VEGETATION OF THE BEAVER CREEK NATURAL RESOURCES CONSERVATION AREA

by

Diane S. Kossen Doss

Accepted in Partial Completion

of the Requirements for the Degree

Master of Science

Dean of the Graduate School

Advisory Committee

Chair

MASTER'S THESIS

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Date May 12, 1994

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Presented to
The Faculty of
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ABSTRACT A baseline botanical inventory of the Beaver Creek Natural Resources Conservation Area, Bellingham, Washington, was performed in 1992. Terrestrial vegetation was sampled on 46 15x25 m plots. Two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DECORANA) were used to classify and ordinate the data.

Topographic, floristic, and community diversity were high. Ridgetops contained dense western redcedar (Thuja plicata) stands or old-growth Douglas-fir (Pseudotsuga menziesii) communities; slopes held mixed coniferous/deciduous stands or old-growth communities dominated by various combinations of Douglas-fir, western redcedar, and western hemlock (Tsuga heterophylla). Sitka spruce (Picea sitchensis) was an important component of two stands, both near wetlands. Bottoms contained red alder (Alnus rubra)/western redcedar "swamps". Understory cover ranged from 6% to 232%. Cover types were primarily related to soil moisture and topographic position; fire and selective logging in the late 1800s also may have contributed to the diversity of vegetation.

One hundred and thirty-seven species of vascular plants and over 30 species of bryophytes were identified. The native plant community is largely intact, although wall lettuce (Lactuca muralis) is well established and reed canarygrass (Phalaris arundinacea), English holly (Ilex aquifolium), and herb Robert (Geranium robertianum) are spreading.

ACKNOWLEDGEMENTS

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Most of all, I am grateful to Ronald J. Taylor for introducing me to the Beaver Creek Natural Resources Conservation Area and providing guidance through the project. His efforts over 25 years are largely responsible for the preservation of this rich and diverse forest ecosystem.

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INTRODUCTION

For thousands of years western Whatcom County was covered with forests typical of the Western Hemlock Zone of western Washington (Brubaker, 1991; Franklin and Dyrness, 1973). Pollen evidence indicates that modern climatic conditions in the Puget Sound region were established about 6,000 years ago. At that time, pollen of Douglas-fir (Pseudotsuga menziesii), alder (Alnus sp.), oak (Quercus sp.) and grass species declined, and pollen of western hemlock (Tsuga heterophylla) and western redcedar (Thuja plicata) increased (Brubaker, 1991). In the intervening millennia, a temperate coniferous forest unique in being dominated by large and long-lived coniferous species has covered the landscape (Franklin and Dyrness, 1973). On an evolutionary time-scale, this forest association is young and may not represent highly coevolved species interactions (Brubaker, 1991).

During the past 150 years most of the original forest has been replaced by clearcuts, "second growth" forest, agricultural land and urban development (Franklin and Dyrness, 1973). Throughout western Washington, less than five percent of the original landscape remains (Franklin et al., 1981). A small portion is preserved, but most of that is federal land and is at high elevations or other remote locations (Norse, 1990). In 1987, the Washington Natural Resources Conservation Areas (NRCA) Act was created to authorize the state Department of Natural Resources (DNR) to acquire property for preservation. The goals of the program are to (1) maintain, enhance or restore ecological systems; (2) maintain exceptional scenic landscapes; (3) maintain habitat for threatened, endangered and sensitive species; (4) enhance sites for primitive recreational and low impact public use; and (5) permit outdoor environmental education (Washington State DNR, 1992). The act authorized the purchase of lands that either (1) have high priority for conservation; (2) have been impacted but retain to some degree or have reestablished their natural character; (3) are examples of native ecological communities; or (4) are environmentally significant sites threatened by incompatible or ecologically irreversible developments (Washington State DNR, 1992).

In 1991, 55.8 hectares of Puget Lowland forest, only eight kilometers from downtown Bellingham, were given protection under the NRCA Act, and the Beaver Creek Natural Resources Conservation Area (NRCA) was established. The site is close to an urban area and a university and is exceptionally diverse, encompassing old-growth conifer forest, mixed deciduous/coniferous forest, alder slopes, and a variety of wetland communities. Microtopography and disturbance history have contributed to a rich mosaic of plant communities.

The purpose of this study was to provide a baseline botanical inventory of the Beaver Creek NRCA. The following questions were addressed:

1) What vascular plant species and common terrestrial bryophytes are found at the Beaver Creek NRCA, and what is their distribution?

2) What is the abundance and distribution of rare and non-native plant species?

3) What is the structure and composition of the forest?

4) What plant communities can be identified?

5) What site attributes are related to the community types? For the last question, only slope, aspect, and topographic position were measured. Soil moisture was inferred from the presence of plant species with known moisture tolerances.

STUDY AREA

The study area is located approximately eight kilometers (km) east of downtown Bellingham, Washington on Lake Louise Road, 0.3 km southwest of Lake Whatcom near Strawberry Point (Figure 1). It includes the 55.8 hectare (ha) Beaver Creek NRCA and an adjacent 4 ha parcel owned by Western Washington University (WWU). The Beaver Creek NRCA is situated in the south half of the southwest quarter of Section 36, Township 38 North, Range 3 East, W.M, and is approximately 1600 meters (m) long and 400 m wide, tapering to 70 m wide at the eastern edge.

Although WWU-owned land is included in the study area, the terms "study area", "site", "Beaver Creek NRCA" and "conservation area" are used interchangeably throughout this paper. It is anticipated that the WWU land will be managed as part of the conservation area when the management plan for the Beaver Creek NRCA is completed. An additional 2.2 ha owned by WWU provides access to the NRCA but was not included in this study.

Geology

The NRCA lies within the Chuckanut Formation, a three km thick sequence of continental sedimentary rocks described by Easterbrook (1971) and McKee (1972). Sediments are derived from a vast alluvial floodplain dating from the late Cretaceous to early Tertiary, about 50-70 million years before present. Beds were folded, truncated by erosion, and scoured by subsequent glaciations. Resistant sandstone

Figure 1. Location of the study area.

and conglomerate remain as steep, roughly parallel ridges, and less resistant shale underlies the narrow valleys. Pooling of water in the valleys may be aided by thick layers of glacial till deposited during glacial advances and retreats in the Pleistocene and by the weight of the glacial ice that compressed the clay and till into a thick, impermeable layer (Easterbrook, 1971:10-14,16; McKee, 1972:88,100).

Topography and Soils

Elevation of the study area generally increases from north to south, following the trend from Lake Whatcom in the north to Lookout Mountain to the south (Figure 1). The lowest point, about 160 m elevation, is near the northwest corner of the study area; the highest point, about 240 m, is located in the south-central part of the site.

Ridges and valleys run in a northwesterly-southeasterly direction. Many of the ridges culminate in vertical or near-vertical sandstone outcrops. All valleys contain seasonal or year-around streams or standing water, and drainages deepen and widen toward the northwest. Beaver Creek flows from a 4-ha beaver pond in the southwest corner of the conservation area, the largest wetland in the study area. Other wetlands occur at the northwest corner (the "northwest wetland") and west of the midpoint of the north boundary (the "north wetland").

Soils are described by Goldin (1992) and are classed as Chuckanut loam, Nati loam, and Labounty silt loam. Chuckanut and Nati loams are well-drained soils formed in a mixture of volcanic ash and colluvium derived from glacial drift and sandstone or siltstone. Chuckanut loam, which covers most of the site, is a deep soil with a high available water capacity, underlain by sandstone, siltstone, or conglomerate at a depth of 1 to 1.5 m. Nati loam, which occupies the steeper areas along the northeastern boundary, is shallower with moderate water capacity. Its depth to bedrock ranges from 0.5 to 1 m.

Labounty silt loam is mapped in the beaver pond area. Labounty is a very deep, poorly drained soil formed in glaciomarine drift with an admixture of loess and volcanic ash. Permeability is moderately low and available water capacity is high (Goldin, 1992). The high water table in other locations may be caused by pockets of impermeable Bellingham drift too small to show on soil survey maps (Whatcom County, 1992).

Climate

The following description of climate is summarized from Goldin (1992). The climate of the study area is tempered by prevailing southwest winds off the Pacific Ocean and by protection from continental airmasses by the Cascade Mountains. Cloudy days are common with 25% of possible sunshine in winter and 60% in summer. Mean annual temperature is 10° C. Average daily maximum in summer is 23° C and minimum in winter is 1° C. Average frost-free period is about 180 days. In some years a dry continental air mass causes several days of abnormal temperatures, either well below freezing in winter or very hot in summer.

Annual precipitation averages 91 cm, of which 30% falls between

April and September. Average relative humidity is 60% at midafternoon and 85% at dawn. On the average, snow exceeds 2.5 cm in depth fewer than three days per year.

Highest average wind speeds are 16 km per hour, but occasional winter storms bring strong winds. Major windstorms in 1921 and 1962 caused extensive blowdowns in western Washington forests (Oliver and Larson, 1990).

Animal Activity

Beavers dammed Beaver Creek creating a 4-hectare pond sometime after 1947 (D. Bohrer, pers. comm.). In the 1992 field season, the most recent evidence of beaver activity (cut trees and branches) appeared to be two to three years old, but branches newly cut by beaver(s) were found in early 1994. Active osprey and heron nests were located on opposite sides of the pond. A wide variety of other birds, including wood ducks, kingfishers, pileated woodpeckers, bald eagles, nuthatches, kinglets, Townsend's warblers, and sapsuckers have been noted on the site.

Deer trails criss-cross the conservation area. Douglas squirrels, red-legged frogs and pacific treefrogs are common. Mountain beavers are present in an alder stand and salamanders have been seen. Coyote behavior during the summer of 1992 suggests coyote reproduction near the center of the site.

Post-settlement Site History and Human Activity

Large bucked logs and partially-cut trees, large Douglas-fir and western redcedar stumps, overgrown roads, and an old railroad grade remain as evidence of logging in the late 1800s when, according to Robinson and Rice (1992), the Lake Whatcom area was being settled and logged.

Large charcoaled snags and stumps scattered throughout the site, and what appears to be charred bark on many large Douglas-firs, suggest that fire has also played an important ecological role in the Beaver Creek preserve. It is likely that the large fire that swept through Whatcom County in July, 1885, "devastating the region about Lake Whatcom" (Roth, 1926), affected the Beaver Creek forest.

The land included in the Beaver Creek NRCA was part of a parcel acquired in 1899 by the State of Washington and placed in trust under the administration of the Department of Natural Resources (DNR). It was first identified as a potential natural area in the mid-1960s by Drs. Wally Heath and Ronald Taylor of WWU. Dr. Taylor then began a protracted campaign to preserve the area (which was on the logging list at the time) for educational use. In 1973 two parcels of private land totalling 6.36 ha, adjacent to the state trust land, were purchased by WWU (Fig. 1). In the same year, the DNR temporarily set aside 80 acres of the site as a study area. In 1991 the site was finally removed from state school trust land status for protection under the DNR's Natural Resources Conservation Area (NRCA) program.

The Beaver Creek NRCA is bordered by private forest land, agricultural land, residential subdivisions, and trust land managed by the DNR. The Lake Louise Road runs through the southwest corner of the site. Presently, there is limited evidence of human impact on the Beaver Creek NRCA. Old roadgrades are present but covered with vegetation. Non-native plants and a few aging trash piles are present. A well-worn trail contours the hillside above the north shore of the beaver pond and continues onto a log that has fallen into the pond. Less well-defined trails circle the pond.

Since Beaver Creek's "discovery" by Drs. Heath and Taylor in the 1960s, the area has been extensively used as an outdoor laboratory by WWU. Classes in botany, ecology, entomology, mycology, and ornithology have used the site for field trips and research. The area is also occasionally used by bicyclists, birders, and mushroom-hunters.

METHODS

Field methods

Vegetation analyses were carried out during the growing season of 1992. Field methods fell into three categories: (1) initial reconnaissance, (2) vegetation sampling, and (3) collection and/or field identification of vascular plants and bryophytes.

Initial reconnaissance

Aerial photos and field reconnaissance were used for an initial survey of plant communities and reflection of site diversity, and to determine the general placement of plots.

Vegetation sampling

Analytic plots. In order to sample vegetation within all recognizable terrestrial plant communities and in all areas of the site, 46 15 m x 25 m plots were established (Figure 2). After a community with relatively uniform slope and aspect was chosen, a plot was randomly located following the method of Henderson et al. (1989). The method involved standing in the center of the area to be sampled and looking at the second hand of a watch twice, at an interval of several minutes, to randomly determine two numbers. The first number was multiplied by six to determine a compass bearing; the second was used to determine the number of paces or feet to walk in that direction. A corner of the plot was placed at the point so determined. The method was modified to fit the community size;

Figure 2. The study area, showing locations of plots.

in smaller communties (ravines, narrow ridgetops) direction and distance of travel were limited. Most plots were placed with the long axis paralleling the contours of the site. According to Daubenmire and Daubenmire (1968) this maximizes soil homogeneity.

The plots were adapted from the design of Fonda and Bernardi (1976) (Fig. 3). Each plot contained three components: (1) the "macroplot", or entire 15 x 25 m plot, in which the diameter of all trees larger than 2.5 cm at breast height (dbh) were measured; (2) ten 1 m diameter microplots (8.4% of the macroplot), in which percent cover of tall understory was estimated; and (3) 24 40 x 50 cm microplots (1.3% of the macroplot), in which percent cover of low understory was estimated and small trees were counted. Microplots were located in the macroplot with a stratified random design using a random number table for placement of microplots.

Cover values were estimated in order to provide information on the dominance of understory species. Percent cover of understory species was estimated by the cover classes of Daubenmire (1959), modified as follows: <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-95%, >95%. To provide information on distribution, frequency was calculated as the percent of possible microplots in which a species occurred. Constancy gives information on distribution on a larger scale and was calculated as the percent of possible macroplots in which understory and overstory species occurred.

All vascular plant species within the macroplot but outside the microplots were recorded as present. Slope, aspect, and topographic position of the plot were recorded on the data sheet.

