	NA.3	NA.0123
1	MN	1	7	--	--	8
	n	5	5	--	--	5
	SD	0	3	--	--	3
	CI	1-2	3-10	--	--	4-12
2	MN	2	8	7	4	15
	n	10	10	6	3	10
	SD	0	3	4	1	7
	CI	1-2	6-10	3-11	2-7	10-20
3	MN	2	11	9	2	22
	n	11	11	10	6	11
	SD	1	6	4	1	11
	CI	1-3	8-15	5-12	1-4	15-30
4	MN	2	17	11	16	39
	n	2	10	10	7	10
	SD	1	13	8	10	29
	CI	-8-12	8-26	6-17	7-25	18-60
5	MN	--	15	15	17	44
	n	--	10	10	9	10
	SD	--	9	11	13	23
	CI	--	8-21	7-22	7-27	28-61
6	MN	--	29	12	--	39
	n	--	5	4	--	5
	SD	--	18	5	--	16
	CI	--	7-51	3-21	--	19-59
1-6	MN	2	14	11	12	29
	n	28	51	40	25	51
	SD	1	11	8	11	22
	CI	1-2	11-17	8-13	7-16	23-35
	r	.23	.50**	.33*	.52**	.56**
2-5	MN	2	13	11	12	30
	n	23	41	36	25	41
	SD	1	9	8	11	22
	CI	1-2	10-15	8-13	7-16	23-37
	r	.12	.32*	.37*	.52**	.53**

Soil Chemical Properties

BA		CAT.0	CAT.1	CAT.2	CAT.3	CAT.0123
1	MN	179	174	--	--	352
	n	5	5	--	--	5
	SD	99	58	--	--	103
	CI	56-301	102-246	--	--	224-481
2	MN	348	370	111	116	819
	n	10	10	6	3	10
	SD	149	248	42	45	262
	CI	241-454	192-548	66-155	4-229	632-1007
3	MN	284	240	100	27	630
	n	11	11	10	6	11
	SD	149	151	44	18	182
	CI	183-384	139-342	69-132	9-45	508-752
4	MN	171	1268	332	750	2160
	n	2	10	10	7	10
	SD	27	1542	530	1252	3106
	CI	-75-417	165-2372	-47-712	-408-1908	-62-4382
5	MN	--	1656	767	990	3314
	n	--	10	10	9	10
	SD	--	830	663	953	1474
	CI	--	1062-2249	293-1242	258-1723	2260-4368
6	MN	--	5982	3602	--	8864
	n	--	5	4	--	5
	SD	--	3271	1240	--	4975
	CI	--	1921-10043	1629-5575	--	2687-15041
1-6	MN	280	1301	677	587	2273
	n	28	51	40	25	51
	SD	147	2047	1153	933	3174
	CI	223-337	726-1877	308-1046	202-972	1381-3166
	r	.03	.63**	.66**	.42*	.64**
2-5	MN	302	868	352	587	1704
	n	23	41	36	25	41
	SD	148	1037	513	933	1974
	CI	238-366	541-1195	178-526	202-972	1081-2327
	r	-.34	.53**	.50**	.42*	.52**

Soil Chemical Properties

BA		CEC.0	CEC.1	CEC.2	CEC.3	CEC.0123
1	MN	36	166	--	--	203
	n	5	5	--	--	5
	SD	8	73	--	--	67
	CI	26-46	76-257	--	--	119-286
2	MN	47	200	163	135	385
	n	10	10	6	3	10
	SD	18	79	99	17	207
	CI	34-60	143-256	59-268	93-176	237-533
3	MN	59	251	209	50	527
	n	11	11	10	6	11
	SD	31	117	124	32	258
	CI	38-80	173-329	121-298	17-84	354-701
4	MN	38	431	240	315	899
	n	2	10	10	7	10
	SD	25	212	141	165	493
	CI	-186-261	279-582	139-340	163-468	546-1252
5	MN	--	356	289	333	944
	n	--	10	10	9	10
	SD	--	200	172	292	437
	CI	--	212-499	166-412	109-558	632-1257
6	MN	--	585	323	--	843
	n	--	5	4	--	5
	SD	--	132	76	--	226
	CI	--	421-749	202-443	--	562-1124
1-6	MN	49	321	241	237	653
	n	28	51	40	25	51
	SD	24	192	138	225	418
	CI	40-58	267-375	197-285	144-329	536-771
	r	.22	.59**	.36*	.46*	.58**
2-5	MN	52	308	232	237	685
	n	23	41	36	25	41
	SD	26	179	141	225	426
	CI	41-63	251-364	184-280	144-329	551-820
	r	.05	.41**	.31	.46*	.54**

