INITIAL DATA SYNTHESIS IN THE

SYNECOLOGICAL CLASSIFICATION

Part 1.

Introduction to the Synecological Classification of Lower Synsystematic Units

by

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INTRODUCTION

General acceptance of an ecosystem approach to forest land management, namely to intensive silvicultrual practices and resource planning, necessitates consolidation and clarification of synecological classification and subsequent interpretations and mapping. This paper introduces the synecological classification developed by Krajina and his students and describes the initial synthesis of environment - vegetation data. An outline of the synecological classification and the classification of lower synsystematic units (particularly plant associations) by tabulation technique using a computer program are emphasized.

A BRIEF OUTLINE OF THE SYNECOLOGICAL CLASSIFICATION

The synecological classification is a natural taxonomic classification of ecosystems (biogeocoenoses) which organizes our knowledge about ecosystems. Specifically, it organizes, names and defines the classes* (or units) used to identify ecosystems for management and research purposes. Furthermore, the classification organizes research data to reveal ecological relationships and formulates useful generalizations about specific cases that may not yet have been directly studied. It also provides a comprehensive framework for predicting the response of ecosystems to different management practices; therefore, it is potentially a most useful tool of forest land managers. Classificatory work is a systematic research tool that can be used for the acquisition of knowledge about vegetation - environment relationships and about factors controlling the development and distribution of ecosystems.

Ecosystems are very complex systems. Because it is designed to reveal relationships among ecosystems and their components, the synecological classification is unavoidably complex.

A few noteworthy features of the synecological classification require mention. Firstly, the classification aims at comprehensive

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* The term class, as used in classification, refers to a group of individuals possessing similar selected properties which distinguish the group from all other classes of the same population.

ecosystem synthesis (a synthesis of many environment - vegetation data) at the very beginning as discussed by Mueller-Dombois and Ellenberg (1974). It is not, as sometimes erroneously supposed, a kind of vegetation classification. Secondly (in accordance with Sukachev and Dylis, 1964), the classification should ultimately be based on functional aspects of ecosystems such as the nature of biogeochemical cycling and energy exchange. Because of the inadequacy of existing data, it is presently necessary to use a number of indirect parameters that are likely to be connected with functional aspects. Lastly, the synecological classification has not been completed. This is true in respect to the categories of the system and to the classes in the categories. In other words, some relevés can be directly related to existing classes and abstracted further in their respective categories (i.e., designation by the names of units which already have been described) while other relevés are used to recognize, name and describe new classes (i.e., the study of newly identified ecosystems). It may be possible, during the abstraction process, to add new classes, new categorical levels or new integration levels to the classification system. However, an understanding of the structure of the system and differentiating characteristics for each integrational and categorical level is required. The classification is expected to evolve as continuing synecological studies improve our understanding of ecosystems.

In general, synecological studies proceed in the following stages:

1/ Data analysis (sampling and evaluation of field and laboratory data).

2/ Data synthesis, including classification, verification of the classification, interpretations and, eventually, mapping (currently mapping is mostly at the biogeoclimatic subzone and variant levels).

In general, the following procedures are applied:

1/ Comparative analysis of observations and measured properties of forest ecosystems.

2/ Successive approximation; i.e., induction followed by deduction in the abstraction of classes, which are developed by stratification of both floristic and habitat variables.

The term "ecosystem" is well understood as a functional entity, including both organisms and their environment - each influencing the other. However, for classification purposes, this interpretation is too broad and the term lacks a definitative level. Such broad concepts may lead to inconsistencies when defining an ecosystem as the object of study or for practical applications. There is a need for a clearly defined and recognizable concept of ecosystem because different concepts would lead to different classifications. Since the forest ecosystem, in addition to other components, includes both vegetation and soil, it follows that the concept of an ecosystem individual must accomodate requirements laid out for both the polypedon and the plant community. A biogeocoenosis (Sukachev, 1944) is considered to be a concrete expression of an ecosystem individual. It represents a certain soil (polypedon) which is manifested by a certain plant community (Table 1).

A biogeocoenosis consists of one or many contiguous sample plots bordered by other sample plots which differ in repsect to one or more diagnostic features for the ecosystem type (type of biogeocoenosis). The principles involved imply that biogeocoenoses can be recognized on the ground. Their lateral boundaries, sometimes distinct (when gradients are lacking), or gradationally connected with the neighboring ones, can be recognized more or less precisely in the field using their plant communities, polypedons or both.

Methods employed in the synecological classification have been recently described by Brooke et al. (1970), Kojima and Krajina (1975), Klinka (1976) and Annas (1977). In essence, vegetation data are collected using the phytosociological techniques of the Zürich-Montpellier School as adapted by Krajina (1933, et seq.) and corresponding habitats are described using selected external and internal soil properties and other habitat features as suggested by Krajina et al. (1963). A complete releve (list of plant species and habitat features recorded from a sample plot) is the basic unit of reference for later synthesis.

According to the above interpretation of the ecosystem for class-

TABLE 1

Relationships Between Sampling Units, Natural Bodies and Basic Taxa in the Soil, Vegetation and Synecological Classification

Fundamental Units	Soil Classification	Vegetation Classification	Synecological Classification
Basic taxon in the classification system	SOIL SERIES	PLANT ASSOCIATION	ECOSYSTEM TYPE (type of biogeocoenosis)
Natural body (individual)	POLYPEDON	PLANT COMMUNITY	BIOGEOCOENOSIS (basic ecosystem)
Sampling unit (minimal size of an individual)	PEDON	SAMPLE PLOT (association individual)	SAMPLE PLOT (including pedons)

ification purposes, the sample plot is considered to be the smallest size of an ecosystem (biogeocoenosis). Sample plots are subjectively selected in the field within the area of an ecosystem so that each plot represents a modal ecosystem individual. Other criteria are governed by the purpose of the study. Because the plant associations, if possible, are referred to the climatic or edaphic climax stages of development (i.e., final or near final developmental or successional stages), initial classification studies attempt to establish sample plots in well developed, mature stands where tree species regenerate beneath their own canopy. Such stands are usually old growth stands or younger stands (approximately one hundred years old) with little apparent recent disturbance. Next, the formidable task of sampling all vegetation and soil variations in the study area (considering requirements for a satisfactory number of replicas) is undertaken. Subsequent studies can be conducted in distrubed stands in order to describe ecosystem dynamics. The recognized units (ecosystem variants or stand types) are referred to as variations of the previously defined "benchmark" plant associations.