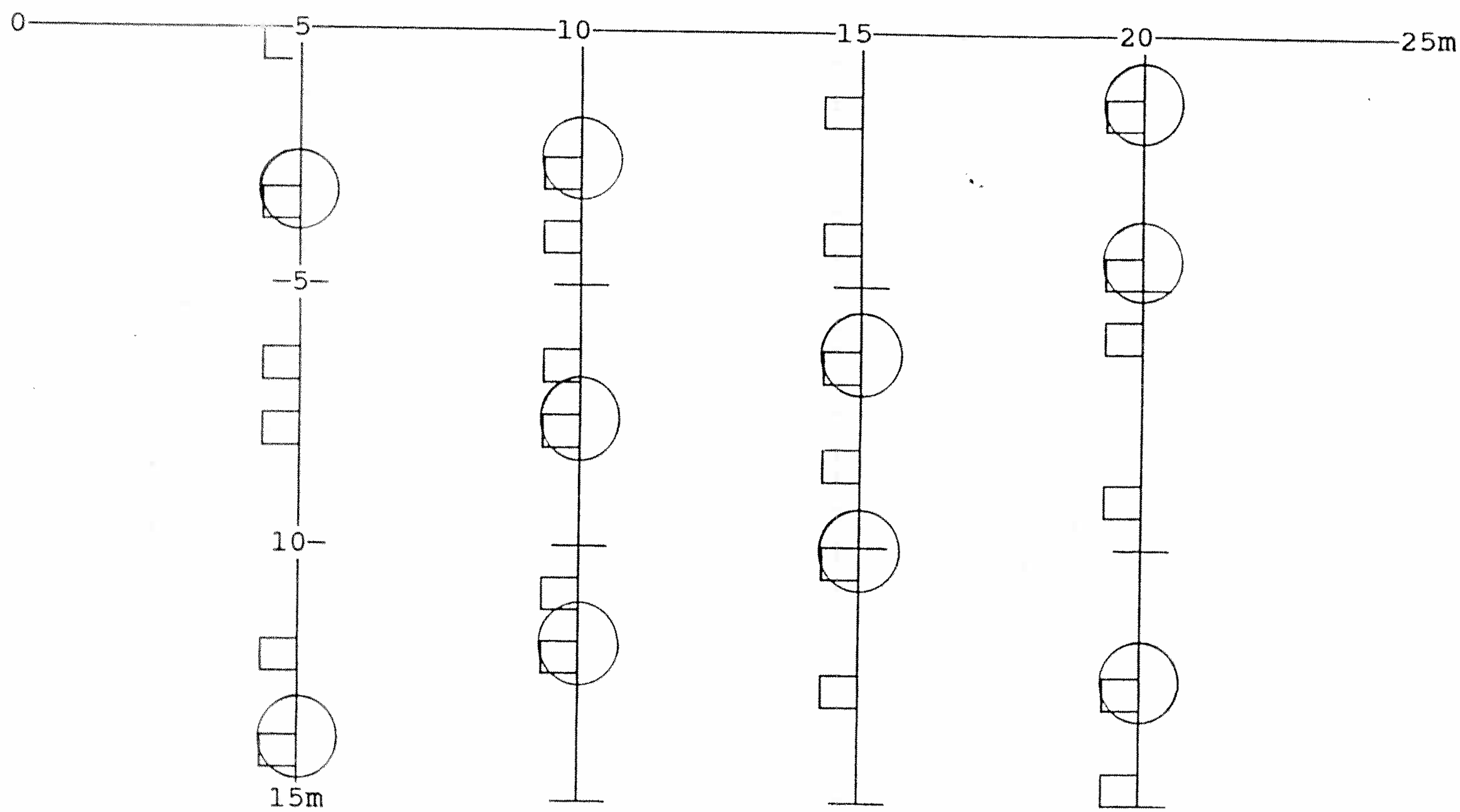


Figure 3. 15x25 m plot, with example of stratified random placement of microplots. Two 40x50 cm microplots are randomly placed in each 5 m segment of the 15 m tapes. One 1 m diameter microplot is randomly located in each 7.5 m segment, and two others are randomly placed on the 15 m tapes. (Not to scale.)

Floristics. All vascular plants encountered on the site, including areas that were not sampled analytically, were identified. Included were emergent aquatics and plants found in narrow ravines and on the edges of the beaver pond, outlet creek and north wetlands. Terrestrial bryophytes found within microplots and occasional specimens found elsewhere on the site were collected and identified.

Except where more recent changes have been noted, nomenclature follows Hitchcock and Cronquist (1973) for vascular plants, Anderson (1990) and Anderson, et al. (1990) for mosses, and Hong (1987) for liverworts. Voucher specimens have been deposited at the Western Washington University Herbarium (WWB).

Data Analysis

Plot data were classified by two-way indicator species analysis using the program TWINSPAN, and ordinated by detrended correspondence analysis with the program DECORANA. These FORTRAN programs, both developed by M. O. Hill (1979*a*, 1979*b*), are complementary and frequently used together in vegetation analysis. Classification groups related species or samples while ordination arranges species and samples along gradients. Both organize community data on the basis of species abundance only, leaving environmental interpretation to a subsequent, independent stage (Gauch, 1982:109). Both also assume a non-normal distribution of data, but without severely deviant outliers (Causton, 1988:207, 220). Principal Components Analysis (PCA), another ordination procedure, was used to supplement TWINSPAN and DECORANA. PCA assumes environmental factors are correlated and the data are normally distributed and uncorrelated (Causton, 1988:153, 207; Gauch, 1982:136).

TWINSPAN and DECORANA were performed using prominence values consisting of density x basal area$^{1/2}$ for trees, and percent cover for understory species. With PCA, density x basal area$^{1/2}$ was again used for trees and prominence values consisting of percent cover x frequency$^{1/2}$ were used for understory. These prominence values were selected to emphasize the roles of density and cover in estimating dominance in a plant community (Fonda, 1991). Cover and prominence values were standardized on a scale of 0-100 for trees and for understory for each plot in order to emphasize species composition, rather than abundance, of each plot (Gauch, 1982:214). All species with at least 1% cover in two or more plots were used in the analysis, with the exception of English ivy (Hedera helix) and English holly (Ilex aquifolium). These two species are recent introductions whose current distribution on the site may not reflect their ecological tolerances (E. Shreiner, pers. comm.).

Two-way Indicator Species Analysis (TWINSPAN)

TWINSPAN is a polythetic, divisive classification technique. The program first constructs a classification of the sampling units (SUs or plots), then uses this classification to obtain a classification of species according to their ecological preferences (Hill, 1979a). To do the SU classification, TWINSPAN performs an ordination based on reciprocal averaging, specifies "indicator species" that are at extremes of the ordination axes, then divides the plots into two groups based on the weights of the indicator species. These steps are repeated for each level of the hierarchy until a predetermined stopping point is reached - either a maximum number of divisions or a minimum number of sampling units per group. Unlike agglomerative clustering methods that compare a single sampling unit with each other unit and build clusters one sampling unit at a time, TWINSPAN looks at, and then divides, the entire data set using all available information during each division (Hill, 1979a; Causton, 1988). One drawback is that the method imposes bisections at each level of the division whether inherent groups are present or not and where more than two subgroups may be indicated.

TWINSPAN operates on a semi-quantitative level using "pseudospecies cut-levels" to divide species into crude abundance scales based on their prominence values. The optimal cut-levels are determined empirically (Whittaker et al., 1989) and, in this case, cut levels of 0, 2, 5, 10, 20, 50, and 80 were used. In order to decrease the influence of rare species, prominence values of 5 and over were given twice as much weight as those under 5. TWINSPAN offers a number of options for analysis. With the exception of the cut-levels and weights, indicated above, default mode was used for all options.

In the first run of TWINSPAN some species selected as indicators were known to have wide and/or sporadic distribution in the study area. In order to test the meaningfulness of the classification, a second run of TWINSPAN was made. In this run, the following species were included in the analysis but omitted as potential indicator species: bracken fern (Pteridium aquilinum), sword fern (Polystichum munitum), wall lettuce (Lactuca muralis), foamflower (Tiarella trifoliata), miner's lettuce (Montia sibirica), and elderberry (Sambucus racemosa) - although elderberry seedlings were present in dry conifer communities, larger plants were found only on moist sites.

TWINSPAN output consists of: (1) a listing of all divisions of species, (2) a listing of all divisions of plots, (3) indicator and preferential species for each division of plots, and (4) an ordered two-way table showing both the classification of species and plots. A dendrogram was produced using the program's output, with indicator or preferential species indicated for each cluster.

Detrended Correspondence Analysis (DECORANA)

DECORANA is a form of reciprocal averaging that was designed to eliminate the arch distortion and compression effects found in many ordinations of data that span broad environmental gradients. As in reciprocal averaging, arbitrary ordination scores are assigned to species. Plot scores are then calculated using weighted averages of species scores. The plot scores are used to rescale original species scores, and several iterations are computed until stable scores are reached. Second and higher axes are detrended relative to the first axis at each iteration (Hill, 1979b; Causton, 1988).

For DECORANA, rare species were downweighted with a predefined option, and data were transformed to the "octave scale" with cut levels of 0.25, 0.75, 1.5, 3, 6, 12, 24, 48, and 82 (recommended by

Hill, 1979b). Default mode was selected for all other options. Output consisted of tables of species scores and plot scores, each on the first four axes of the ordination. From these tables, graphs were produced showing the placement of species and plots on the axes of the ordination.

Principal Components Analysis (PCA)

Principal Components Analysis is a multivariate linear ordination method that uses matrix algebra and an eigenanalysis approach to extract axes of maximum variation from a species or samples resemblance matrix. The technique "rotates" the original data "species space" into a new space of reduced dimensionality to expose underlying community patterns (Ludwig and Reynolds, 1988:223-241). Although PCA is highly effective with relatively homogeneous data, if the data are markedly discontinuous the extremes will be distinct but the central portion of the data may remain undifferentiated. For this reason PCA is not commonly used in ecological studies with heterogeneous data sets (Kershaw and Looney, 1985:200-204).

Despite its limitations, PCA can provide useful information. Because of its availability and ease of use, the program was employed in this study as a supplemental ordination technique, including frequency in the prominence value for understory species, and as a means of examining relationships between plots based on tree composition.

PCA output consists of a list of coordinates on the first three principal components for each species and sampling unit, a list of eigenvectors and eigenvalues, and the percent of variation in the data set accounted for by each eigenvalue. Based on the output, a three-dimensional ordination of species or plots can be produced.

RESULTS & DISCUSSION

Vegetation Analysis

Classification of species

TWINSPAN classified species into 16 groups (Fig. 4). Species commonly associated with dry habitats and those associated with wet habitats are on opposite sides of the classification. Species in the middle of the classification are found throughout the site.

Ordination of species

The species ordination also placed species associated with dry habitats on the left and those associated with wet habitats on the right of Axis 1 (Fig. 5). In Fig. 6 species names are replaced with moisture classes as listed in Klinka et al. (1989). The earliest comprehensive studies of vegetation in the western hemlock zone stressed the usefulness of understory species as indicators of site quality, and subsequent studies have shown spectra of communities arranged along moisture gradients (Franklin and Dyrness, 1973).

A note on "indicator species"

In this paper the term "indicator species" is used in two contexts. When used in the context of a TWINSPAN division, the term refers to species at the extremes of TWINSPAN's ordination. More commonly it refers to a plant species that is indicative of a particular soil moisture regime as reported by Klinka et al. (1989). In this context, a phrase such as "indicator of moist soil" is used.

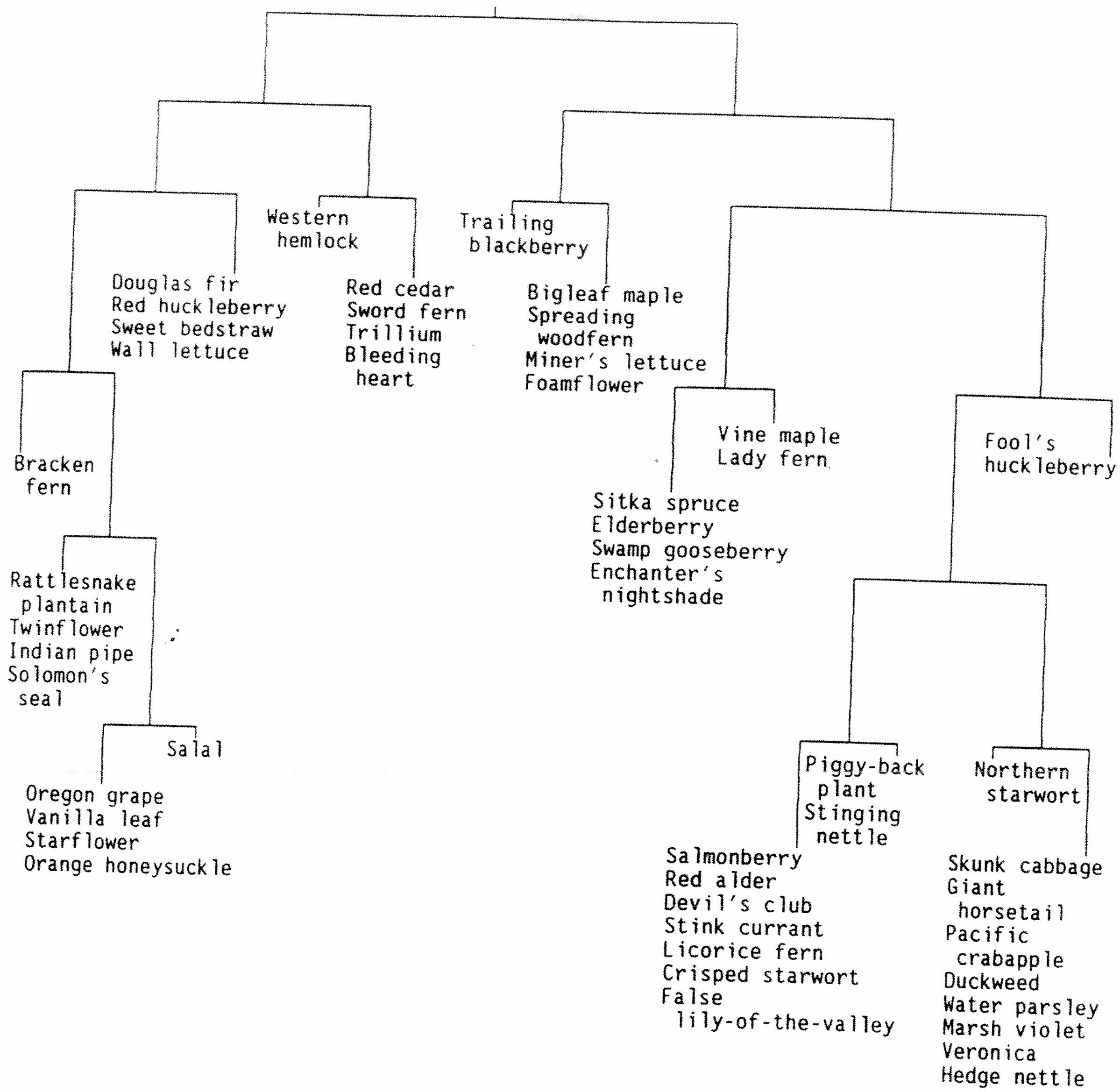


Figure 4. TWINSPAN classification of the species.