APPENDIX L - CANONICAL VARIABLES FOR SITE AND SOIL PROPERTIES

In this appendix, canonical variables (CNVR) 1, 2, and 3 are given for the four discriminant analyses (DA01, DA02, DA03, and DA04) of site and soil properties. Also shown is the biogeocoenotic association (BA) to which each plot belongs.

PLOT	BA	DA01 CNVR1	DA01 CNVR2	DA01 CNVR3	DA02 CNVR1	DA02 CNVR2	DA02 CNVR3
1.	3.	1.364	-0.274	0.131	2.266	0.408	-0.214
2.	5.	-3.364	2.940	-0.268	-1.568	-2.727	0.217
3.	3.	1.163	-1.187	-0.640	3.257	0.809	-0.814
4.	3.	1.731	-0.549	-0.574	3.525	-0.691	-2.085
5.	4.	-2.290	0.397	1.709	0.970	-0.769	0.293
6.	3.	0.545	-0.916	0.048	3.579	2.263	-1.397
7.	3.	2.349	-0.384	-0.392	3.199	1.277	-0.356
8.	3.	1.140	-0.313	-0.236	3.327	0.114	-0.722
9.	5.	-1.678	1.235	-0.179	-0.222	-2.440	-1.192
10.	4.	-0.808	1.757	0.230	1.050	-2.260	1.005
11.	2.	0.175	-1.353	-0.112	0.888	0.489	-1.002
12.	2.	1.363	0.161	1.002	1.011	2.871	2.572
13.	6.	1.334	0.607	0.605	-9.434	2.509	-0.142
14.	4.	-1.500	-0.334	1.350	0.964	-0.093	0.624
15.	5.	-2.965	-1.459	1.224	-0.080	-2.689	-0.459
16.	5.	-2.537	0.364	0.230	-2.677	-2.317	-1.086
17.	4.	-4.067	-0.829	0.136	-0.732	-3.297	1.061
18.	6.	1.638	0.977	0.796	-10.219	0.810	-0.791
19.	3.	0.724	-0.971	0.167	4.173	1.907	-2.193
20.	4.	-1.981	0.865	-0.370	-0.595	-3.415	-0.789
21.	4.	0.028	-2.462	-0.770	0.722	0.263	-0.509
22.	4.	-1.590	-0.189	-0.103	-0.385	-2.026	1.137
23.	3.	0.724	-2.323	-1.196	3.373	0.901	-1.828
24.	4.	-1.498	-0.642	-0.330	3.145	-3.891	3.119
25.	5.	-0.895	-0.872	0.357	0.348	-1.925	1.042
26.	4.	-1.922	-1.009	0.207	0.620	-0.701	0.525
27.	5.	-1.342	1.792	0.837	-3.390	-0.951	1.345
28.	3.	-0.268	-1.434	-0.466	2.162	-0.399	-0.096
29.	5.	-3.417	0.190	-0.997	-1.165	-2.464	-0.957
30.	5.	-5.781	2.145	-1.233	-1.606	-1.711	0.508
31.	6.	1.134	2.321	-1.720	-8.552	0.790	0.387
32.	2.	0.755	-0.934	0.186	2.016	0.642	0.543
33.	2.	1.536	0.318	0.818	3.618	2.097	-0.030
34.	2.	1.753	0.214	0.450	1.903	2.316	0.847
35.	1.	2.925	1.876	0.962	-0.680	1.497	1.837
36.	5.	-3.579	-0.880	-0.281	-1.289	-2.423	-2.749
37.	2.	0.972	-0.248	1.121	1.299	1.557	-0.093
38.	2.	-0.054	-1.947	-0.470	0.993	0.260	-0.326
39.	6.	2.494	1.887	-5.193	-7.224	1.618	0.249
40.	6.	1.638	0.977	0.796	-10.657	1.657	-1.520
41.	5.	-1.660	0.800	0.132	-1.870	-2.034	0.442
42.	3.	0.631	-0.798	0.175	2.703	0.167	-0.685
43.	3.	0.802	-0.562	0.429	2.931	1.357	-0.541
44.	2.	0.977	-1.045	-0.252	1.864	0.907	0.292
45.	4.	0.673	-1.415	-0.443	0.605	-0.260	-0.120
46.	2.	2.476	0.318	-0.325	-0.223	1.689	1.409
47.	1.	2.155	0.609	0.191	0.696	1.331	1.387
48.	2.	0.835	-1.600	-0.920	0.701	1.208	-0.889
49.	1.	2.011	0.924	1.264	0.833	0.371	0.972
50.	1.	2.501	1.714	1.127	1.671	2.361	0.194
51.	1.	2.652	1.543	0.790	0.962	3.038	1.576