Five synecological and two population integration levels of the classification system were outlined by Krajina (1977). The functional (edatopic), treatment and population integration levels are not directly linked into the structure of the classification system. The biogeoclimatic along with higher and lower synsystematic (biogeocoenotic) units represent closely related integration levels. The categories and differentiating characteristics of these levels are presented in Table 2. Presently, efforts are concentrated on completion of classification and mapping of biogeoclimatic subzones (and eventually variants) using either an inductive approach or a deductive approach. The inductive approach, which is necessary for application for management purposes, requires the classification of lower synsystematic units through sampling. The deductive approach involves the tentative subdivision of zones on the basis of reconnaissance survey.

TABLE 2

The Structure and Criteria for Defining Categories and Taxa for Various Integration Levels

Integration Level	Category	Criteria for Defining Categories and Taxa
Biogeoclimatic units	Formation Region Zone Subzone Variant	The total effect of a macroclimate on ecosystems as expressed by the presence of mesic ecosystems (their vegetation and soils); climatic parameters; prevailing pedogenic processes; characteristic combination of zonal or subzonal species; pattern of synsystematic units such as orders, alliances and plant associations
Higher synsystematic units	Class Order Alliance	Progressively higher abstraction above the level of the plant association (according to vegetation and soil relationships); characteristic combination of species; soil properties associated with moisture and nutrient regimes; effect of vegetation on soil development.
Lower synsystematic (biogeocoenotic) units	Plant association	The central unit in the classification system; uniformity of the floristic structure and composition in relation to habitat and vegetation development; characteristic combination of species; soil properties important for a special type of vigor of plants.
	Ecosystem type	Plant association associated with homogeneous soils according to texture, humus form, soil subgroup (kind and arrangement of horizons, physical and chemical properties), and parent materials.
	Ecosystem variant (stand type)	Variations in plant association or ecosystem type (syngenetic or derivative units) referring to their various successional changes. The ecosystem variant represents an ecosystem type associated with homogeneous vegetation (forest stand) cover (i.e., uniformity of the tree species composition, age, stocking, etc.).

THE CLASSIFICATION OF LOWER SYNSYSTEMATIC UNITS

Following ecosystem analysis (including both field and laboratory data), the next step is synthesis (i.e., grouping and averaging of similar plots). According to the Zürich-Montpellier School, the plant association has sets of both analytical and synthetic characteristics. Therefore, the plant association corresponds to a type (Cajander 1926 and 1949; Sukachev and Dylis, 1964). The plant association (as well as any other ecosystematic unit) cannot be described in this sense from a single plot, but only through the synthesis of data from several to many plots.

Before discussing the abstraction of plant associations, (i.e., the classification process) it is necessary to clarify the concept and to provide characterization for the plant association and derived lower synsystematic units (e.g., ecosystem type and ecosystem variant).

Plant Association

Following a resolution of the International Botanical Congress in 1910, it was agreed to apply the term "association" only to communities of definite floristic composition and uniform physiognomy occurring in uniform habitats. However, the requirement of habitat uniformity was found difficult to follow, particularly without simultaneous sampling of environmental features. The association was understood as a category of vegetation classification. It could be defined as a vegetation type derived from a number of relevés having a certain number of their total species in common. Therefore, only certain groups of species, namely those that recur over a wide area, could be emphasized. Only those plant communities showing the same group of certain species were included in a plant association. The concept of the plant association (sensü Braun-Blanquet) evolved a dependence on the concept of character species (i.e., species unique to a plant association) (Table 3)*.

A plant community was recognized in the field as a member of a plant association by the presence of a diagnostic group of character species. Recently the concept of plant association has been narrowed to provide for a more adequate description of climatic and edaphic variations. This has resulted in a reduction of the number of character species. Consequently, many plant associations have no character species of their own. They are differentiated by the alliance character species

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* i.e., each plant association was required to possess its own (or preferably its own) character species which differentiated one particular unit from another.

Table 3 Character (Fidelity) Classes (Braun-Blanquet, 1932)*

Name	Class	Description
Character Species	V	Exclusive species. Species exclusively or almost exclusively confined to a certain plant association.
	IV	Selective species. Species found most frequently in a particular unit but infrequently in other units.
	III	Preferential species. Species present in several units but with their optimum occurrence definitely in one particular unit.
Companions	II	Species lacking pronounced affinity to any particular unit.
Strangers	I	Species from other plant communities (accidentals).

in combination with differential species*. Therefore, the requirement for character species is not mandatory anymore.

As the scope and scale of phytosociological studies expanded, difficulties arose in providing each plant association with well defined character species. This problem has been recently discussed by Shimwell (1972, p. 208-215) and Mueller-Dombois and Ellenberg (1974, p. 205-209) who indicate that ecologically valid similarities and differences between plant communities can be established only within restricted geographic areas (e.g., biogeoclimatic subzones, etc.).

In developing the system of synecological classification Krajina (1960) proposed the following definition for a plant association:

> A plant association is a definite uniform phytocoenosis that is in dynamic equilibrium with a certain complex of environmental factors (ecotope or habitat); its floristic structure (i.e., layering), species significance and other floristic features lie within limits governed not only by climate, soil, relief and biotic environmental factors, but also by the historical factors of the vegetational development.

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* Mutually exclusive, recurring groups of species of intermediate constancy which have been found to be useful for distinguishing groups of relevés are designated differentiating or, preferably, differential species.

According to the definition, the plant association can be interpreted as an abstraction of ecosystems (biogeocoenoses) whose plant communities are uniform in their floristic composition and structure as determined by their analytic and synthetic characteristics. However, the ecosystems within a plant association may differ in their ecotopes (habitats). Variability is permitted for a number of soil properties providing that the total climatic and edaphic (moisture and nutrient) effect upon vegetation is similar.

The plant association sensu Krajina is environmentally a more homogeneous unit than that of Braun-Blanquet. It is an important category in the synecological classification. It is not entirely dependent upon character species which do not occur anywhere else but in the plant communities of a particular plant association. Such species occassionally do not exist, but their absence is no way detracts from the validity of the associations determined by other means. This is the major reason that some plant associations sensu Braun-Blanquet are relatively more general than those of Krajina; i.e., there is an obligation, arising from the character species concept (fidelity), to group together plant communities which are ecotopically considerably heterogeneous. In essence, ecologically well distinguished and recognizable plant communities that have marked and measurable floristic and environmental properties form the conceptual basis of the plant association.

Characteristic combination of species (Braun-Blanquet, 1932; and Krajina, 1933) (the term used instead of character species) determined in the abstraction of a plant association is employed as a differentiating characteristic. The combination of ecologically related species which function within narrow environmental limits helps to assess the degree of similarities and differences between units. Other floristic features, such as layering, species significance and vigor, are used to set apart closely related plant associations (particularly when a characteristic combination of species is lacking). The species included in a characteristic combination of species are usually very precise indicators. According to Major (1969), they are more precise indicators for management purposes than figures describing a number of climatic and soil measurements.