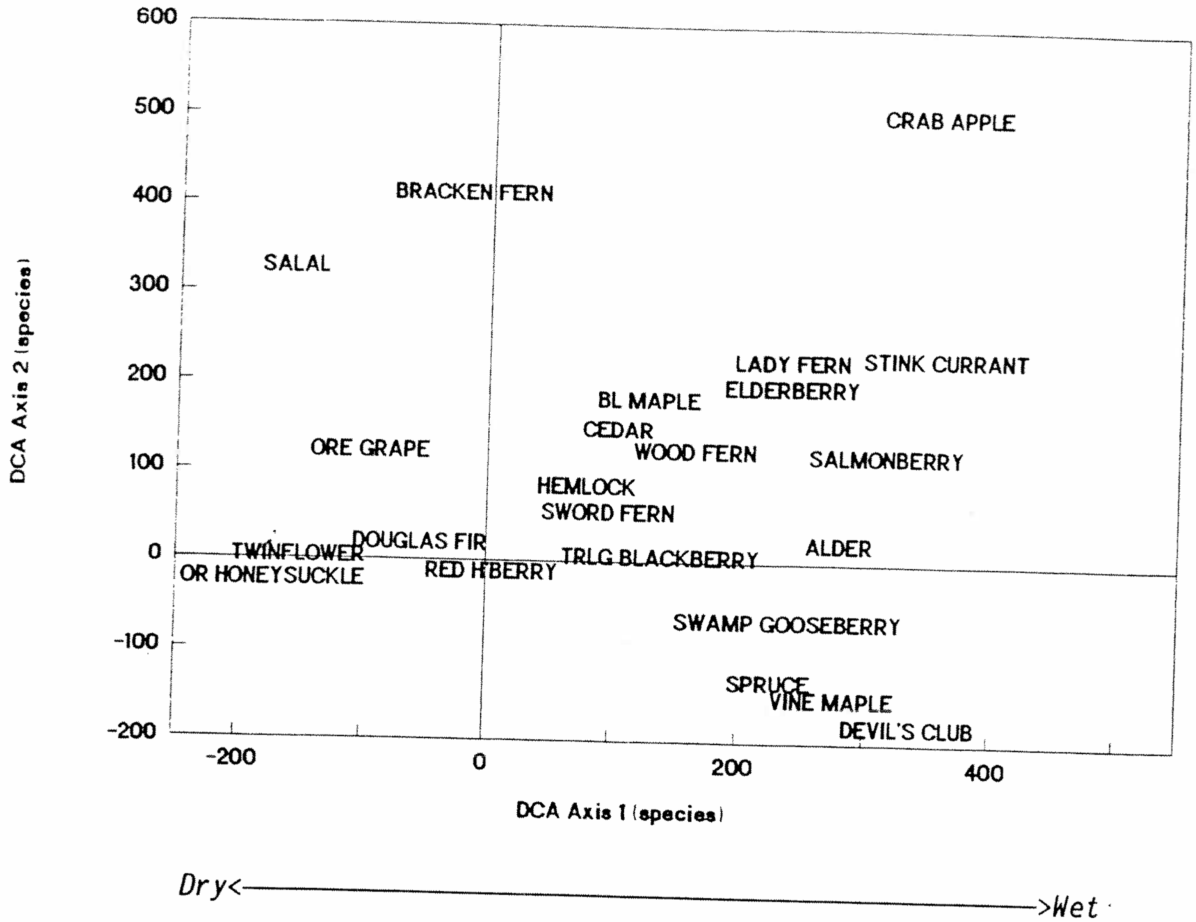
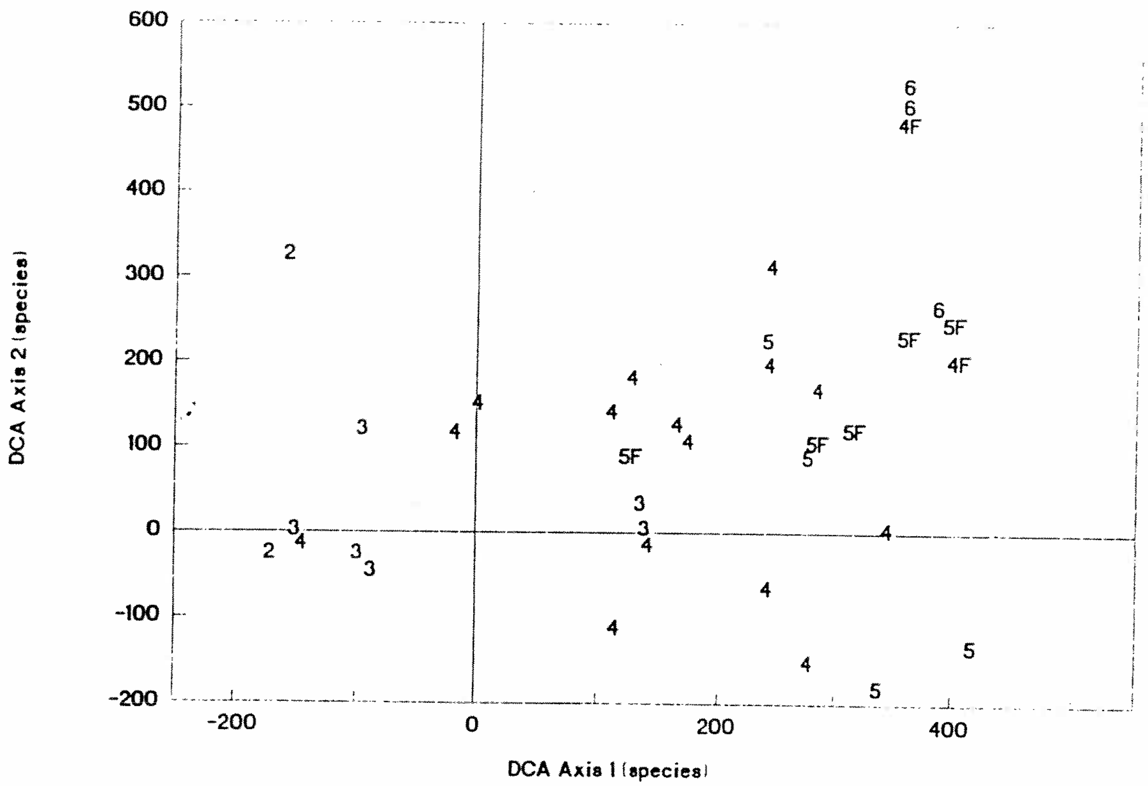


Figure 5. DECORANA ordination of selected species. Trees, shrubs and ferns are shown.



Dry<——————————————————————>Wet

Figure 6. DECORANA ordination of the species. Overstory and understory species names have been replaced by moisture class indicators from Klinka et al. (1989). 2 = very dry and moderately dry, 3 = moderately dry and fresh, 4 = fresh and very moist, 5 = very moist and wet, 6 = wet and very wet, F = may occur on sites with prominently fluctuating groundwater tables.

Classification of Plots

The first level of the TWINSPAN classification distinguished between plots dominated by Douglas-fir or other conifers (and containing Douglas-fir) from plots lacking Douglas-fir but including red alder (Fig. 7). On the left side of the dichotomy, the second level of classification separated conifer plots containing three indicators of moderately dry and fresh soils - Oregon grape (Berberis nervosa), rattlesnake plantain (Goodyera oblongifolia) and starflower (Trientalis latifolia) - and vanilla leaf (Achlys triphylla) (Group I) from those containing red alder and having higher values of species of more mesic soils (Group II). On the right side of the dichotomy, the second level separated plots containing skunk cabbage (Lysichitum americanum), water parsley (Oenanthe sarmentosa), and/or giant horsetail (Equisetum telmateia) (indicators of wet and very wet soils or periodically flooded sites) (Group IV), from those on slopes or benches and lacking those species (Group III). TWINSPAN produced the same groups whether or not species with wide or sporadic distribution were used as indicator species.

Seventeen plant cover types were identified by TWINSPAN. Many consisted of loose aggregations of plots. Forty-two percent of plots in Group I, 27% in Group II and 20% in Group III were "borderline" at some point in the analysis; an additional 5% of Group I and 27% of Group II were "misclassified" (ie., the ordination and the indicator species placed plots on opposite sides of the division). Due to use of the program's default "stopping rule", groups of less than five plots were not subdivided further, regardless of level of similarity.

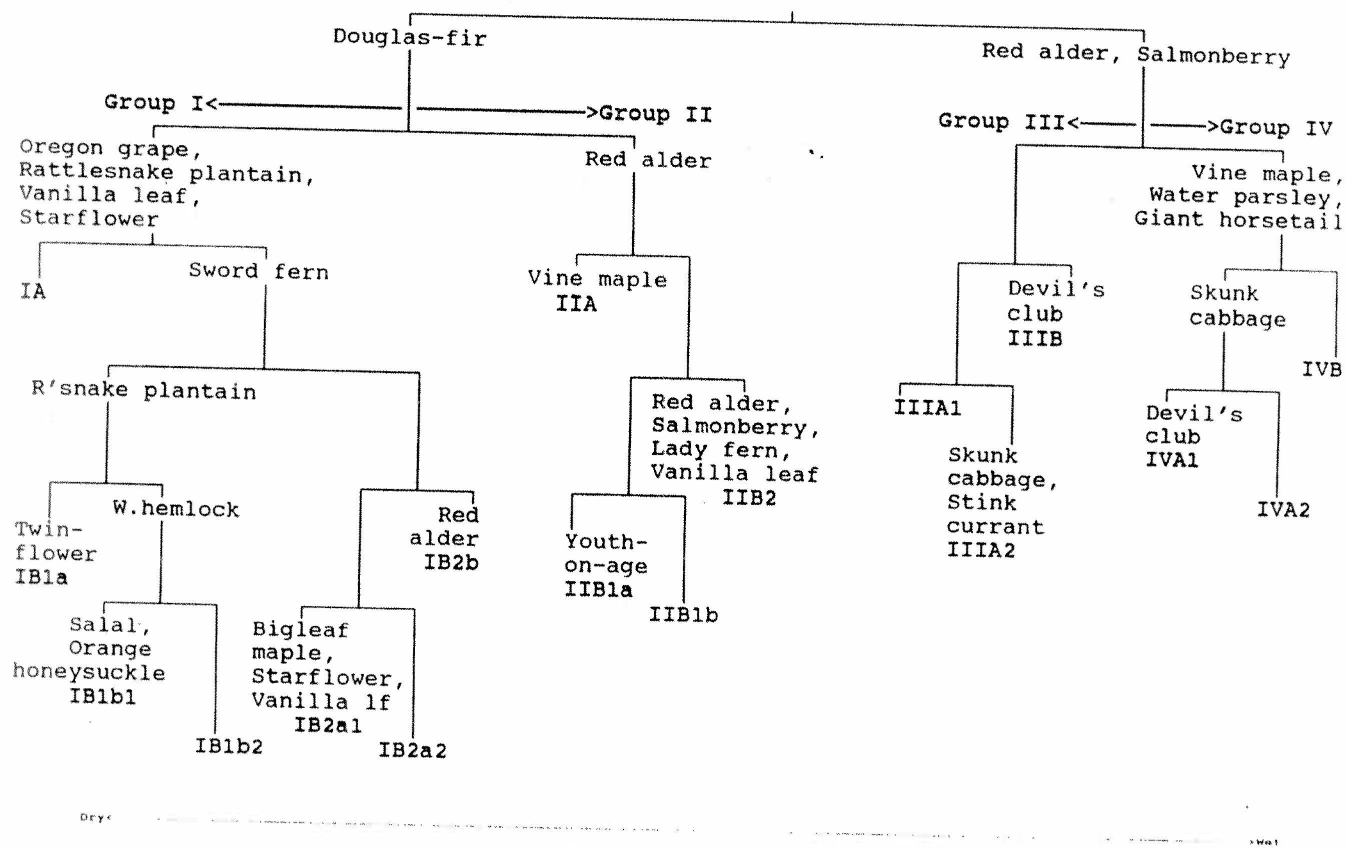


Figure 7. TWINSPAN classification of the vegetation plots. The hierarchy has been annotated with indicator species for each dichotomy and with group numbers as used in text.

Ordination of plots

The DECORANA ordination of plots, annotated with the 17 TWINSPAN groups, is presented in Figure 8. Plots located on ridgetops and high hillsides, dominated by conifers and with low vascular understory cover, occupied the left extreme of the first DCA axis. Communities located in wet bottoms, dominated by deciduous species and with high understory cover, occupied the right extreme. For many of the TWINSPAN groups, plots are widely separated in the ordination.

In both species and samples ordinations, the second and third axes were not correlated with any measured environmental variables.

PCA Ordination

Results of the PCA with understory and tree species generally support DECORANA and TWINSPAN results and are not presented in this paper. Drier, conifer-dominated communities were at one end of the ordination, while communities in habitats with standing water part of the year were at the other end. The first three eigenvalues accounted for 36% of the variation.

PCA of trees put red alder-dominated plots at the left extreme and Douglas-fir-dominated plots at the right extreme of the x-axis, both above the y-axis. Most western hemlock-dominated plots were between red alder-dominated and Douglas-fir-dominated plots. Western redcedar-dominated plots and the only bigleaf maple-dominated plot were below the x-axis. Although the PCA was not used for formal analysis of community types, it helped in interpretation of relationships between tree distribution and topography.