		DA03			DA04		
PLOT	BA	CNVR1	CNVR2	CNVR3	CNVR1	CNVR2	CNVR3
1.	3.	1.150	0.238	-0.777	-0.774	1.033	-0.338
2.	5.	-0.362	1.565	-0.227	3.017	-1.774	-1.085
3.	3.	0.937	-1.147	-1.459	-0.399	1.866	0.546
4.	3.	1.582	-0.729	-1.654	-0.060	1.464	0.817
5.	4.	-0.945	1.363	0.416	-0.134	-1.000	1.788
6.	3.	1.415	-1.548	3.111	-2.975	2.658	-0.815
7.	3.	2.825	-1.596	-1.833	-1.424	1.586	1.224
8.	3.	0.518	0.674	-0.808	-1.691	1.137	-1.855
9.	5.	-0.584	1.462	-0.250	2.207	-1.878	-0.759
10.	4.	0.303	1.871	-0.159	2.093	-1.077	-0.017
11.	2.	-0.354	-0.161	-0.062	-2.069	0.234	-0.849
12.	2.	1.497	0.743	0.177	-4.228	-1.790	1.255
14.	4.	-0.929	1.042	0.723	2.997	1.330	2.504
15.	5.	-2.323	0.223	1.039	3.919	-0.446	0.905
16.	5.	-1.385	0.958	0.168	1.735	-1.296	-1.156
17.	4.	-2.608	-0.200	1.097	2.465	-1.424	-0.655
19.	3.	0.874	-0.737	0.501	-1.606	4.250	-1.312
20.	4.	-1.027	1.258	-0.295	3.008	-1.515	-1.342
21.	4.	-0.323	-2.021	-0.993	1.014	1.898	-2.080
22.	4.	-1.376	0.998	-0.049	1.462	-1.584	-0.749
23.	3.	0.460	-2.549	-2.190	-1.082	2.063	-0.166
24.	4.	-1.703	0.880	-0.176	1.280	-1.660	0.212
25.	5.	-1.403	1.099	-0.064	0.636	-1.471	0.785
26.	4.	-2.067	0.824	-0.101	0.098	-1.107	0.887
27.	5.	0.161	1.917	-0.062	3.412	-1.011	0.332
28.	3.	-0.367	-0.879	-1.415	0.403	0.964	-0.669
29.	5.	-2.357	0.645	-0.430	2.949	-1.503	0.021
30.	5.	-2.357	0.645	-0.430	2.755	-0.674	-0.309
32.	2.	0.461	-0.126	-0.640	-3.570	-0.584	1.275
33.	2.	1.718	0.697	0.305	-2.957	1.850	1.510
34.	2.	1.956	0.245	-0.172	-2.591	0.879	1.217
36.	5.	-2.953	0.415	-0.191	2.835	-1.866	0.108
37.	2.	1.957	-0.598	2.472	-3.033	0.619	-0.576
38.	2.	0.301	-2.091	1.888	-0.866	-0.551	0.384
41.	5.	-0.497	1.029	0.553	2.308	-1.271	-0.037
42.	3.	0.525	-0.130	0.540	-1.979	0.683	-0.948
43.	3.	0.669	0.224	0.209	-1.802	2.020	-0.155
44.	2.	1.202	-1.265	0.169	-2.350	-0.040	0.114
45.	4.	0.667	-1.351	-0.105	0.052	0.115	-0.604
46.	2.	3.638	-1.629	1.016	-2.776	-1.284	0.530
48.	2.	1.106	-2.255	0.160	-2.278	0.157	0.066