Because the concept of plant association sensu Krajina does not rely on the possession of preferential or even exclusive character species, related plant associations may be differentiated by the presence as well as the absence of a characteristic combination of species. Furthermore, the same species, occurring with either a similar or different species significance, may be included in more than one characteristic combination of species.

When it is not possible to provide a well defined characteristic combination of species, plant associations are differentiated on the basis of salient habitat features. In such cases, the species with the highest constancy and species significance (though non-characteristic) are used to name plant associations. Such species might have been employed as a characteristic combination of species if they were not present with a high species significance in other plant associations. However, they may be used as a characteristic combination of species for higher synsystematic units (e.g., plant alliance or plant order) or biogeoclimatic units.

Deviation in the concept of plant association from the original Zürich-Montpellier School is justified on the grounds that the original phytocoenotic approach was changed to an ecosystematic approach (Krajina, 1977). However, it is our belief that the concept of character species (fidelity concept) may be helpful in distinguishing different plant associations though such helpful species are not always present.

Plant associations and higher synsystematic units are named in accordance with the Zürich-Montpellier School to indicate synsystematic rank (Drees, 1953; Moravec, 1964; and Neuhausl, 1968). The different ranks are designated by a particular suffix added to the root of the Latin genus name of an especially characteristic and dominant species (Table 4).

Table 4 Nomenclature of Synsystematic Units

Rank	Suffix	Nomenclature* (Full Latin Names)
Order	-etalia	Pseudotsugetalia menziesii
Alliance	-ion	Gaultherio (shallonis) - Pseudotsugion menziesii
Association	-etum	Stokesiello (oreganae) - Hylocomio (splendentis) - Gaultherio (shallonis) - Pseudotsugetum menziesii

* A simplified nomenclature or its abbreviations consisting of either Latin or common names can be used to facilitate communication at the operational level**. A decision should be made concerning the use of abbreviations for the common tree species names; i.e., whether to use the B. C. Forest Service (1974) or the Canada Land Inventory (1970) abbreviations.

Rank	Abbreviated Latin Names	Common Names**
Order	*PM*	FIR
Alliance	*GAULTHERIA (SH.) - PM*	SALAL - FIR
Association	*Gaultheria (sh.) - PM*	Salal - F

The abstraction of plant associations should conform to the following standards:

1/ The validity of each plant association should be supported by its analytic and synthetic values in a published form; i.e., the complete environment - vegetation table and the table showing the characteristic combination of species for the plant association [or, if lacking for the plant association, then for the immediately higher units (e.g., plant alliance)].

2/ The name of the author. The name of the first author to name the plant association without a valid description should be noted in brackets, followed by the name of the first author to publish valid tables.

Plant association names are usually formed from the generic name of a tree species preceded by a few characteristic or dominant species from the moss (including lichen, liverwort and moss species), herb and shrub layers in order from left to right (Table 4). The nomenclature for the ecosystem type and ecosystem variant includes, in addition to the plant association name, selected environment and vegetation features as explained in the following sections.

Ecosystem Type

The plant associations are further subdivided into ecosystem types. The ecosystem type (type of biogeocoenosis) as defined by Sukachev (1960) implies uniformity of all components [climate, soil (edatope), vegetation (phytocoenose), animal population (zoocoenose) and micro-organisms (microbiocoenose)]. This categorical level reflects the fact that certain plant associations, similar in their floristic structure as determined by their analytic and synthetic characteristics, may differ in their habitats (ecotopes); i.e., mainly in external and internal soil properties and climate. Consequently, different soils may be found which have developed a similar vegetation (i.e., they support similar plant communities) providing that their total climatic and edaphic (moisture and nutrient) affect is similar. This is a result of both the species-poor flora of British Columbia and of compensating effects of environmental factors on vegetation.

For example there are six different soils occurring with plant communities abstracted into the *Gaultheria (sh.) - PM* plant association in the Coastal western hemlock drier subzone (CWHa)(Table 5). These soils have some common features, such as their moisture and nutrient regimes, as well as some different features such as their topographic position, humus form, texutre, content of coarse fragments, depth, number and arrangement of horizons and parent materials.

TABLE 5

Plant Association and Its Associated Soils

Plant Association	Forest Ecosystem Types	Soil Units (Polypedons)
GAULTHERIA (SH.) – PM [1]	*Gaultheria (sh.) – TH – PM*	1. on loamy sand Lithic Mini Humo-Ferric Podzol with moder humus, developed on morain veneer over quartzdiorited bedrock
		2. on sandy loam Lithic Podzol with F-mor humus, developed on moraine venner over quartzdiorite bedrock
		3. on Lithic Folisol with F-mor humus, developed from organic veneer over quartzdiorite bedrock
		4. on sandy loam Mini Humo-Ferric Podzol with F-mor humus, developed on moraine blanket over quartzdiorite bedrock
		5. on sandy loam Mini Humo-Ferric Podzol with moder humus, developed on glaciofluvial deposits
	Gaultheria (sh.) – Mahonia (nerv.) – TP – PM	6. on loamy sand Mini and Orthic Humo-Ferric Podzols with F-mor humus, developed on colluvial veneer over quartzdiorite bedrock

Therefore, these soils qualify to be separated at the series level. It is suggested that the typified soil component of the ecosystem type (within the limits of its plant association) corresponds to a soil series. However, it appears that a more general grouping of the soils, equivalent to the soil family level, is more appropriate. The differentiating criteria for families of mineral soils are (C.S.S.C., 1976): texture (particle size), mineralogy, reaction (pH), depth and pedoclimate. Values for the parameters are determined from soil analysis. Pedoclimate is adequately accomodated by relating the soils to a biogeoclimatic subzone and, within a subzone, to a soil moisture regime [an aspect of the functional (edatopic) synecological integration level].

Most of the classification work has not yet advanced to the stage of classifying ecosystem types. As a result, numerous taxa are not defined. In the current initial stages of defining ecosystem types, the following soil features are recommended criteria: texture (particle size), soil subgroup (and modifier), humus form, parent material and, if applicable, bedrock geology (to indicate the mineralogy of the parent material) (Table 5).

When defining the ecosystem types it is sometimes possible to further subdivide the vegetation component (i.e., of the plant association) into floristically based subunits, subassociations or variants, derived through standard phytosociological procedures. However, these subunits, in keeping with the foregoing discussion, are termed ecosystem types. The ecosystem type is named by the abbreviated Latin name of the vegetation component (the plant association or its lower unit) and the descriptive name of the soil component (Table 5) with a provision for numerical coding.