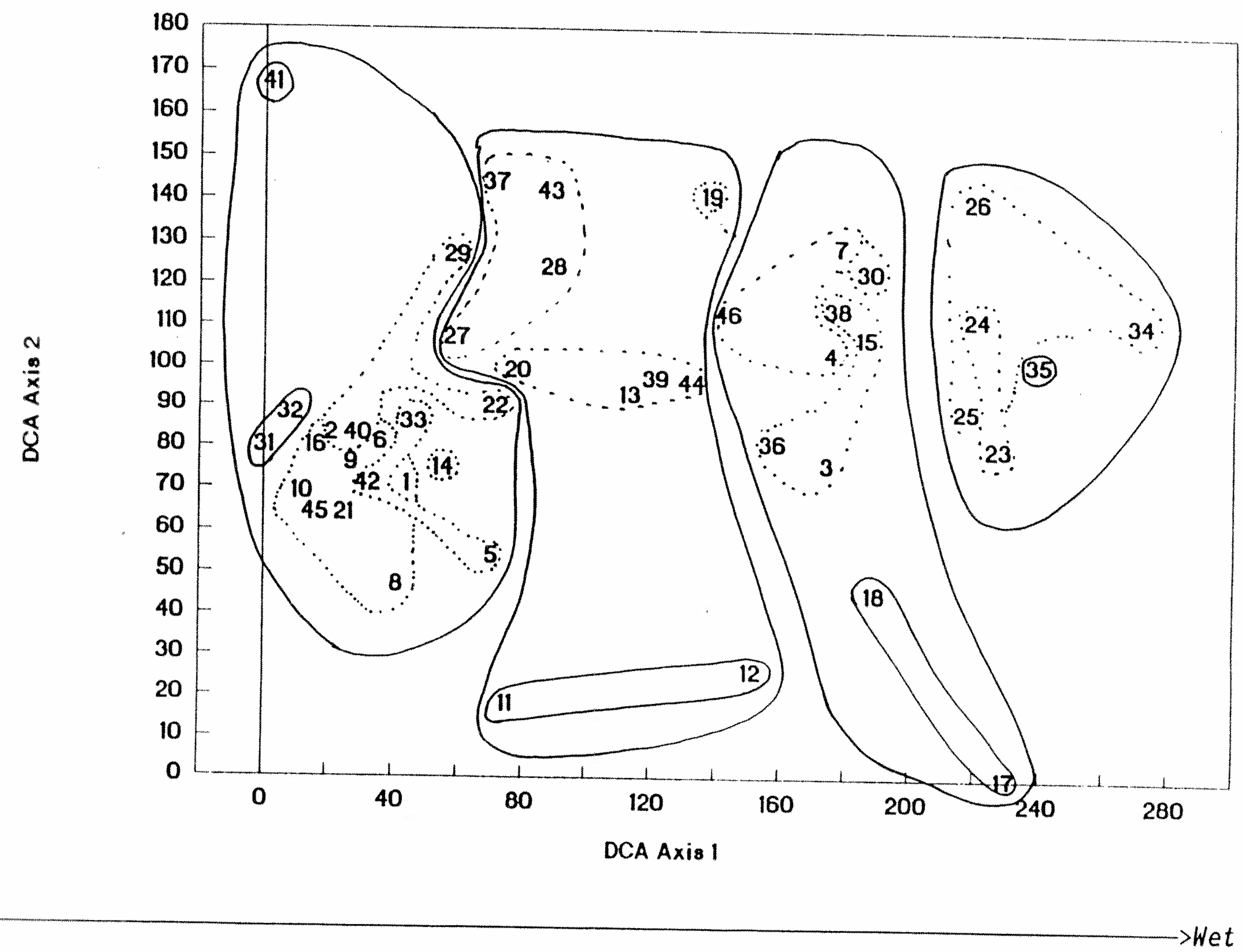


Figure 8. DECORANA ordination of the plots. TWINSPAN group divisions are outlined. From left to right, the four largest outlines surround plots within Groups I, II, III, and IV.

Relationship of classification and ordination position to environmental variables

Groups of plots on the left of the TWINSPAN and DECORANA outputs and containing more species of drier sites were mostly located on ridges and upper slopes, while those on the far right of the analyses were located in low-lying areas (Fig. 9). This relationship was not linear, however. The microtopography and disturbance history of the site preclude simple gradients. No trends were evident in the relationship of TWINSPAN groups to slope or aspect.

Community descriptions

All groups defined by TWINSPAN are discussed in the following section. Transformations of the data to prominence values, options selected for running the program, and the program itself affected the results in several respects: (1) TWINSPAN makes divisions based on "indicator species" as defined by presence and absence in plots - the indicator species may or may not be the most ecologically significant species. (2) Prominence values weighted density over basal area so a tree species having a larger number of individuals was weighted more than one having fewer, larger individuals. (3) Prominence and cover values were standardized within each plot so plots were compared on the basis of relative, rather than absolute, dominance. (4) Understory and overstory were standardized separately so in plots with only a few understory species, they had as much weight as tree species in the analysis. (4) Plots were selected to be representative

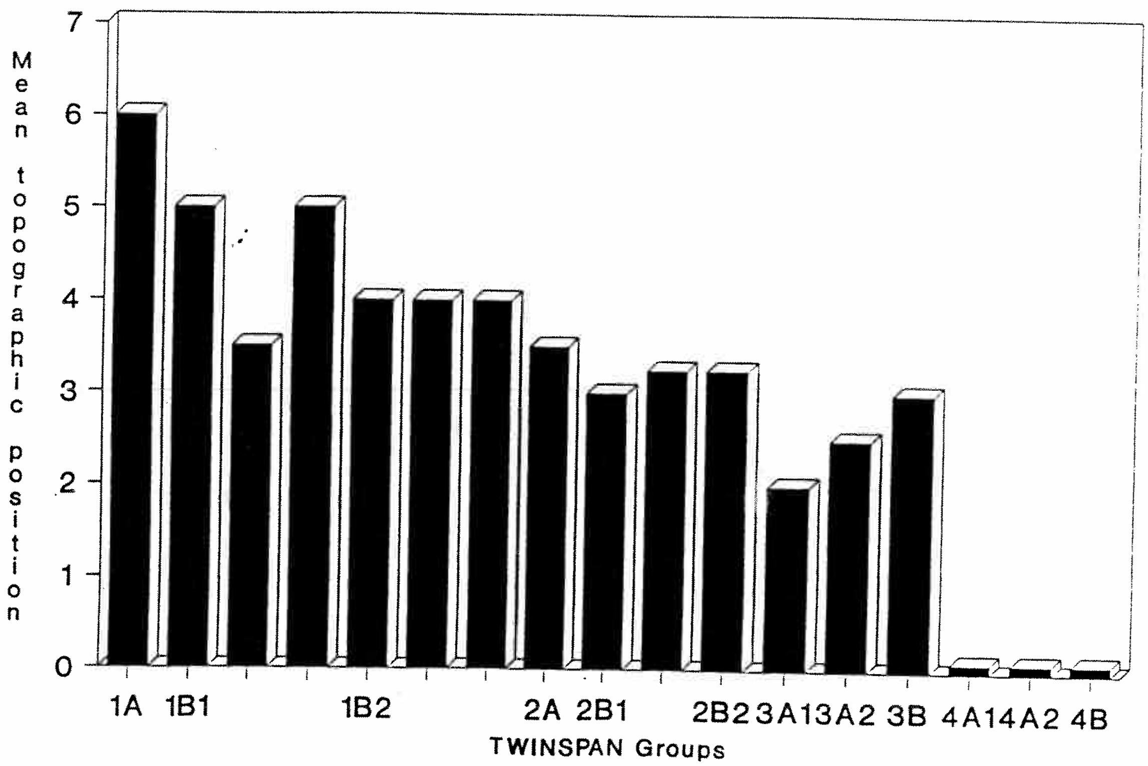


Figure 9. Mean topographic position for plots within TWINSPAN groups. 0 = bottom with some standing water, 1 = surrounded by water, 2 = lower slope, 3 = bench or draw, 4 = midslope, 5 = upper slope, 6 = ridgetop.

of larger areas but the relatively small size of the plots affected the description of each community type. Still, in the five cases in which pairs of plots were located adjacent to each other (plots 8 and 9, 11 and 12, 17 and 18, 25 and 26, and 31 and 32) both members of the pair were placed in the same group by TWINSPAN even though measured values for trees and understory differed.

Two comparisons were made between the 17 TWINSPAN groups at Beaver Creek NRCA (based on current vegetation) and other Pacific Northwest forests. First, each plot was "keyed out" to a forested plant association in the Mt. Baker-Snoqualmie National Forest as described by Henderson, et al. (1992). The national forest is located about 30 km east of the study area. Associations are based on potential climax vegetation, and each association encompasses a broader range of species assemblages and community structures than the community types delineated at Beaver Creek NRCA. The Mt. Baker-Snoqualmie classification is based on the assumptions that without major disturbance, most stands in the area will eventually develop into climax forests dominated by western hemlock and distinguished by the presence of particular understory species; and that these understory species are stabilized by the time the stand is 50 years old (Henderson, et al., 1992). The 46 plots at Beaver Creek NRCA would classified into seven Mt. Baker-Snoqualmie associations with 70% of the plots fitting the description of the western hemlock/sword fern-foamflower association.

In addition, tree composition of each plot was examined in light of two definitions of old-growth forest. For a community to be considered "old-growth" under the revised definition of Franklin and Spies (1991), the following are minimum requirements per ha: 10 trees 100 centimeters (cm) or more in diameter (dbh, diameter at breast height); 10 shade associates (western redcedar, western hemlock, or bigleaf maple, Acer macrophyllum) 40 cm dbh; four conifer snags 50 cm dbh and five m tall; a deep, multilayered canopy; and 30 tons of log biomass, including 10 pieces 60 cm diameter and 15 m long. The earlier interim definition required 20 trees 80 cm dbh or at least 200 years old; 30 trees 40 cm dbh; and 10 snags (Old-Growth Definition Task Group, 1986). Classification of Beaver Creek NRCA stands as old-growth is based on the live tree criteria only, as snags and downed wood were not measured in the study site, even through they were frequently observed and occasionally noted.

Classification and ordination positions and physical locations of plots are repeatedly referred to in the following descriptions. Plot classification is found in Figure 7, ordination in Figure 8, and physical locations in Figure 2. Table 1 summarizes measured environmental characteristics of all plots. The four groups that emerged at the second level of the TWINSPAN classification are used as a framework for discussion and are referred to as Groups I, II, III and IV. The final 17 groups are treated as subsets of these divisions, although variation is continuous in most cases. Except in the context of a TWINSPAN division, the term "indicator species" refers to an indicator of a particular soil regime described by Klinka et al. (1989).

Table 1. Environmental characteristics of plots at Beaver Creek NRCA. "Group" refers to TWINSPAN group number, slope is in percent, aspect is in degrees from north, "cover" refers to total percent cover of understory vascular plant species.

GROUP	PLOT	SLOPE	ASPECT	COVER	TOPOGRAPHY
IA	41	2	310	6	Ridgetop
IB1a	31	41	230	110	Top slope
IB1a	32	78	45	59	Top slope
IB1b	1	21	210	35	Upper slope
IB1b	6	21	210	35	Upper slope
IB1b	8	33	220	14	Upper slope
IB1b	9	12	150	68	Upper slope
IB1b	10	10	135	17	Ridgetop
IB1b	45	58	28	60	Midslope
IB1b	16	7	315	100	Midslope bench
IB1b	21	42	30	113	Midslope
IB2a1	5	12	310	64	Draw
IB2a1	33	14	35	81	Bench
IB2a1	42	16	310	84	Broad, low ridgetop
IB2a2	2	10	35	66	High draw
IB2a2	22	38	200	68	Slope above draw
IB2a2	29	58	50	89	Slope above draw
IB2a2	40	35	20	66	Midslope
IB2b	14	21	20	66	Midslope
IIA	11	16	210	49	Low ridgetop
IIA	12	28	30	94	Slope from ridge to creek
IIB1a	19	21	340	45	Pondside draw
IIB1b	27	10	180	40	Low ridgetop, near wetland
IIB1b	28	14	320	43	Draw on bench
IIB1b	37	12	300	12	High draw
IIB1b	43	38	4	53	Midslope
IIB2	13	28	40	88	Midslope
IIB2	20	3	310	106	Midslope bench
IIB2	39	36	30	97	Midslope
IIB2	44	31	54	79	Midslope
IIIA1	3	0	0	77	Flat, near pond
IIIA1	36	0	0	27	Flat, peninsula
IIIA1	15	45	40	98	Midslope
IIIA1	38	36	30	77	Midslope
IIIA2	4	6	120	100	Draw
IIIA2	7	0	0	102	Flat, near pond
IIIA2	30	7	20	119	Bench
IIIA2	46	10	150	87	Midslope
IIIB	17	21	20	169	Upper slope
IIIB	18	29	20	140	Upper slope
IVA1	23	5	214	203	Creek bottom
IVA1	24	2	300	144	Creek bottom
IVA2	25	0	0	167	Bottom
IVA2	26	2	290	172	Bottom
IVA2	34	0	0	232	Creek bottom
IVB	35	7	340	222	Low draw/bottom

Group I: Conifer-dominated communities

The first of TWINSPAN's four large divisions contains plots with the highest Douglas-fir density and basal area and the highest western redcedar density (Table 2). The largest western hemlocks are also found in this group. All plots were located on or above midslope benches and contained low to moderate vascular understory cover dominated by species of moderately dry to dry soils (Table 3). At the first division of Group I, one plot (41) containing no sword fern was separated from the rest of the group.

Group IA. "Doghair" cedar. One "doghair" cedar plot (41) was located on a narrow ridgetop along the south boundary. A few similar stands were noted on ridgetops, but this was the only one found large enough for a plot. No such stand covered more than about 1000 m^2. Plot 41 had the second-highest tree density found (Fig. 10) and included 33 western redcedars ranging in size from 3 to 44 cm dbh. One large (105 cm dbh) and several small Douglas-firs, two western hemlocks, and two paper birch were present. Meter-wide stumps and large charred snags were found in the plot.

Understory cover was the lowest of any plot (Table 3). A moss, _Eurynchium oreganum_, was the most abundant species with 4.3% cover. Oregon grape and salal (_Gaultheria shallon_) were the only other species with more than 1% cover, and only four other vascular species were present. This was one of only two plots in the Beaver Creek NRCA that had no sword fern, and it was the most isolated plot on the DECORANA ordination.