APPENDIX M - DESCRIPTIVE STATISTICS FOR MENSURATION VARIABLES

In this appendix, means (MN), sample sizes (n), standard deviations (SD), and 95% confidence intervals (CI) are given for eight mensuration variables. Data is stratified according to biogeocoenotic association (BA). Correlation coefficients (r) for linear relationship between the mensuration variables and the BA codes are also given.

In the following tables, the codes used to indicate the mensuration variables are defined as follows:

SI - site index of Douglas-fir (m/100 yrs)
GC - growth class of Douglas-fir
VOLUME - gross volume (m^3/ha)
STEMS - number of stems (stems/ha)
AGE - stand age (years)
MAI - mean annual increment (m^3/ha/yr)
DBH - diameter breast height (cm)
BA - basal area (m^2/ha)

Mensuration Variables

BA		SI	GC	VOLUME	STEMS
1	MN	--	--	266	1724
	n	--	--	5	5
	SD	--	--	123	1910
	CI	--	--	113-419	-648-4095
2	MN	29	6	247	1271
	n	10	10	10	10
	SD	5	1	60	534
	CI	26-32	6-7	204-290	889-1652
3	MN	44	4	591	996
	n	11	11	11	11
	SD	4	1	136	560
	CI	41-46	3-4	500-683	620-1372
4	MN	54	2	878	556
	n	10	10	10	10
	SD	5	1	142	229
	CI	50-58	1-3	776-980	393-720
5	MN	55	2	964	484
	n	10	10	10	10
	SD	4	1	301	146
	CI	52-58	1-2	748-1179	379-588
6	MN	--	--	279	580
	n	--	--	5	5
	SD	--	--	137	234
	CI	--	--	109-449	289-870
1-6	MN	--	--	591	894
	n	--	--	51	51
	SD	--	--	339	768
	CI	--	--	495-686	678-1110
	r	--	--	.48**	-.49**
2-5	MN	45	3	668	831
	n	41	41	41	41
	SD	11	2	330	514
	CI	42-49	3-4	564-772	669-993
	r	.88**	-.88**	.83**	-.61**

Mensuration Variables

BA		AGE	MAI	DBH	BA
1	MN	69	4	22	52
	n	5	5	5	5
	SD	5	2	5	32
	CI	62-76	1-6	16-29	13-91
2	MN	60	4	21	40
	n	10	10	10	10
	SD	8	1	4	8
	CI	54-66	4-5	18-24	34-45
3	MN	62	10	30	60
	n	11	11	11	11
	SD	13	3	6	11
	CI	54-71	8-12	26-34	52-67
4	MN	65	14	42	70
	n	10	10	10	10
	SD	9	3	8	13
	CI	58-71	12-16	36-48	61-79
5	MN	68	14	45	73
	n	10	10	10	10
	SD	12	3	8	15
	CI	60-76	12-16	39-51	63-84
6	MN	55	5	29	36
	n	5	5	5	5
	SD	10	2	5	9
	CI	43-67	2-8	23-35	25-47
1-6	MN	63	9	33	57
	n	51	51	51	51
	SD	11	5	11	20
	CI	60-66	8-11	29-36	52-63
	r	-.05	.49**	.60**	.24
2-5	MN	64	10	34	61
	n	41	41	41	41
	SD	11	5	12	17
	CI	60-67	9-12	31-38	55-66
	r	.29	.79**	.81**	.72**

APPENDIX N - DESCRIPTIVE STATISTICS FOR INDICES OF SOIL N STATUS

In this appendix, means (MN), sample sizes (n), standard deviations (SD), and 95% confidence intervals (CI) are given for sixteen indices of soil N status. Data is stratified according to growth class (GC) of Douglas-fir (Pseudotsuga menziesii). Correlation coefficients (r) for linear relationship between the indices of soil N status and GC are also given.