Ecosystem Variant (Stand Type)

The ecosystem type is distinguished by the uniformity of its ecotyope (habitat) (i.e., microclimate, relief, parent materials and, to a certain degree, soils) and successional trends. However, the present vegetation cover, particularly the forest cover of an individual biogeocoenosis, may still be very heterogeneous. Differences in the forest cover may affect, in varying degrees, the composition and structure of the understory vegetation and some soil properties, principally those of the humus layers. Considering only two key variables of the tree layers - tree species composition and age a great variability of the forest cover, reflecting differences in both structure and function, is apparent within the limits of the plant association or ecosystem type (Figure 1).

To account for this variability, the ecosystem types can be subdivided into ecosystem variants (or stand types). The ecosystem variants [syngenetic units (Braun-Blanquet, 1932), derivative biogeocoenoses (Sukachev and Dylis, 1964)] refer to various successional stages of plant communities and their habitats that can be ecologically defined. Ecosystem variants related to a certain ecosystem type or to a plant association do not constitute identical biogeocoenoses despite the similarity of their soil and floristic characteristics. However, they are similar in the process of their restoration to a certain vegetation composition through succession*.

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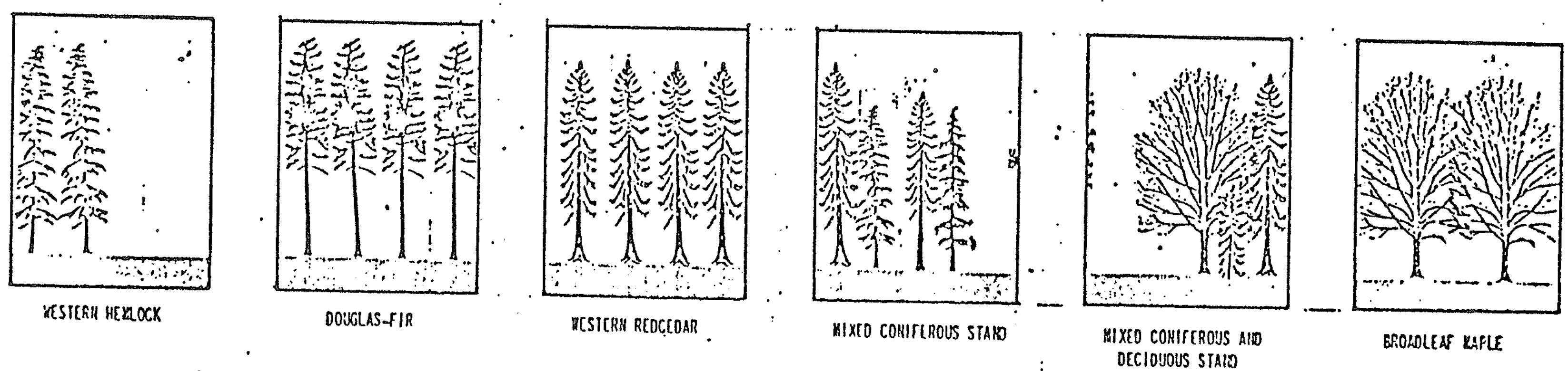
* It should be noted, however, that the reoccurrence of identical ecosystems following various disturbances,

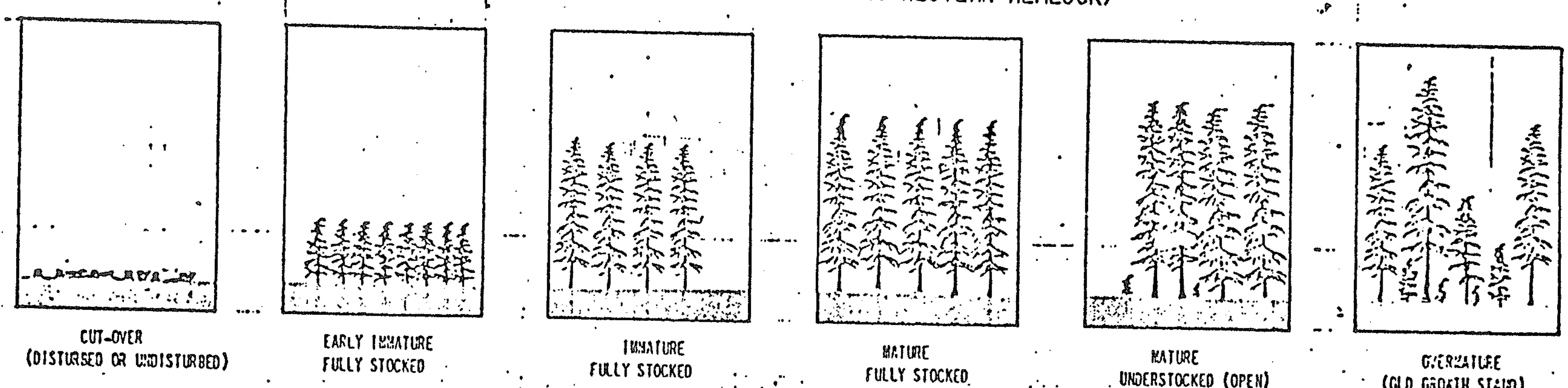
Figure 1 Variations of the forest cover within the limits of the ecosystem type

Ecosystem type: CWHa, Moss - western hemlock on sandy loam Orthic Humo-Ferric Podzol with H-mor humus, developed on moraine deposits

VARIATIONS IN THE COMPOSITION OF TREE LAYERS (FULLY STOCKED, SECOND GROWTH STANDS, 80 YEARS OLD)



AGE VARIATIONS OF THE FOREST COVER (THE TREE SPECIES COMPOSITION: WESTERN HEMLOCK)



The ecosystem variant is considered the lowest category among the lower synsystematic (biogeocoenotic) units. Very little classification work has been carried out at this level so that numerous taxa are not ecologically described and their significance for management is not generally realized. However, general trends in biogeochemical cycling, consequently reflected in the composition of the understory vegetation and soil properties acquired in response to changes in the age and composition of the forest cover, are known (Sukachev and Dylis, 1964; Likens, et al. 1970; Reichle, 1970; and Odum, 1971).

The differentiating criteria for an ecosystem variant include those used to describe the composition and structure of plant communities and soil properties (with emphasis on the humus layers and the upper soil horizons). Ecosystem variants are designated by describing briefly their present successional status which is attached as an adjective to the name of the plant association or ecosystem type as follows:

A cut-over *GAULTHERIA (SH.) - TH - PM*

or

A cut over *Gaultheria (sh.) - TH - PM*
on loamy sand, Lithic Mini Humo-Ferric Podzol
with moder humus developed on moraine veneer
over quartzdiorite bedrock.