Table 2. Mean composition of the tree layer for the first four divisions of TWINSPAN. Density (Den, trees/ha), basal area (BA, m²/ha) and constancy (Con, % of plots in which species is found) are for all trees larger than 2.5 cm dbh.

Species	Group I (n=19)			Group II (n=11)			Group III (n=10)			Group IV (n=6)		
	Den	BA	Con	Den	BA	Con	Den	BA	Con	Den	BA	Con
Douglas-fir	184	106.8	89	80	58.5	73	8	0.1	10	-	-	-
Western hemlock	185	6.4	95	337	13.7	91	136	5.4	70	45	1.8	50
Western redcedar	281	18.3	100	196	19.9	100	141	28.8	90	121	10.6	83
Bigleaf maple	29	3.6	50	80	9.1	64	37	7.4	80	13	3.4	17
Red alder	10	1.1	11	48	6.3	45	270	20.6	100	214	25.3	100
Sitka spruce	-	-	-	2	3.3	9	43	1.4	20	4	+	10
Pacific yew	3	+	5	-	-	-	-	-	-	-	-	-
Paper birch	3	+	5	1	0.5	9	-	0.1	10	-	-	-
Cascara	-	-	-	-	-	-	3	+	10	-	-	-
Totals	695	136.2		744	111.3		638	63.8		397	41.1	

Table 3. Mean composition of the understory for plant communities classified in TWINSPAN Group I. Cv = % cover; F = % frequency; Cn = constancy; + = <0.05%; OG = old-growth.

	"Doghair" IA		High Ridge IB1a			Douglas-fir/sword fern (IB1b) (NE corner)			(Pond area)			OG Douglas-fir IB2a1			OG Redcedar IB2a2			"Borderline" IB2b		Group I (n=19)		
	Cv	F	Cv	F	Cn	Cv	F	Cn	Cv	F	Cn	Cv	F	Cn	Cv	F	Cn	Cv	F	Cv	F	Cn
Shrubs																						
Oregon grape	3.3	80	26.2	95	100	12.6	65	100	2.3	18	67	13.1	47	100	16.3	66	100	7.8	20	11.2	52	95
Salal	1.6	30	3.9	30	100	1.9	5	50												0.7	5	21
Elderberry	0.1	10				0.2	5	100	0.1	7	50	+	3	33	+		25	0.2	30	0.1	6	47
Red huckleberry	+		5.5	35	100	2.9	25	100	2.7	33	100	1.7	20	67	1.8	18	100			2.4	25	89
Orange honeysuckle			1.7	15	50				0.0	2	17	0.1	3	33						0.2	3	16
Twinflower			1.4	11	100	0.1	2	100	0.4	4	33									0.3	3	26
Baldhip rose			0.8	5	50	0.0		50							0.4	3	25			0.2	1	16
Trailing blackberry			0.5	25	100	0.2	5	50	+	2	17	0.1	3	33	0.1	8	75			0.1	6	42
English holly			+		100	+		50	0.6	17	100	+		33	0.5	4	75			0.3	6	68
Fool's huckleberry						2.7	10	50												0.3	1	5
Salmonberry						0.1	5	50												+	1	5
Vine maple									+	2	33	1.8	7	33						0.3	2	16
Swamp gooseberry									+	2	17									+	1	5
Ferns and fern-allies																						
Bracken fern	0.4	30	0.1	5	50										0.5	5	50			0.1	3	11
Sword fern			17.2	90	100	39.6	90	100	20.0	75	100	46.0	100	100	49.0	100	100	40.8	80	33.4	88	95
Spreading wood fern			0.8	5	50	4.9	25	100	1.1	25	83	2.1	20	67	0.5	8	50	3.3	30	1.6	18	74
Lady fern			0.2	5	50				0.9	5	17				0.5	8	25			0.4	4	16
Maidenhair fern						1.5	10	50	+		17									0.2	1	11
Forbs																						
Wall lettuce	0.1	8	17.2	73	100	12.2	58	100	5.5	45	100	0.5	17	100	0.8	16	100	0.6	8	5.5	38	100
Sweet bedstraw			3.7	38	100	14.1	65	100	4.5	38	100	4.4	36	100	1.0	16	75			4.5	34	84
Vanilla leaf			1.5	9	50	8.4	27	100	2.3	11	83	2.5	15	100	0.2	3	50	8.2	17	3.2	13	74
Starflower			1.3	17	100	+		100	0.7	8	67	0.6	11	100	0.1	2	50	3.3	25	0.7	9	74
False Solomon's seal			0.5	4	100				0.2	1	17				+		25			0.1	1	16
Evergreen violet			0.5	9	50	0.8	2	100	0.1	2	17									0.2	2	21
Foamflower			0.4	4	50	5.1	29	100	0.3	5	83	2.5	38	100	0.5	9	50			1.2	13	68
Trillium			0.3	2	100	+		50	0.2	3	83	+	1	100	0.2	1	50			0.2	2	68
Baneberry			+		50	0.3	2	100												+	0	16
Bleeding heart			0.3	2	50	0.1	2	50	0.1	1	33				+		25	1.6	3	0.2	1	37
Rattlesnake plantain			0.2	15	100	1.2	8	100	0.3	13	100	0.3	3	33						0.3	7	58
Spotted coralroot			0.0		50	+		100	+		50	+	3	33						+	0	37
Trail plant						0.1	2	50				0.2	1	33						+	0	11
Miner's lettuce						0.1	2	50	0.4	7	50	0.6	9	100	+	1	25			0.2	4	42
Pinesap									0.1	1	50	+	1	33						+	1	21
Graminoids																						
Grass spp.			1.0	11	50	0.2	4	50	+	1	17									0.1	2	16
Mosses and liverworts																						
Eurynchium oreganum	4.3	58	9.0	54	100	3.7	21	100	2.5	46	100	3.4	41	100	1.2	8	50	2.2	8	3.6	38	89
Hylocomium splendens			2.0	15	100	2.6	13	50	1.2	11	50	2.3	14	100	1.3	4	50			1.8	12	58
Rhytidiadelphus loreus			0.4	7	50	+	4	50				0.3	6	33	+	2	50	0.8	8	0.1	3	32
Plagiomnium insigne			0.3	2	50	0.4	4	100	1.6	3	33	4.1	41	100	0.2	4	50	6.4	13	1.7	10	58
Rhizomnium glabrescens			0.1	9	50	0.7	8	100	0.1	4	33	0.9	11	67	0.1	3	25	0.1	4	0.3	6	47
Leucolepis acanthoneuron			+	2	50	1.4	4	50				4.0	21	100	+	1	25			0.8	4	32
Eurynchium praelongum						1.7	29	100	+	2	17	0.1	6	67	1.8	19	75	0.9	17	0.6	10	47
Plagiothecium undulatum						1.5	9	50	0.8	9	50	0.4	7	67	0.2	4	50			0.5	6	42
Liverwort spp.	0.3	29	0.1	25	50	0.2	17	50	0.6	6	17	0.4	16	100	+	4	75			0.5	13	52
TOTAL COVER	11.1		99.4			122.5			51.0			94.2			79.9			76.2		79.9		

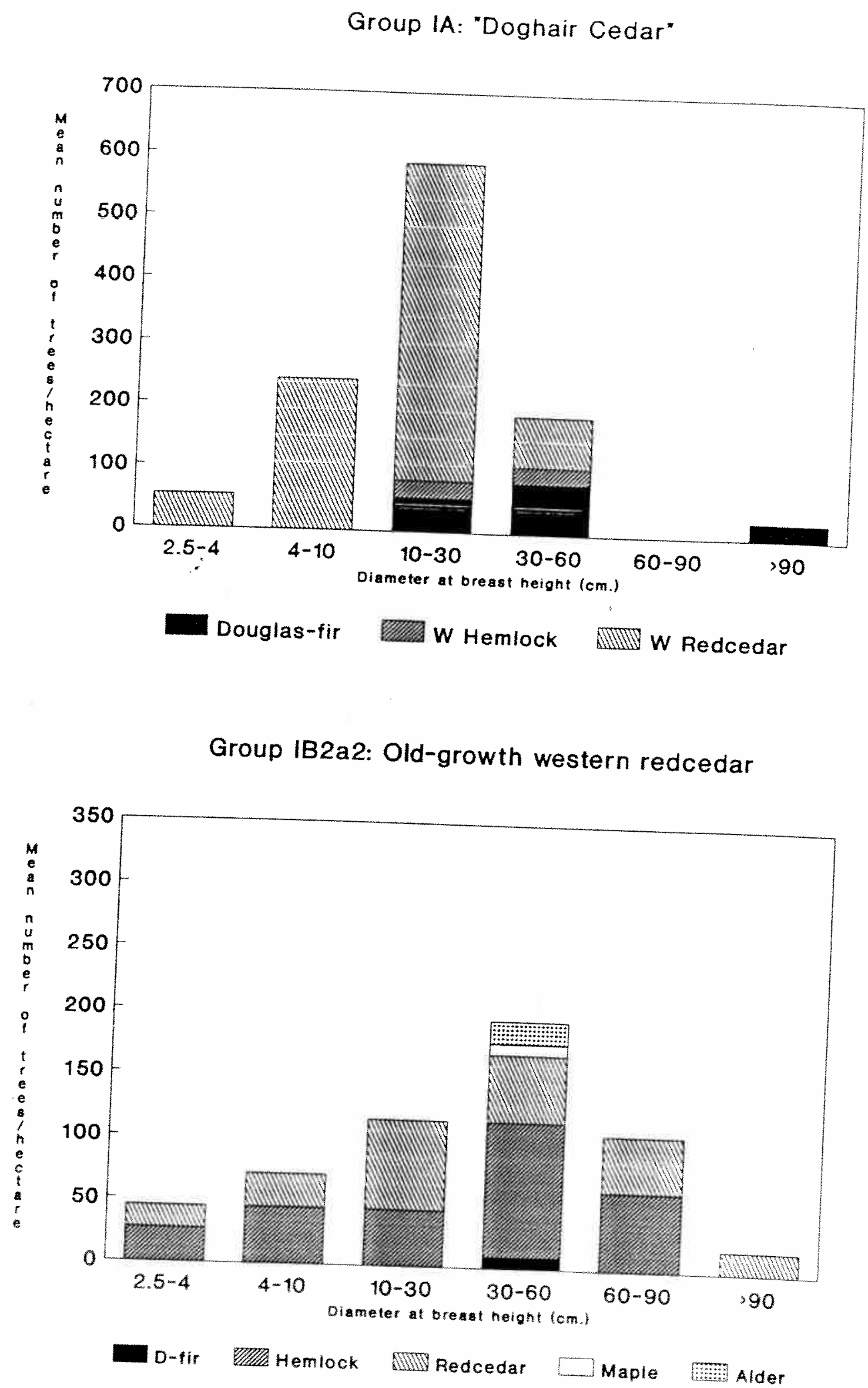


Figure 10. Size class distribution of trees in selected western redcedar plots in Group I.

Western redcedar is commonly associated with moist sites where it frequently reaches maximum size. But this is due more to its longevity and the long interval between fires than to a preference for moist conditions. Given the same successional time, the species appears to actually prefer drier areas (Henderson, 1991).

Group IB1. Douglas-fir dominated conifer stands. The 18 other plots in Group I were then divided into two subgroups, with those containing the highest values of Douglas-fir and rattlesnake plantain (Goodyera oblongifolia) on one side of the division. This group (IB1) was further divided as follows.

Group IB1a. Douglas-fir/sword fern/Oregon grape (high ridgesides). This group consists of two plots (31, 32) located on opposite sides of the ridge that descends from the highest point on the site. TWINSPAN separated these plots from the rest of Group IB due to the lack of western hemlock, which was present in all other Group I plots (100% constancy), and the presence of twinflower.

The north-facing plot (32) was the steepest sampled in the study area, with a slope of 78%. It easily falls within the interim definition of old-growth Douglas-fir (Old-growth definition task force, 1986), containing two Douglas-firs larger than 90 cm dbh, western redcedars in a range of size classes, and two small Pacific yews. The south-facing plot (31) contained smaller Douglas-firs and nearly a dozen small cedars. Thin, dry soils and relatively poor growing conditions on the steep, exposed south slope may have considerably slowed the growth of trees there. Like plot 41, western redcedar was the understory tree on this dry site. Stumps were not observed in either plot, suggesting that logging may not have occured here, perhaps due to steepness and position below the high, narrow ridge.

The most abundant understory species in both plots were sword fern, Oregon grape, wall lettuce, and the moss, Eurynchium oreganum (Table 3). Understory cover on plot 32 was 59%, including 9% cover of red huckleberry (Vaccinium parvifolium), the second-highest cover of that species in any plot. Plot 31 contained twice the understory cover of plot 32, including 25 different vascular species, second only to the area near the NRCA entrance (plot 46) in its diversity.

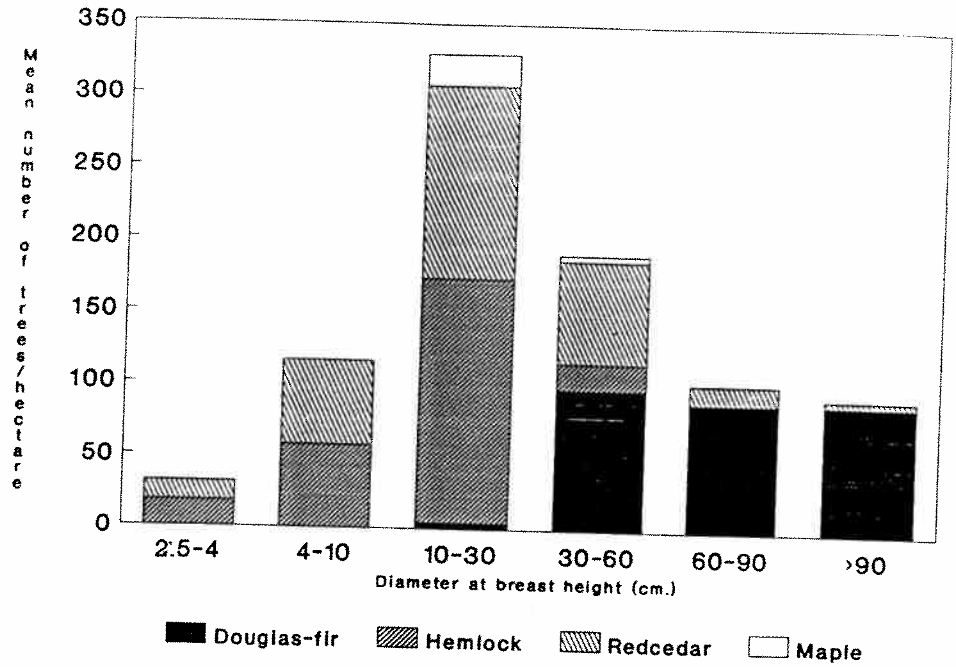
Only four vascular plant species found at Beaver Creek are indicators of moderately dry to very dry soils: baldhip rose (Rosa gymnocarpa), orange honeysuckle (Lonicera ciliosa), ocean spray (Holodiscus discolor) and creeping snowberry (Symphoricarpos hesperius). The former two species were present in small amounts in only a few plots but reached their highest cover values on the high south slope of plot 31. The latter two shrubs were found only on the ridge above plots 31 and 32, toward the highest point on the site.