In the following tables, the codes used to indicate the indices of soil N status are defined as follows:

TN - total N ($kg \bullet ha^{-1}$)
MN - mineralizable N ($kg \bullet ha^{-1}$)
CN - C:N ratio

In the following tables, the soil layer codes indicate the following:

layer 0 = the ectorganic layer
layer 1 = the upper mineral layer (0-30 cm)
layer 2 = the middle mineral layer (30-60 cm)
layer 3 = the lower mineral layer (60-90 cm)
layer 123 = the mineral soil (weighted to rooting depth)

N.B. HF refers to the humus form

Indices of Soil N Status

GC		TN.0	TN.1	TN.2	TN.3	TN.123
1	MN	--	2333	1725	2067	6125
	n	0	5	5	5	5
	SD	--	1589	1215	1050	2226
	CI	--	359-4306	217-3234	763-3370	3361-8888
2	MN	--	2449	1074	1324	4406
	n	0	12	12	8	12
	SD	--	1114	617	1102	2325
	CI	--	1741-3157	682-1466	403-2246	2928-5883
3	MN	551	1933	1248	659	3412
	n	5	6	5	4	6
	SD	246	1638	682	633	2675
	CI	246-856	215-3652	401-2095	-348-1666	605-6219
4	MN	359	1049	686	208	1874
	n	6	6	6	4	6
	SD	208	422	367	101	769
	CI	141-578	606-1492	301-1071	48-368	1067-2681
5	MN	329	689	431	106	1038
	n	4	4	3	1	4
	SD	133	151	327	--	514
	CI	117-541	448-930	-382-1243	--	219-1857
6	MN	412	1266	1008	890	2718
	n	4	4	4	2	4
	SD	176	441	808	211	1730
	CI	132-692	564-1967	-279-2294	-1003-2783	-35-5471
7	MN	490	962	739	662	1313
	n	4	4	1	1	4
	SD	152	412	--	--	408
	CI	248-731	307-1618	--	--	664-1961
1-7	MN	428	1722	1054	1078	3304
	n	23	41	36	25	41
	SD	195	1202	743	1010	2412
	CI	343-512	1343-2102	802-1305	661-1495	2543-4066
	r	-.06	-.49**	-.33*	-.49*	-.58**

Indices of Soil N Status

GC		MN.0	MN.1	MN.2	MN.3	MN.123
1	MN	--	101	9	1	112
	n	0	5	5	5	5
	SD	--	60	32	14	59
	CI	--	26-176	-30-49	-17-19	38-186
2	MN	--	41	3	6	47
	n	0	12	12	8	12
	SD	--	30	10	18	41
	CI	--	22-59	-4-9	-9-21	21-74
3	MN	1	30	6	2	36
	n	5	6	5	4	6
	SD	1	39	11	3	41
	CI	0-2	-12-71	-8-21	-2-6	-7-79
4	MN	1	10	-2	-1	7
	n	6	6	6	4	6
	SD	1	15	5	1	12
	CI	0-1	-6-26	-8-3	-2-0	-6-20
5	MN	0	4	-1	-1	4
	n	4	4	3	1	4
	SD	0	16	1	--	15
	CI	0-0	-21-29	-3-2	--	-20-28
6	MN	1	-3	0	-2	-3
	n	4	4	4	2	4
	SD	0	12	2	3	12
	CI	0-1	-22-17	-4-4	-30-27	-23-16
7	MN	1	4	-12	-8	-1
	n	4	4	1	1	4
	SD	1	11	--	--	16
	CI	-1-2	-13-21	--	--	-26-25
1-7	MN	1	31	2	2	34
	n	23	41	36	25	41
	SD	1	43	14	12	49
	CI	0-1	17-44	-2-7	-3-7	18-49
	r	-.18	-.61**	-.25	-.21	-.63**