ABSTRACTION OF PLANT ASSOCIATIONS

A short description of the abstraction of plant associations as applied in the synecological classification is provided in the following pages. Once the plant associations are delineated, the abstraction of higher and lower synsystematic (biogeocoenotic) units is relatively easy.

In classifications based on floristic criteria*, the task of separating indivudual vegetation samples (relevés) into classes (i.e., plant associations) is resolved after the species lists of all relevés are transferred into a single table. Such a table, showing floristic information of all relevés under comparison, is referred to as a synthesis table. In addition to being an aid to abstraction of relevés, a synthesis table often reveals information that was not apparent in the field. This method of distinguishing plant associations is referred to as tabular comparison (tabulation of data or tabulation technique). Detailed descriptions of recording, organizing and tabulation of vegetation data using the method of tabular comparison are given by Poore (1955 and 1962), Ellenberg (1956), Becking (1957),

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* The rationale for employing the floristic features, mainly floristic composition and structure, is substantiated by the essential role of the vegetation component in the functional aspects of ecosystems. Furthermore, the vegetation component is one of the most useful expressions of the integrated effect of all environmental and biological factors influencing an ecosystem. Vegetation is readily observable allowing an accurate and efficient floristic assessment.

Moore (1962), Küchler (1967), Shimwell (1972) and Mueller-Dombois and Ellenberg (1974). The objective of the tabulation is to produce a differentiated table. This table shows groups of differential species (species which differentiate between abstracted units) sorted into blocks and separated from other species which are listed underneath in order from high to low constancy. The differentiated table then allows the recognition of phytosociological species distribution and the distinction of character species. The phases of the method of tabular comparison for arriving at a working stage of the differentiated table are as follows (Mueller-Dombois and Ellenberg, 1974):

1/ Construction of a raw table (an annotated or an outlined raw table).

2/ Rewriting the above table into a constancy table.

3/ Extracting the species of intermediate constancy and, from these, determining differential species with the aid of partial (or extract) tables.

4/ Rearranging the relevés (columns) and species accordnng to the presence or absence of groups of differential species into a differentiated (or partial) table.

5/ Determining character species through summary tables.

6/ Rearranging the differentiated table into a characterized summary table.

Because of the previously noted differences, mainly that the plant association (sensu Krajina and his students) is defined as an ecosystematic unit, and the logistical problems in dealing with a massive amount of data (the number of relevés usually exceeds one-hundred) an alternative to manual tabulation is desirable. An electronic computer can be employed to construct various tables at a much reduced time and cost. The abstraction and classification of synsystematic units is not based entirely on floristic criteria. To accomodate the requirements for environmental limits for the plant association a number of selected environmental criteria are considered; the macroclimate (expressed by the biogeoclimatic subzone or variant), soil moisture and nutrient regime are the most relevant. This is necessary for a complete understanding of the ecology and distribution of a plant association. The approach used is in agreement with the recent concept of Braun-Blanquet (1969) who maintains that environmental factors are best reflected in the vegetation. Therefore, in the synthesis tables, environmental values as well as floristic composition and structure are compared.

Since there are a great number of relevés under comparison, the initial objective is to produce synthesis tables for floristically and environmentally similar groups of relevés (which will eventually conform to the level of the plant association). The synthesis tables are called "environment - vegetation tables".* Data from each relevé

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* Presently the computer program provides for printouts of detailed environment - vegetation tables and a summary vegetation table.

are summarized in the tables in columns containing mean values and the range of species significance, values for vigor or sociability and presence (in percent) for each listed plant species. Mean values for some environmental features are also summarized. Simultaneously a summary vegetation table (another kind of synthesis table) is generated. The summary vegetation table lists all species in the environment - vegetation table accompanied by their mean values of species significance and constancy classes for each differentiated unit in the corresponding columns. A summary vegetation table is considered as a working table for the preparation of a table showing the characteristic combinations of species for the abstracted plant associations as well as for higher synsystematic units.

The tabular comparison seemingly demands no knowledge of species ecology. This may be true under certain conditions, such as when dealing with floristically well defined relevés which usually do not represent a complete sampling of a study area. In most cases the abstraction of plant associations does require a thorough consideration of the ecological amplitude of each species. It is because of the lack of basic field knowledge of environment - vegetation relationships that the abstraction process could not be properly applied or comprehended.

The three major steps in the abstraction of plant associations are as follows:

1/ Initial Groupings

When dealing with a great number of plots, despite an option to form large groupings of up to ninety-nine relevés, emphasis is placed on prestratification using mainly environmental features. Prestratification according to biogeoclimatic subzones (macroclimate), habitat characteristics (e.g., soil moisture and nutrient regime) and kind of habitat (e.g., rocky ridges, excessively steep slopes with shallow soils, depressions, floodplains, etc.) can be helpful in preparing initial groupings. Correspondingly, sorting instructions can be prepared while coding environment - vegetation data. It is recommended to arrange the groupings according to increasing moisture and nutrient gradients and relevés within the groupings according to other factors such as increasing elevation, slope gradient or, perhaps, floristic features.

The existence of biogeoclimatic units greatly facilitates the abstraction of plant associations by narrowing their environmental limits. Similar plant associations may occur in closely related biogeoclimatic subzones but usually on soils with different moisture (and, to a certain degree, nutrient) regimes. The plant association can be regarded as a category which unites floristically similar relevés within a biogeoclimatic subzone, whereas the higher synsystematic units unite floristically similar plant associations at a progressively higher level of abstraction both within and outside biogeoclimatic subzones or even zones.

This also presents an advantage in providing plant associations with well defined characteristic combinations of species. When a plant association is very broadly defined it may occur over a wide geographic range because of its wide environmental limits. As a result, some species included in the characteristic combination of species may be characteristic for only a part of the geographical range of the plant association. By imposing macroclimatic limits to a plant association, its characteristic combination of species remains valid throughout its geographical range.

The first printout of the environment - vegetation tables are subjected to exhaustive study for similarities and differences among the relevés in each initial grouping. Floristic compostion, species significance, vigor and presence for each species and layer are evaluated fully considering the ecological function of each species. The procedure follows the recommendations of Poore (1955) and Dahl (1956) for areas where plant communities have few species and particularly where the flora of the general area is not as rich in species as continental Europe. To be ecologically significant, plant species composition cannot be reduced merely to absence or presence of species as is frequently the case in some schemes of vegetation classification. Species significance (abundance and dominance) and species vigor reflect the proportionate role of a species in biogeochemical cycling of mineral elements in a particular ecosystem. Ecologically significant floristic discrepancies are cross-checked for corresponding environmental differences, differences in age, productivity, stand characteristics or strata, and ground coverage. If significant floristic and environmental differences are apparent the relevés should be excluded (and placed in different groupings).