Plots 31 and 32 would fit into the western hemlock/sword fern-Oregon grape association of Henderson et al. (1992).

Group IB1b. Douglas fir/sword fern. Six plots (1, 6, 8, 9, 10, 45) located on upper slopes and ridgetops north and east of the beaver pond, and two located above the northeast corner of the site (16, 21), were clustered together by TWINSPAN. The eight plots are tightly grouped on the DECORANA ordination.

These plots had the largest basal area of Douglas-fir of any area sampled (Fig. 11). Hillside and ridgetop stands near the beaver pond

Group IB1b, pond area



Group IB1b, NE corner (plots 16, 21)

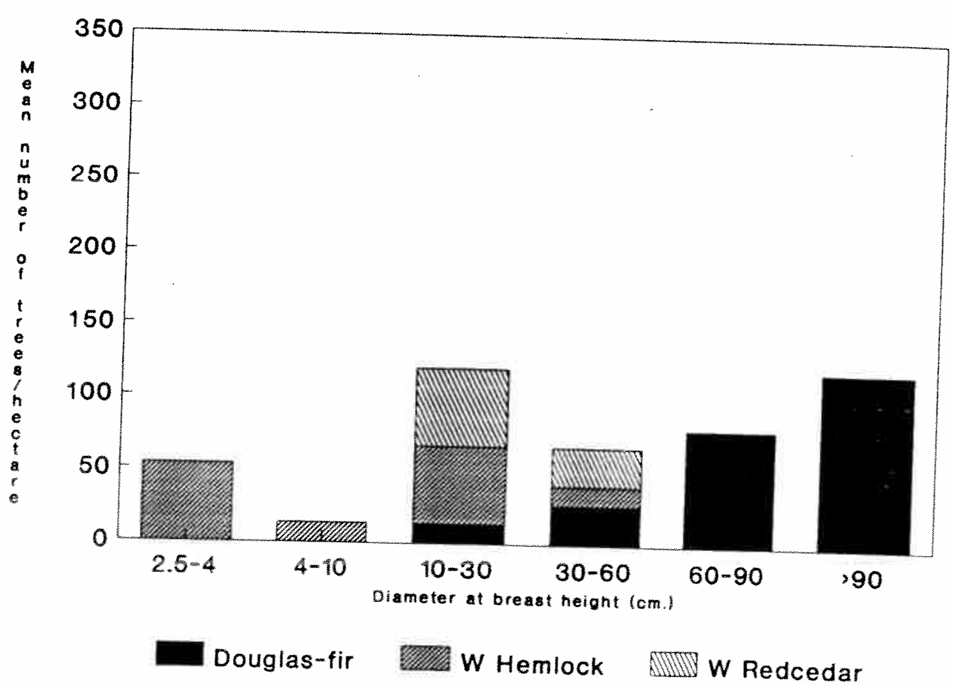


Figure 11. Size-class distribution of trees in old-growth Douglas-fir stands, Group IB1b.

averaged 136 m^2/ha for Douglas-fir, and the two stands above the northeast corner averaged 167 m^2/ha. Western hemlock and western redcedar were found in all plots; in most plots redcedar outnumbered the hemlocks. Bigleaf maple was found in half the pond-area plots, but no other deciduous trees were found in this group.

Only three of the plots (1, 6, 10) would be considered old-growth, all under the revised definition of Franklin and Spies (1991). Although the other plots had sufficient numbers of large Douglas-fir trees and a multilayered canopy, the shade-tolerant associates were not large enough to meet old-growth criteria.

The cover type represented by the plots in the vicinity of the pond had sparse to moderate understory cover, ranging from 17% to 68% for vascular plant species (Table 3). Plots above the northeast corner had 100% and 113% vascular plant understory cover. Understory species with 100% constancy in the group, in order of abundance, were sword fern, wall lettuce, sweet bedstraw (Galium triflorum), red huckleberry, and Eurynchium oreganum. Spreading wood fern, English holly, and rattlesnake plantain were present in all but one plot. All plots fit into the western hemlock/sword fern-foamflower association of Henderson et al. (1992), except plots 16 and 45, which fall into the western hemlock/sword fern-Oregon grape association. These latter two plots were also classified separately by TWINSPAN but are grouped with the other plots in Group IB1 by DECORANA.

This cover type contained four understory species found in no other group: twinflower (Linnaea borealis), pink wintergreen (Pyrola asarifolia), false Solomon's-seal (Smilacina racemosa), and evergreen violet (Viola sempervirens). The saprophytes, Indian pipe (Monotropa uniflora), Pinesap (Hypopitys monotropa), and spotted coralroot (Corallorhiza maculata), were found only in this group and in Group IB2.

Group IB2. Mixed conifer. Plots in this group were located in draws and on hillsides, most with fairly low slope, and had slightly greater total understory cover than group IB1. Stands generally had higher values of western redcedar and lower values of Douglas-fir than those in Group IB1. All stands fell under Franklin and Spies' (1991) definition of old-growth Douglas-fir or western redcedar forest, and all but one (see plot 14, below) represent the western hemlock/sword fern-foamflower association of Henderson et al. (1992).

TWINSPAN split Group IB2 into 3 subgroups, but the subgroups do not form clusters on the DECORANA ordination like Group IB1 does. Each plot is located closer to a plot in Group IB1 or Group II than to one in its own group. Plots in Group IB2 were more varied in topography and tree composition than those in Group IB1.

No species were found exclusively in Group IB2 but sword fern, Oregon grape, and wall lettuce were present in all plots (Table 3). Sword fern was the most abundant understory species, averaging 47% cover, and Oregon grape averaged 15% cover. Red alder, vine maple (Acer circinatum), and lady fern (Athyrium filix-femina), found in one or two plots each, were not found elsewhere in Group I.

Group IB2a1. Old-growth Douglas-fir. The first cover type consists of a plot (5) in a high draw in the south-central area of the site and two plots (33, 42) located along an old roadbed over the intervening ridge. All three plots had relatively low slopes and were dominated by Douglas-fir, although large western redcedars were found in the middle of the draw in plot 5 and surrounding a wet area in the middle of plot 33. Each plot contained one of the seven largest bigleaf maples measured in the study area. Sword fern and Oregon grape were the dominant understory species in the roadbed, sword fern and vine maple in the draw (Table 3). These stands can be classified as old-growth Douglas-fir (Franklin and Spies, 1991), and as part of the western hemlock/sword fern-foamflower association (Henderson et al., 1992).

Group IB2a2. Old-growth western redcedar. This group includes a plot in a draw above the beaver pond (2), one on the hillside above the northeast boundary (40), and two on short slopes between ridgetops and high draws (22, 29). The latter two plots were widely separated on the same long ridge, had very similar topographic position and understory, and were the only plots in Group I lacking Douglas-fir. Plot 22 faced southwest and plot 29 faced northeast. All four plots would be included in the western hemlock/sword fern-foamflower association of Henderson et al. (1992). Stumps were noted in plots 2, 22, and 40; large trees were found in all plots; and nearly 90% of the understory in each plot was composed of sword fern and Oregon grape (Table 3).

In the draw (plot 2) western redcedar had the highest density and largest individuals, but several large Douglas-firs were also present. The third largest western redcedar measured on the site, 113.4 cm dbh, was found here. This is the only stand sampled at Beaver Creek NRCA that meets the criteria of Franklin and Spies (1991) for old-growth Douglas-fir/western red cedar.

The other three plots (22, 29, 40) contained the five largest western hemlocks measured on the site, as well as the fourth and sixth largest cedars. Only plot 40 contained a Douglas-fir, and all three plots are classified borderline with Group II by TWINSPAN. The only trees in plot 22 were western hemlocks and western redcedars, in approximately equal numbers and sizes. The cover type represented by this plot, extending along the ridge, was the only one sampled that would be classified as old-growth western redcedar/western hemlock according to the interim definition of the Old-growth task group (1986). Cover types represented by plots 29 and 40 would be considered old-growth western redcedar by that definition.

Group IB2b. Borderline with Group II. The remaining group in IB2 is composed of a single plot (14) located on a sloping bench above a steep area near the northeast corner. The largest Douglas-fir was 79.5 cm dbh and abundant western redcedar trees larger than 40 cm dbh were present. The stand was unusual in containing all five of the study area's major tree species. Red alder is an important component of this coverage type.

Plot 14 contained only eight understory vascular plant species, with moderate total cover (Table 3). Sword fern was the dominant understory species, and other understory species were as diverse as the trees in the plot. Oregon grape, an indicator of moderately dry and fresh soils, Plagiomnium insigne, an indicator of very moist and wet soils, and vanilla leaf all had more than 5% cover. The plot also had the highest cover at Beaver Creek NRCA of bleeding heart (Dicentra formosa), an indicator of fresh and very moist soils. Plot 14 could be classified in the western hemlock/sword fern-Oregon grape association of Henderson et al. (1992), only found elsewhere on the site on high, dry hillsides. DECORANA placed the plot close to the cluster of Group IB1, while TWINSPAN classified the plot borderline with Group II.

This plot was a microcosm of the diversity at BCNRCA. Logging, evidenced by the presence of several stumps over 120 cm in diameter, opened the canopy and may have allowed the growth of red alder within a stand that is close to old-growth. The microtopography (a midslope bench) allowed some accumulation of moisture that would normally be lost down the steep slope. Most midslope benches on the site contained at least a small area with a higher water table. In some cases this was evidenced by a mucky area and the presence of skunk cabbage (*Lysichitum americanum*); in others the muck was absent and the evidence was seen in less showy indicator species such as the mosses *Plagiomnium insigne*, *Leucoplepis menziesii*, or *Eurynchium praelongum*. In plot 14, *P. insigne* had almost as much cover as Oregon grape, but the two species were found in different parts of the plot.

Group II: Old-growth Douglas-fir and western redcedar

The second of the four largest divisions by TWINSPAN contains plots located from pond-side to ridgetop, but average topographic position and slope were lower than in Group I (Table 1, Fig. 9). On the DECORANA ordination, almost all plots are closer to plots in Group I or Group III than to another Group II plot. All plots contained western redcedar and sword fern, and all but one contained western hemlock and spreading wood fern. Following the definition of Franklin and Spies

(1991), all could be considered old-growth Douglas-fir or western redcedar. Plots with the fourth and sixth largest basal areas of Douglas-fir are in this group, although mean density and basal area were considerably lower than in Group I, and some plots contained no Douglas-fir. More than half the plots contained red alder. No species were found solely in this group; but bracken fern (Pteridium aquilinum), miner's lettuce (Montia sibirica), and foamflower (Tiarella trifoliata) had their highest cover values here.

TWINSPAN divides this group of 11 plots into four subgroups. Two plots on a low ridge above the northwest wet area are joined at the fourth level of similarity based partially on the abundance of vine maple, the indicator species. The other groups consist of loose associations of plots dominated by different combinations of the five major tree species on the site. With the exception of plot 11, discussed next, all plots fit the description of the western hemlock/sword fern-foamflower association (Henderson et al., 1992).

Group IIA. Mixed conifer/vine maple. This group consists of two plots (11, 12) located on a narrow ridge in the northwest corner of the site, bounded by a wide wetland to the south and a creek to the north. The plots are widely separated on the ordination. Plot 11, which contained large Douglas-firs, numerous western hemlocks, and a few western redcedars, was similar in overstory composition to plots in Group I; while plot 12, which contained no Douglas-firs but did have an alder and a spruce, is closer to plots in Group III.

The south-facing plot (11) was mostly flat and located 3-4 m above the level of the wetland. Distinguishing this plot from all others seen at Beaver Creek NRCA was the composition of the understory (Table 4). Vine maple had 43% cover. Two mosses, Hylocomium splendens (7% cover), and Eurynchium oreganum (5% cover) had the next highest cover values. Red huckleberry and Oregon grape were the only vascular plant species (besides vine maple) with more than 1% cover. This is the only cover type found that fits the definition of the western hemlock/vine maple-Oregon grape association of Henderson et al. (1992).

In the north-facing plot, western hemlock and western redcedar shared dominance. Again, vine maple was the dominant understory species. In this case ferns (sword fern and spreading wood fern combined) had 56% coverage, and a moss, Plagiomnium insigne, had higher coverage than any herbaceous flowering plant species. This moss is an indicator of very wet to moist soils. Plot 12 was steeper than plot 11, and descended to a creek where there was one large Sitka spruce.

Group IIB1a. Western redcedar/sword fern/lady fern. Plot 19, in a draw between the beaver pond and the trail, stands alone in the TWINSPAN output, connected to the mixed conifer plots at the third level of similarity. Western redcedar was dominant. Total vascular understory cover was 45% with sword fern, lady fern, and spreading wood fern together accounting for more than 80% of that amount (Table 4). Enchanter's nightshade (Circaea alpina), not present in other Group I or II plots, had its highest cover (5%) in the study area in this stand.

Group IIB1b. Mixed conifer/sword fern. These plots (27, 28, 37 and 43) had low levels of understory cover (Table 4). Sword fern was the only vascular plant species with more than 5% cover, with the exception of red huckleberry which was found in one plot. All four plots were

Table 4. Mean composition of the understory for plant communities classified in TWINSPAN Group II. Cv = % cover; F = % frequency; Cn = constancy; + = <0.05%; OG = old growth.