Indices of Soil N Status

GC		CN.0	CN.1	CN.2	CN.3	CNHF	CN.123
1	MN	--	22	17	19	22	20
	n	0	5	5	5	5	5
	SD	--	3	2	4	3	2
	CI	--	18-26	15-20	15-23	18-26	17-22
2	MN	--	22	18	18	22	20
	n	0	12	12	12	12	12
	SD	--	6	3	4	6	5
	CI	--	18-26	16-20	16-21	18-26	17-23
3	MN	40	25	19	19	36	23
	n	5	6	6	6	6	6
	SD	4	5	3	2	10	5
	CI	34-45	19-30	17-22	17-21	26-47	18-28
4	MN	44	24	21	21	44	23
	n	6	6	6	6	6	6
	SD	10	3	6	6	10	4
	CI	34-54	21-27	15-27	15-28	34-54	18-27
5	MN	44	28	21	19	44	25
	n	4	4	3	2	4	4
	SD	4	1	4	4	4	3
	CI	37-51	26-29	11-30	-13-51	37-51	21-30
6	MN	38	27	22	26	38	26
	n	4	4	4	3	4	4
	SD	1	4	3	7	1	3
	CI	36-40	21-33	18-27	8-44	36-40	21-30
7	MN	42	31	31	27	42	31
	n	4	4	1	1	4	4
	SD	5	7	--	--	5	6
	CI	34-50	20-42	--	--	33-51	21-41
1-7	MN	42	25	20	20	33	23
	n	23	41	37	35	41	41
	SD	6	5	4	5	12	5
	CI	39-45	23-26	18-21	18-22	29-37	21-25
	r	-.05	.51**	.53**	.46**	.69**	.62**

APPENDIX O - DESCRIPTIVE STATISTICS FOR INDICES OF SOIL CA STATUS

In this appendix, means (MN), sample sizes (n), standard deviations (SD), and 95% confidence intervals (CI) are given for five indices of soil Ca status. Data is stratified according to growth class (GC) of Douglas-fir (Pseudotsuga menziesii). Correlation coefficients (r) for linear relationship between the indices of soil Ca status and GC are also given.

In the following table, the code used to indicate the index of soil Ca status is defined as follows:

CA - exchangeable Ca ($kg \bullet ha^{-1}$)

In the following table, the soil layer codes indicate the following:

layer 0 = the ectorganic layer
layer 1 = the upper mineral layer (0-30 cm)
layer 2 = the middle mineral layer (30-60 cm)
layer 3 = the lower mineral layer (60-90 cm)
layer 123 = the mineral soil (weighted to rooting depth)

Indices of Soil Ca Status

GC		CA.0	CA.1	CA.2	CA.3	CA.123
1	MN	--	1149	631	1168	2948
	n	0	5	5	5	5
	SD	--	570	781	835	1356
	CI	--	442-1856	-339-1601	130-2205	1264-4631
2	MN	--	1329	387	693	2178
	n	0	12	12	8	12
	SD	--	1351	501	1131	2725
	CI	--	470-2187	69-705	-253-1639	446-3909
3	MN	228	566	209	131	827
	n	5	6	5	4	6
	SD	118	1083	403	248	1656
	CI	82-374	-571-1702	-292-710	-264-526	-911-2566
4	MN	189	189	70	23	275
	n	6	6	6	4	6
	SD	121	179	97	17	281
	CI	62-316	2-377	-31-171	-4-50	-20-570
5	MN	240	189	88	2	256
	n	4	4	3	1	4
	SD	149	72	59	--	98
	CI	2-477	74-304	-59-234	--	99-412
6	MN	253	181	39	96	268
	n	4	4	4	2	4
	SD	110	137	13	50	181
	CI	78-427	-36-399	19-59	-356-548	-20-556
7	MN	306	373	31	38	390
	n	4	4	1	1	4
	SD	151	265	--	--	242
	CI	66-546	-49-795	--	--	5-776
1-7	MN	238	712	270	489	1247
	n	23	41	36	25	41
	SD	123	970	458	834	1909
	CI	184-291	406-1018	115-425	145-834	645-1850
	r	.26	-.42**	-.41*	-.45*	-.46**