Some relevés, particularly those from young, dense, second growth stands do not provide adequate floristic features for separation and characterization on a floristic basis. Therefore, habitat parameters are used in relating such relevés to their respective units. Furthermore, floristic characteristics should be interpreted bearing in mind the kind of substrate supporting the vegetation. For example, *Gaultheria shallon* (on the coast) or *Pachistima myrsinites* (in the interior) occur in most plant communities on decaying wood; i.e., they are not always characteristic of the habitats or plant communities. Species occurring with a low species significance and presence may be considered as companions or strangers.

It is well recognized that no relevés, despite a good sampling and comparative standard, are exactly identical in every detail. However, comparison of the environment and vegetation data usually reveals that certain plots have many similarities in both habitat and floristic characteristics. Ecosystems are perceived both by their environmental and floristic characteristics and by comparison. Exhaustive comparison of relevés for similarities, differences, consistency of groups and conformity to a general pattern of relationships is the essence of the classification procedure applied to the abstraction of plant associations. The process of grouping and averaging of similar relevés represents the formation of abstract units or classes (i.e., typification).

The abstraction of a class based on many samples presents the opportunity to observe the range of individual properties within a class. Some samples represent modal properties whereas others represent outer range limits of properties [despite the fact transitional areas (or ecotones) between two different biogeocoenoses are avoided during sampling]. In other words, some relevés may have transitional properties, necessitating the assignment of class limits on the range allowed in the characteristics or combination of characteristics that differentiate between two plant associations. Aside from the floristic features, differences in any environmental property or combination of properties that have some significance in ecosystem development or function, particularly those affecting plant growth, should be scrutinized. However, class limits should be wide enough to allow easy identification and to facilitate mapping.

The study of the tables results, in addition to the correction of possible transcription errors, in a new deck of sorting instructions which can include tentative names for plant associations.

2/ Intermediate Groupings

The second and subsequent printouts of the tables may already reveal a satisfactory degree of consistency, especially when dealing with a small number of relevés (e.g., fifty or less). Usually, new printouts are again studied and compared using the previously outlined procedure several times while altering and improving the deck of sorting instructions. Eventually, through the process of successive approximation, the final tables are printed. When approaching the final stage, the summary vegetation table must be examined to evaluate floristic relationships among the units and to initiate the extraction of characteristic combinations of species for plant associations. The summary vegetation table aids in selecting and ranking species for a characteristic combination of species.

The characteristic combination of species (Braun-Blanquet, 1932; Krajina, 1933) is employed as a kind of differentiating characteristic for the plant association. The choice of species for the characteristic combination of species is based on tabulated data and assessment of the ecological function of the species combined with the examiner's experience in the study area. The species employed may include characteristic, constant and differential species.

Characteristic species are those designated as exclusive, selective or preferential according to their fidelity classes (Table 3).

Constant species are those in constancy class V for one or more plant associations but which may also occur with a lower constancy in other plant associations. If high constancy is associated with a high species significance (e.g., greater than 3.0), such species are referred to as constant dominants.

Differential species are also species which may be non-characteristic for a plant association. They can be considered as important companions (not belonging to any of the above categories)

(Braun-Blanquet, 1932; Krajina, 1933; and McVean and Ratcliffe, 1962). Companions and strangers (or accidental species) are not usually included in the characteristic combination of species. It is stressed that either presence or absence of the characteristic combination of species can be used in differentiating plant associations. Plant species listed in parentheses are less characteristic or less frequently occurring in a particular characteristic combination of species, although they may be characteristic for a different plant association in the same or in different biogeoclimatic subzones and zones. Furthermore, the same species may be included in more than one characteristic combination of species. A summary vegetation table (Table 6) along with an example of the extraction of several species and evaluation of their suitability for the characteristic combination of species are presented on the following pages.

Abies amabilis — An important component of several plant associations. Consequently, it will be used in naming units 12, 13, 22, 23, 31 and in higher synsystematic units where it occurs with a constancy class of V and with high species significance and vigor. It may be used as a constant dominant in the units mentioned; however, it will be better for characterizing higher synsystematic units and especially for characterizing the subzone (the Coastal western hemlock, wetter subzone).