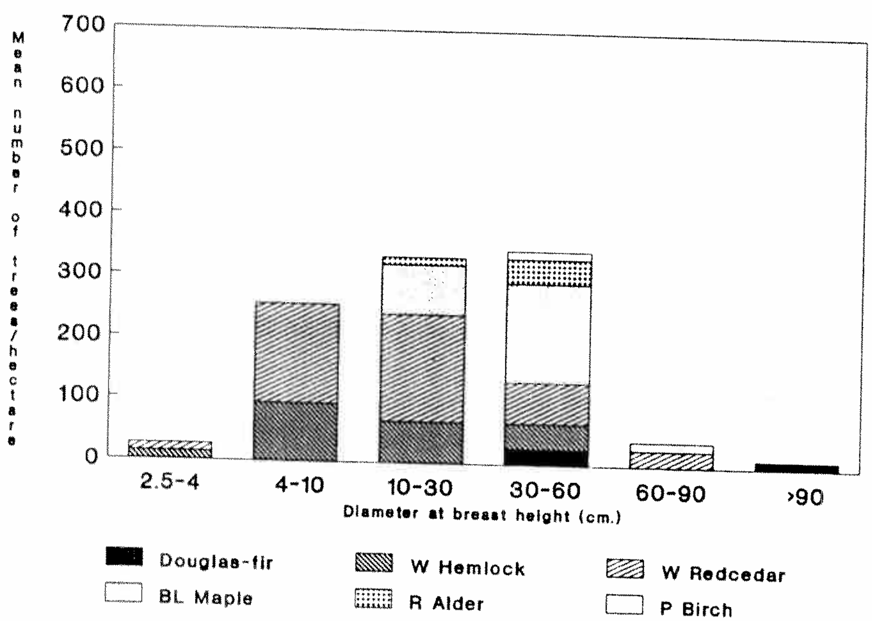
	OG/Vine maple (IIA)				OG Redcedar/fern		OG Conifer/sw.fern			OG Douglas-fir			Group II		
	Plot 11		Plot 12		IIB1a		IIB1b			IIB2			(n=11)		
	Cv	F	Cv	F	Cv	F	Cv	F	Cn	Cv	F	Cn	Cv	F	Cn
Shrubs															
Vine maple	42.5	80	34.3	90									7.0	16	18
Red huckleberry	4.8	40			0.1	10	4.1	18	50	0.9	10	25	2.2	15	45
Oregon grape	1.5	10					0.1	3	25	0.2	5	50	0.2	4	36
English holly	0.1	10					2.1	3	50	0.4	7	50	0.9	5	45
Elderberry					0.1	20	0.3	18	50	1.8	40	100	0.8	23	64
Thimbleberry										0.4	3	25	0.1	1	25
Ferns and fern-allies															
Sword fern	0.4	20	35.6	90	16.4	80	24.5	68	100	54.5	100	100	33.5	78	100
Spreading wood fern			19.5	100	8.1	70	1.1	18	100	9.3	63	100	6.3	45	91
Lady fern					12.6	70	0.5	8	25	7.0	33	100	3.9	21	55
Bracken fern							2.9	30	100	0.4	3	25	1.2	12	45
Maidenhair fern										0.4	3	25	0.1	1	9
Licorice fern										0.4	3	25	0.1	1	9
Forbs															
Foamflower	0.1	5	3.4	20	0.1	4	+	2	25	4.1	19	100	1.8	10	73
Rattlesnake plantain	+	5	0.1	3			+	1	25				+	1	27
Wall lettuce	+	4			+	4	0.4	5	75	2.0	21	100	0.9	10	82
Sweet bedstraw	+	3	+	3	1.6	4	0.6	5	75	4.5	22	50	2.0	11	73
Trillium	+		1.0	5			+		25	+	1	50	0.1	1	36
Miner's lettuce			+	5	0.3	8	0.4	2	50	3.7	38	100	1.5	16	73
Enchanter's nightshade					5.4	21							0.5	2	9
Youth-on-age					0.6	8				1.1	2	50	0.4	2	27
Vanilla leaf							+	1	75	1.8	8	50	0.7	3	45
Crisped starwort										0.3	1	25	0.1	+	9
Bleeding heart										0.6	3	25	0.2	1	9
Mosses and liverworts															
Hylocomium splendens	7.3	30	1.6	10			1.4	7	25	1.0	9	75	1.7	9	55
Eurynchium oreganum	5.2	46	2.0	26	0.2	13	2.7	20	75	0.8	7	50	2.0	17	73
Plagiothecium undulatum	2.7	60	1.6	40	0.9	13	0.7	12	75	0.6	8	75	1.0	17	82
Rhytidiadelphus loreus	1.4	30	0.2	26	0.6	8	0.2	7	50	0.5	11	100	0.5	12	82
Plagiomnium insigne	1.0	16	9.7	76	0.2	17	0.1	5	50	7.7	42	100	3.8	27	82
Eurynchium praelongum	0.8	40	3.7	50	1.1	29	0.2	3	25	2.8	36	100	1.6	25	73
Rhizomnium glabrescens	0.3	36	0.7	36	3.3	33	1.1	11	50	0.9	7	25	1.1	16	55
Eurynchium sp.							0.8	5	50	0.8	10	50	0.6	5	36
Rhizomnium sp.							0.2	7	75	0.1	4	50	0.1	4	45
Moss spp.	0.2	25	0.9	17	0.1	4	0.6		100	0.6	1	100	0.5	5	100
Liverwort spp.							0.5	15	75	0.3	3	25	0.3	6	36
TOTAL COVER	68.5		114.9		51.7		45.4			111.4			78.4		

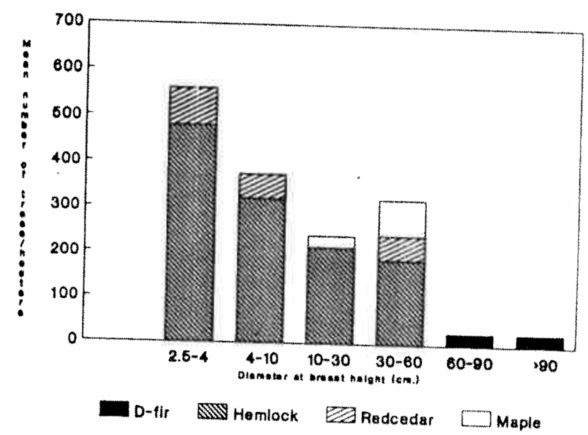
located near the north line in the central or western part of the conservation area. This was the only group in which bigleaf maples larger than 40 cm dbh were found in every plot.

Plot 27 is classified borderline with plots 11 and 12. Located on a flat above the north wetland, its aspect, slope, and height above standing water were similar to plot 11. Plot 27 had two large Douglas-firs, several western redcedars, and nearly 60 western hemlocks that were over two meters tall (Fig. 12). This cover type had the highest density of trees on the site. Vascular understory, mostly sword fern and red huckleberry, covered 40% of the plot (Table 4). Like plot 11, Hylocomium splendens and Eurynchium oreganum were the dominant ground-level species, each having a cover value of 6%.

Plot 37 was located in a slight concavity on top of a ridge. Like the Douglas-fir dominated community north of the beaver pond (Group IB1b), it contained several Douglas-firs greater than 100 cm dbh (Fig. 12). But in plot 37 bigleaf maples were the second largest trees, and western redcedar was more abundant than it was in the beaver pond area. Vascular understory cover was only 12% and included sword fern, bracken fern, elderberry seedlings and miner's lettuce (Table 4). Bigleaf maple leaves covered the ground.

Plots 28 and 43 represented a fairly large area up the ridge to the east of the north wetland. Plot 28 had numerous western redcedars, plot 43 redcedars and western hemlocks, and both had the highest density and basal area of bigleaf maple of any area sampled. Large Douglas-firs were present but not abundant and red alder and paper birch were present (Fig. 12). At least two-thirds of the understory cover was sword fern.





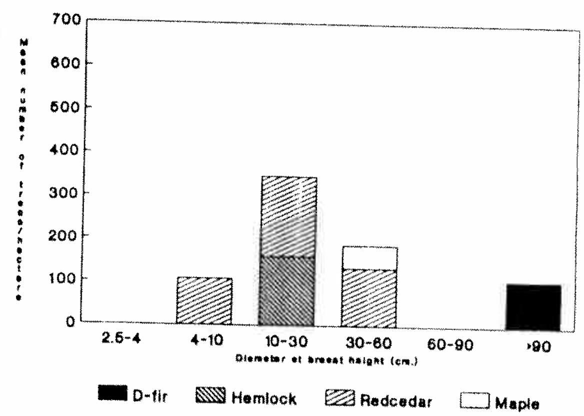


Figure 12. Size class distribution of trees in selected Group II plots.

Group IIB2. Douglas-fir dominant, red alder present or lady fern abundant. These four plots (13, 20, 39, 44) would all be classified old-growth Douglas-fir according to the system of Franklin and Spies (1991). They were located on northeast- or northwest-facing midslopes or benches and had nearly 100% understory cover. Old cut stumps were present in or near all plots. Sword fern was the dominant understory species, with 44-74% cover. Spreading wood fern, miner's lettuce, and foamflower (Tiarella trifoliata), all indicators of fresh and very moist soils, and lady fern, an indicator of very moist and wet soils, were common in all plots (Table 4).

Plots 13 and 20 were located above the northeast corner and had tree composition similar to the Douglas-fir-dominant plots of Group IB1 (Figs. 11, 13), but with the higher understory cover and the indicators of fresh to very moist or wet soils mentioned above. Plot 20 contained the largest Douglas-fir found in the conservation area, 214 cm dbh. An old wedge cut (about 35 cm deep) was present in the tree. Two large cut Douglas-firs were lying on the ground nearby and other large Douglas-firs were in the vicinity.

The other two plots (39, 44) were dominated by Douglas-fir but had much smaller total basal area of that species, smaller western hemlocks and western redcedars, and relatively high basal areas of red alder and/or bigleaf maple (Fig. 13). These plots were located on broad hillsides and represented mixed stands covering large areas. Due to a few large bigleaf maples and/or red alders the canopy appears largely deciduous in aerial photos, but substantial numbers of western hemlock were present under the canopy.

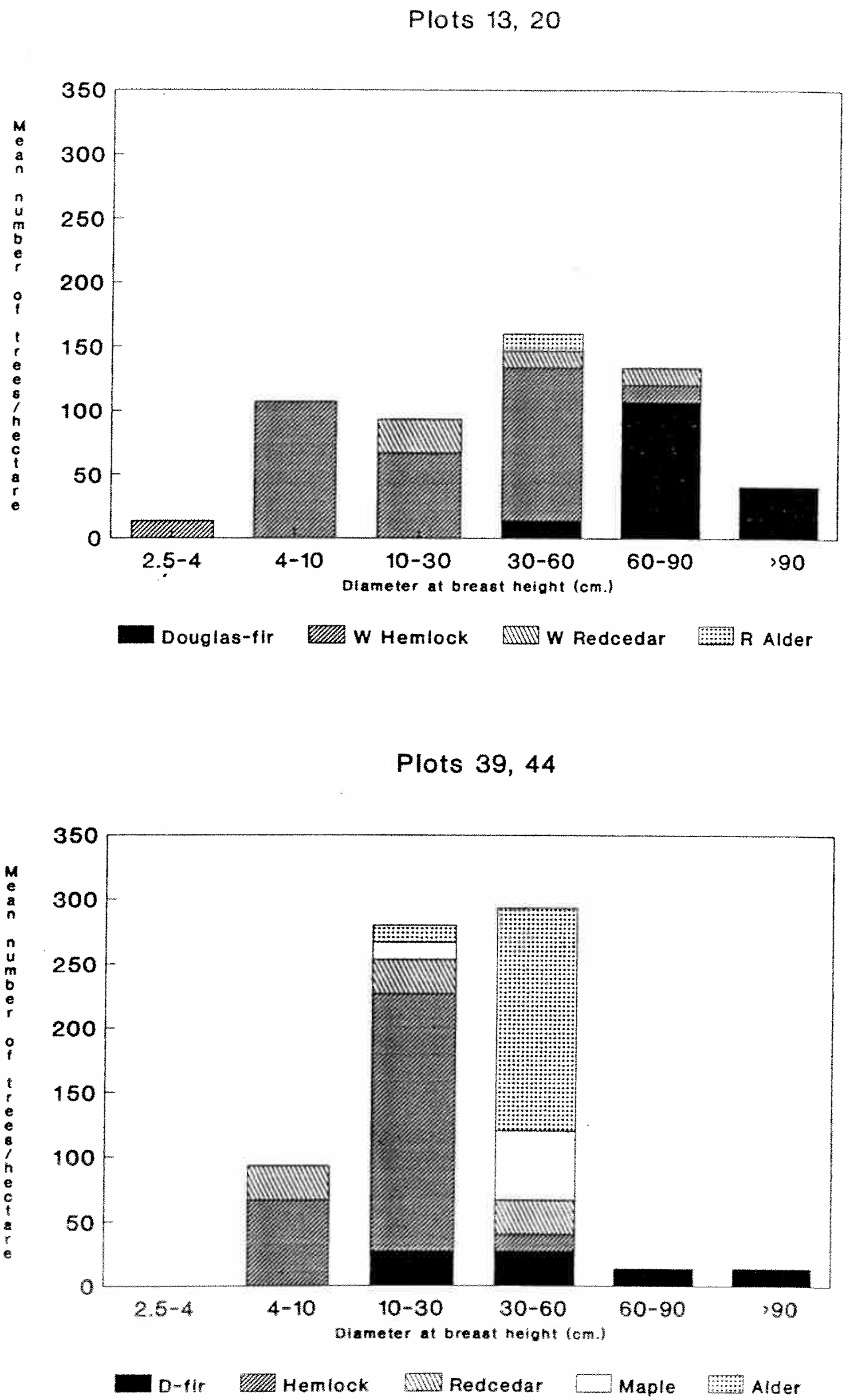


Figure 13. Size-class distribution of trees in selected Group II plots.