TABLE 6

A WORKING EXAMPLE OF A PART OF THE SUMMARY VEGETATION TABLE

BRITISH COLUMBIA FOREST SERVICE
RESEARCH DIVISION

SYNSYSTEMATIC UNITS	11	12	13	21	22	23	24	31	41	42	51
SPECIES	PRESENCE CLASS AND MEAN SPECIES SIGNIFICANCE										
ABIES AMABILIS	IV 4.6	V 5.1	V 5.1	IV 4.0	V 6.1	V 5.8	V 2.4	V 5.4	IV 2.3	.	III 2.6
ADENOCAULON BICOLOR	.	.	.	.	.	.	.	.	.	.	II +.2
ADIANTUM PEDATUM	.	.	.	I 2.0	.	.	III +.0	II +.3	.	.	I +.7
ALNUS RUBRA	.	.	.	I 1.2	.	.	.	.	II 3.1	.	III 3.3
ANAPHALIS MARGARITACEA	.	.	.	.	.	.	.	.	.	.	I +.0
ANGELICA GENUFLEXA	.	.	.	.	.	.	.	.	.	.	I +.0
ANTITRICHIA CURTIPENDULA	.	.	.	.	.	.	.	.	.	.	I +.0
ARUNCUS SYLVESTER	.	.	.	I +.0	.	.	.	.	.	.	.
ATHYRIUM DISTENTIFOLIUM	.	.	.	.	.	.	.	.	.	.	I +.0
ATHYRIUM FILIX-FEMINA	.	.	.	IV 2.8	I +.0	II 2.1	.	V 2.5	II 2.1	.	V 3.0
BARBILOPHOZIA BARBATA	.	.	.	.	.	.	.	.	II +.0	.	.
BAZZANIA AMBIGUA	.	.	.	I +.0	.	II 1.2	.	.	.	.	.
BAZZANIA DENUDATA	III 1.2	III 1.2	III 1.3	III 1.8	III 1.1	II 1.2	III 1.6	III 1.6	IV 1.6	III 1.0	I +.0
BAZZANIA TRICRENATA	.	.	.	.	.	.	III 2.6	.	.	.	.
BLECHNUM SPICANT	V 4.1	V 4.0	IV 2.1	V 5.3	V 5.1	V 5.1	V 3.4	V 5.3	V 3.9	V 4.5	IV 4.1
BLEPHAROSTOMA ARACHNOIDEUM	.	.	.	.	.	.	III 1.0	.	.	.	.
BLEPHAROSTOMA TRICHOPHYLLUM	.	I +.0	.	I +.0	.	.	.	.	.	.	.
BOYKINIA ELATA	.	.	.	.	I +.0	IV 1.2	III +.0	II +.3	.	.	IV 2.0
BRACHYTHECIUM ALBICANS	.	.	.	.	.	II 3.1	.	II 1.1	.	.	.
BRACHYTHECIUM PLUMOSUM	.	.	.	.	.	.	.	.	II +.0	.	.
CALLIERGON CORDIFOLIUM	.	.	.	.	.	.	.	.	II +.0	.	.
CALTHA BIFLORA	.	.	.	.	.	V 2.2	V 3.6	II 1.1	.	V 4.8	.
CALYPOGEIA NEESIANA	III 1.6	V 2.7	III 1.0	IV 2.1	IV 2.7	.	III 1.0	IV 1.6	IV 1.0	.	.
CALYPOGEIA TRICHOMANIS	I +.0	.	.	I +.0	.	.	.	.	.	.	I +.0
CARDAMINE BREWERI	.	.	.	.	.	.	.	III 1.0	II 1.2	.	I +.0
CAREX DEWEYANA	.	I +.0	.	I +.0	.	.	III +.0	III 1.0	V 1.3	III +.0	III 1.6
CAREX HENDERSONII	.	.	.	.	.	II +.6	V +.5	.	II +.0	.	.
CAREX MERTENSII	.	.	.	.	.	.	.	.	.	.	I +.0
CAREX NIGRICANS	.	.	.	.	.	.	.	.	.	III 3.5	.
CAREX DISRUPTA	.	.	.	.	.	.	.	.	.	.	I 2.2
CEPHALOZIA BICUSPIDATA	I +.0	II +.6	II +.0	.	.	II 3.1	.	.	II +.6	.	.
CEPHALOZIA CONNIVENS	.	I +.0	.	.	II +.5	.	.	III 1.0	II +.6	.	.
CEPHALOZIA SPP.	.	.	II +.0	I +.5	.	.	.	.	II +.0	III +.0	.
CEPHALOZIELLA DIVARICATA	.	.	.	.	.	.	.	II +.3	.	.	.
CEPHALOZIELLA SUBDENTATA	I +.0	.	.	.	.	.	.	.	.	III +.0	.
CERATODON PURPUREUS	.	.	.	.	.	.	.	.	II +.6	.	.
CHAMAECYPARIS NOOTKATENSIS	.	.	III 4.0	.	.	II 2.1	V 5.8	.	II +.6	V 5.8	.
CHILOSCYPHUS RIVULARIS	.	.	.	.	.	.	.	IV 2.1	II +.6	.	.
CINNA LATIFOLIA	.	.	.	.	.	.	.	.	.	.	III 1.7
CIRCAEA ALPINA	.	.	.	.	.	.	.	II 1.1	II +.6	.	V 4.9
CLADINA MITIS	.	.	.	.	.	.	.	.	.	III 1.6	.
CLADINA RANGIFERINA	.	.	.	.	.	.	.	.	.	V 2.9	.
CLADONIA CHLOROPHAEA	.	.	.	.	.	.	.	.	.	III 2.6	.
CLADONIA GRACILIS	.	.	.	.	.	.	.	.	.	III 1.6	.
CLADOPODIUM WHIPPLEANUM	.	.	.	.	.	.	.	II 1.1	.	.	.
CLINTONIA UNIFLORA	.	I +.0	II +.3	I +.0	.	.	.	.	II 2.1	III +.0	.
CONOCEPHALUM CONICUM	.	.	.	III 3.2	.	II 1.2	.	IV 4.4	II 3.1	.	IV 4.1

Adenocaulon bicolor A preferential species for unit 51.

Adiantum pedatum A companion. (The constancy class in unit 24 is misleading since the unit has only two relevés.)

Alnus rubra A differential species for unit 41, a preferential species for unit 51 and a companion species in unit 21.

Anaphalis margaritacea An accidental species in unit 51.

Angelica genuflexa Due to a low constancy class and low species significance, a companion in unit 51.

Antitrichia curtipendula As above (an epiphyte species).

Aruncus sylvester May be considered as a differential species for unit 21.

Athyrium distentifolium Due to a low constancy class and low species significance, a companion in unit 51.

Athyrium filix-femina A preferential species for units 21, 31 and 51; a differential species for units 23 and 41. A companion for unit 22.

3/ Final Groupings

The final tables are printed when synthesis and stratification of data for both floristic and environmental variable reveals a maximum degree of consistency for each particular group of relevés. Then the final, full (or abbreviated) Latin names and numerical codings for the abstracted plant associations can be added to the deck of sorting instructions. Simultaneously, preparation of the final table of characteristic combination of species for each plant association can begin along with the abstraction of higher synsystematic units (Table 7). This table shows, on the horizontal axis, the abstracted plant associations (and their higher groupings, using numerical codes). The species included in characteristic combinations of species are shown on the vertical axis and are sorted into blocks separated from other blocks by heavy lines. Species within blocks are listed in order of tree, shrub, herb, moss and lichen species and in decreasing order of constancy class and mean species significance. The next step is to provide a synopsis of the synsystematic units, describing the plant associations with particular attention to environmental features and other aspects which can characterize ecosystem dynamics and environment-vegetation relationships.

Table 7. CHARACTERISTIC COMBINATION OF SPECIES FOR THE ORDERS, ALLIANCES AND ASSOCIATIONS.

Order	I PSEUDOTSUGETALIA MENZIESII			II TSUGETALIA HETEROPHYLLAE							III THUJETALIA PLICATAE									IV POPULETALIA BALSAMIFERAE
Alliance	1			2	3	4		5			6				7			8	9	10
Association	11	12	13	21	31	41	42	51	52	53	61	62	63	64	71	72	73	81	91	101
Biogeoclimatic subzone	a	b	a	a	a/b	b	b	b	b	b	b	a/b	a/b	a/b	a/b	a/b	a	a/b	a/b	b
Number of plots	5	4	18	14	11	8	12	13	5	6	5	8	19	6	13	11	4	12	14	4
Order I and Alliance 1:																				
Pseudotsuga menziesii	V 5.5	V 3.2	V 1.1	V 6.0	V 5.4	V 3.9	III 3.5	IV 4.4		III +.4	III +.0	V 3.6	V 5.0	V 5.2	IV 5.1	III 3.3	IV 4.2	IV 4.4	I +.8	V 2.1
Gaultheria shallon	V 6.0	V 7.2	V 7.7	V 4.2	V 4.2	V 5.8	IV 4.1	V 2.0		V 3.2	IV 1.8	V 5.4	IV 3.0	V 1.7	IV 2.0	IV 1.8	IV 1.6	II 1.5	V 4.0	V 3.3
Vaccinium parvifolium	V 2.2	IV 2.3	V 3.3	V 2.1	V 2.5	IV 3.3	III 1.1	IV 1.1		V 1.8	IV 1.8	V 3.2	V 2.2	V 2.0	V 2.4	IV 2.2	V 1.6	V 2.0	IV 1.9	IV 1.8
(Holodiscus discolor)	III 1.0		II +.5	I +.2							II +.0	I +.0	II +.0							
Amelanchier alnifolia	I +.2	II +.0	I +.0									II +.0	I +.0			I +.0				II +.0
Rosa gymnocarpa	I +.0		I +.0									I +.0						I +.0		
Luzula multiflora	I +.0	II +.3	I +.0								II +.4	III +.8								II +.0
Festuca occidentalis	II +.0		I +.0								III 1.1		I +.0							II +.0
Hieracium albiflorum		II +.0													I +.0					
Stokesiella oregana	V 6.5	II +.3	V 5.8	V 4.7	V 5.1	I +.7	II 1.0	IV 1.3			V 2.7	V 3.9	V 3.9	V 4.1	V 3.7	V 4.0	V 2.9	V 2.7	III 2.1	IV 3.3
Dicranum howellii	V 4.0	V 5.0	IV 1.1	II +.7		IV 2.8	II 2.7	III +.7	III 1.2	III 2.3	IV 4.0	V 2.5	III 2.4	II 1.5	II 1.2	IV 2.0		III 1.0	IV 2.1	V 1.5
Ceratodon purpureus			I +.0																	
Association 11:																				
Polytrichum juniperinum	IV 1.0	III 1.1	I +.0								IV 1.8	I +.0	I +.0							II +.0
Peltigera membranacea	IV 1.2	III 1.0	I +.0			I +.0	II +.4	I +.0			IV 1.0	IV +.5	I +.0						I +.0	
Peltigera aphthosa	IV 1.0	III +.6				III +.0					IV 1.0	III +.4								
Cladonia impexa	I +.0																			
Cladonia macrophylla	I +.0																			
Grimmia apocarpa	I +.0																			
Association 12:																				
Pinus contorta		V 5.4				I 3.0						I +.0							I +.0	
Vaccinium membranaceum		III 2.8				I +.0			I +.0											
(Cladothamnus pyrolaeflorus)		II 3.7					I +.0													II +.0
Arctostaphylos uva-ursi		II 1.1																		
Selaginella wallacei		IV 1.6										I +.0								
Danthonia spicata	I +.0	V 1.5	I +.0								I +.2									
(Saxifraga ferruginea)		V 1.3									I +.2									II +.0
Dicranum tauricum		V 1.6																		
Diplophyllum taxifolium		V 1.4	I +.0	I +.0		I +.0	II +.0				III +.5	V 2.1	I +.9							II +.0
Cladina rangiferina	III 1.9	V 3.2	I +.1			III 1.3	I +.0				IV 2.5	III 1.2								
Dryptodon patens	I +.2	IV 2.6	I +.0			II 1.4					II +.4									
Polytrichum piliferum	III 1.6	IV 3.2									II +.0	I +.7								
(Gymnomitrion obtusum)		IV 1.6									II 2.5									
Cladina arbuscula		IV +.8																		
Cladina squamosa		IV +.2				II +.2					III +.5	IV 1.2								
Rhacomitrium canescens	IV 2.1	IV 5.5	I +.4			V 2.0					V 3.0	IV 3.1								IV 1.6
Pseudoleskea baileyi		III 2.0																		
Cladonia cariosa		III 1.6																		
Stereocaulon alpinum		III 1.1																		
Cladonia pocillum		III +.0																		
Cornicularia aculeata		III +.0																		
Douinia ovata		III +.0				II +.2					III +.0	IV +.1								
Cladonia uncialis		II 1.8																		
Agyrophora rigida		II +.0																		
Order II:																				
Tsuga heterophylla	IV 4.3	V 2.9	V 3.3	V 4.7	V 6.5	V 5.7	V 7.1	V 6.8	V 5.0	V 5.0	II +.0	V 3.7	V 4.9	V 6.0	V 5.2	V 5.1	IV 3.2	V 5.2	V 5.6	V 9.0
(Tsuga mertensiana)		III +.3				III +.7				I +.0									I +.0	II 1.8
(Sorbus sitchensis)					I +.0	I +.0	I +.0	I +.0	II +.4			I +.0							I +.0	
Goodyera oblongifolia		III +.6	II +.1	II +.0	I +.0	V 1.5	IV 1.2	II +.1		IV +.5		I +.0	II +.1		I +.0			I +.0	I +.0	
Linnaea borealis	II 1.0	II +.3	III 1.2	II 1.2	II 1.4	III 1.4	III 3.0	II 1.8		III 1.2		I +.0	II 1.5		II 1.7	I +.0		II +.9	II 1.0	
Listera caurina		II +.0			I +.0	III +.4	III +.6	I +.0	III +.6	IV 1.1					I +.0				II +.3	
Listera cordata	I +.0	III +.0	I +.0	I +.0		I +.0	III +.3	I +.3		II +.2			I +.0						I +.0	
Corallorhiza mertensiana							II 1.0	I +.0		III +.4			I +.0					I +.0		
(Rhytidiopsis robusta)	II 3.3	V 3.3	II 1.7		I +.0	V 4.9	V 5.5	I +.0	IV 2.8	II 1.4	II 1.7	III 1.2	I 2.0		I +.0				I 1.0	

In conclusion, a progressive synthesizing procedure is used where lists of environment - vegetation values are compared for similarities and differences conforming to a general pattern of relationships. In order to perform the tabulation of plant associations, relevés are grouped and regrouped working through the described steps until the final environment - vegetation tables and summary vegetation table are printed. The computer program is described in detail by Klinka *et al.* (1977).

S U M M A R Y

A brief discussion of the synecological classification is presented in order to consolidate understanding of the system amongst individuals and agencies involved in the program of ecological stratification. The lower synsystematic units (e.g., plant association, ecosystem type and ecosystem variant) and their classification through a synthesis of similar plots into abstract units are emphasized.

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