Group III: Alder, no Douglas-fir (lacks standing water table)

Group III is distinguished from Groups I and II by the presence of red alder and species found on moist substrates and the absence of Douglas-fir in nearly all plots (Table 2). Like Group II, III contains a wide variety of community types and species. Slopes ranged from 0% to 45%. Plots were located in a variety of topographic positions, but no ridgetop or bottoms stands were classified in this group (Table 1).

Four of the six largest measured maples were found in Group III. Average understory cover, 120%, was the second highest on the site. The only vascular plant species with 100% constancy were sword fern and spreading wood fern. No species were found exclusively in the group, but several reached their highest cover values here, including sword fern (69%), vine maple (64%), spreading wood fern (38%), Plagiomnium insigne (30%), and devil's club (Oplopanax horridum, 26%) (Table 5).

TWINSPAN classifies two plots representing an alder stand distinct from the rest of the group. The second division separates plots dominated by red alder or containing Sitka spruce from low-slope old-growth western redcedar communities.

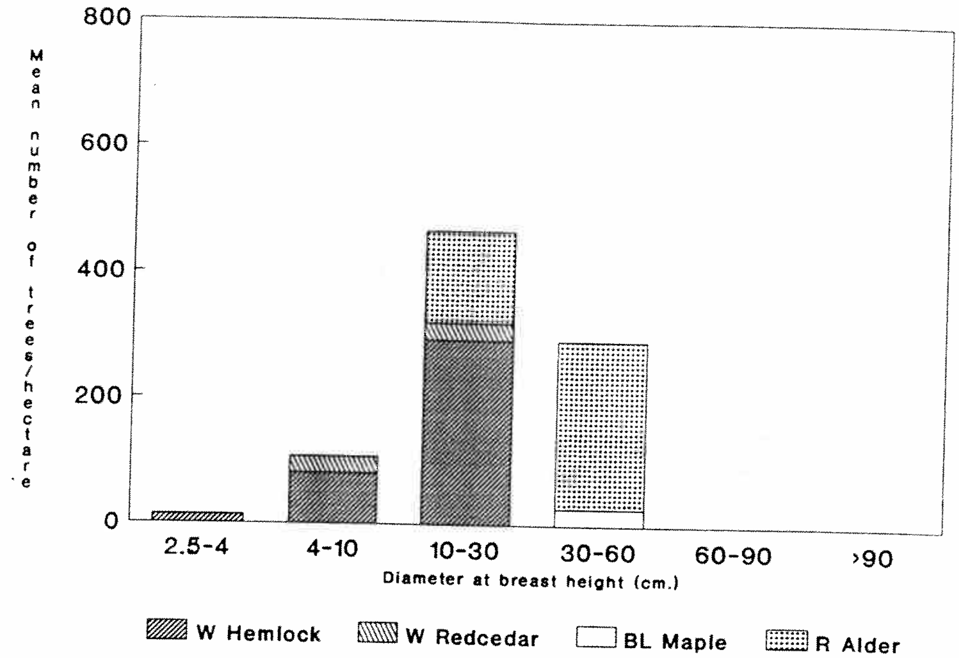
Group IIIA1. Mixed alder/conifer. This group of four plots represents three different community types, all containing red alder, western redcedar and western hemlock. All plots were flat or midslope.

Two plots (15, 38) that occupied midslope positions above the northeast boundary represented a mixed coniferous/deciduous forest covering a fairly long hillside (Fig. 14). The community was similar to that represented by plots 39 and 44 (Group IIB2), but red alder dominated the tree layer. Plot 15 had 24 western hemlocks under 27 cm dbh.

Table 5. Mean composition of the understory for plant communities classified in TWINSPAN Group III. Cv = % cover; F = % frequency; Cn = % constancy; + = <0.5%; OG = old-growth.

	Alder Hillside IIIB			OG Redcedar IIIA2			Spruce/Alder IIIA1 (Plot 3)		Spruce/Conifer IIIA1 (Plot 36)		Mixed conifer/alder IIIA1 (15, 38)			Group III (n=10)		
	Cv	F	Cn	Cv	F	Cn	Cv	F	Cv	F	Cv	F	Cn	Cv	F	Cn
Shrubs																
Vine maple	54.8	80	100	2.9	8	25								12.1	19	30
Devil's club	17.1	50	100											3.4	10	20
Salmonberry	2.8	20	100	7.1	38	100	15.4	75	0.3	10	2.7	15	50	8.9	31	90
Elderberry	1.6	20	100	2.6	23	75	6.7	25			4.1	50	100	2.9	26	80
Red huckleberry	1.6	15	100	0.1	8	25	0.4	13	0.1	10	0.1	5	50	+	10	60
Swamp gooseberry	0.9	15	50								0.1	5	50	+	4	20
Trailing blackberry	0.4	15	100	1.1	8	25	7.0	50			0.2	5	50	1.2	12	50
Stink currant				1.4	8	50								+	3	20
Oregon grape				0.4	3	25								+	1	10
Ferns and fern-allies																
Sword fern	59.6	90	100	27.9	93	100	5.1	25	18.4	80	60.4	95	100	37.5	75	100
Spreading wood fern	2.4	30	100	13.9	58	100	37.9	88	3.5	60	5.1	35	100	8.4	51	100
Lady fern	0.2	5	50	18.5	63	100			1.0	40	3.8	35	100	8.3	37	80
Licorice fern				0.2	3	25					2.0	10	100	+	3	30
Forbs																
Stinging nettle	4.8	20	100	4.5	8	25					1.8	2	50	3.1	8	40
Northern starwort	3.1	7	100											+	1	20
Foamflower	2.0	12	100	4.2	28	75			1.3	8				2.2	14	60
Miner's lettuce	1.2	15	100	1.7	28	100	3.4	27			2.8	48	100	1.8	15	90
Youth-on-age	0.6	4	100	4.0	15	50					2.4	7	50	2.2	8	50
Trillium	0.5	2	100	0.2	2	50	0.5	4	0.1	4				+	2	60
Wall lettuce	0.2	7	50	2.1	13	100	+	3			0.3	13	100	1.0	10	80
Enchanter's nightshade	0.1	2	50	1.8	13	75								1.0	6	40
Bleeding heart	+		100	0.6	3	25	+	2			0.7	5	50	+	2	50
Skunk cabbage				2.9	5	50								2.0	2	20
Sweet bedstraw				0.6	8	75					0.3	2	50	+	4	40
Creeping buttercup				0.6	3	25								+	1	10
Creeping Charlie				0.4	3	25								+	1	10
Goatsbeard				0.4	2	25								+	1	10
False lily-of-the-valley									2.3	17				+	2	10
Crisped starwort											1.3	2	50	+	+	10
Graminoids																
Woodreed	1.4	4	50											+	1	10
Sedge spp.				0.6	3	25								+	1	10
Mosses and liverworts																
Plagiomnium insigne	9.3	54	100	15.2	38	100	2.9	3			3.9	19	100	9.0	30	90
Eurynchium praelongum	5.2	48	100	3.7	30	100	0.5	17			6.3	40	100	3.9	31	90
Rhytidiadelphus loreus	2.5	10	100	0.4	4	100			1.1	25	0.1	2	100	0.8	7	90
Plagiothecium undulatum	1.5	8	100	0.7	7	75			3.2	21	0.3	2	50	1.0	7	70
Hylocomium splendens	0.6	4	50	0.7	1	25			0.1	4	0.1	2	50	+	2	40
Rhizomnium glabrescens	0.4	12	100	2.0	8	50	1.0	13						1.0	7	50
Eurynchium oreganum	0.3	4	100	1.7	8	25	0.5	10			0.7	11	100	0.9	7	60
Leucolepis acanthoneuron	0.3	2	50	+	2	50					0.4	6	100	+	2	50
Isothecium stoloniferum				0.5	6	50					0.7	6	50	+	+	30
Eurychium spp.				0.5	7	50			5.8	54				0.8	8	30
Isopterygium elegans				0.2	4	25					0.1	2	50	+	2	20
Rhizomnium spp.				+	3	25			5.1	38	0.3	2	50	0.6	5	30
Isothecium spp.				+	1	25			1.3	33				+	3	20
Rhytidiadelphus triquetrus				+	1	25					1.4	8	50	+	2	20
Moss spp.	0.6	8	100	0.4	4.3	50			7.2	38	0.6	13	50	1.1	4	60
Liverwort spp.	+	2	100	0.2	7.5	50								+	3	40
TOTAL COVER	175.3			128.6			81.4		52.5		102.6			115.1		

Plots 15, 38 (Group IIIA1)



Group IIIA2: Old-growth western redcedar

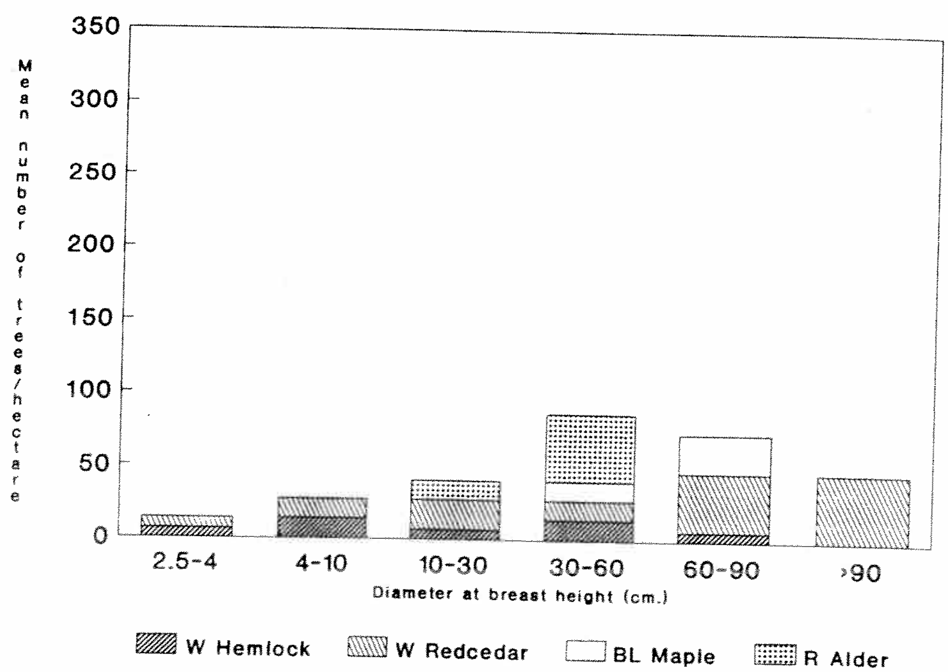


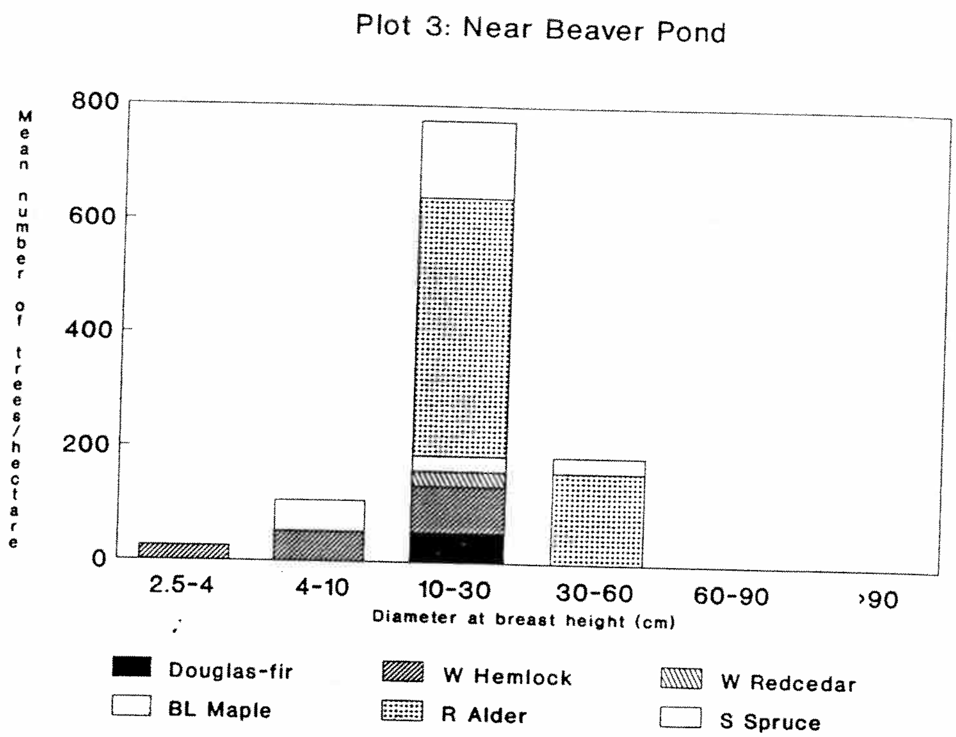
Figure 14. Size-class distribution of trees in selected Group III plots.

Plot 38 had fewer, but larger, trees. The dominant understory species in both plots was sword fern, and a moss, either Eurynchium praelongum or Plagiomnium insigne, had the second-highest cover in each plot (Table 5). Both mosses are indicators of very moist and wet soils.

The other plots were located near wetlands, one between the beaver pond and outlet creek, and the other on a peninsula within the north wetlands. Each contained western hemlock, red alder, and eight Sitka spruce ranging in diameter from about 10 cm to 30 cm (Fig. 15). In other respects, the vegetation of the communities differed.

The north wetland plot (36) was dominated by western redcedar and western hemlock and had only 27% vascular understory cover, two-thirds of that sword fern (Table 5). Rattlesnake plantain, an indicator species for the Douglas-fir-dominated communities in Group I, was present.

The plot (3) between the beaver pond and outlet creek was dominated by red alder. Vascular understory cover was 77% and included spreading wood fern, elderberry and salmonberry (Rubus spectabilis), indicators of fresh, very moist and wet soils. Cores taken from a few standing trees and the presence of windthrown trees nearby suggest that the community might have originated after the Columbus Day windstorm of 1962. On mineral soil with side shade and overhead light, Sitka spruce is a fast-growing tree (Fowells, 1965). Red alder and Sitka spruce grow well over shallow water tables that are flowing (Minore and Smith, 1971). This is one of only two plots in this study that could not be categorized by the classification of Henderson, et al. (1992). The other Group IIIA1 stands are described by the western hemlock/sword fern-foamflower association.



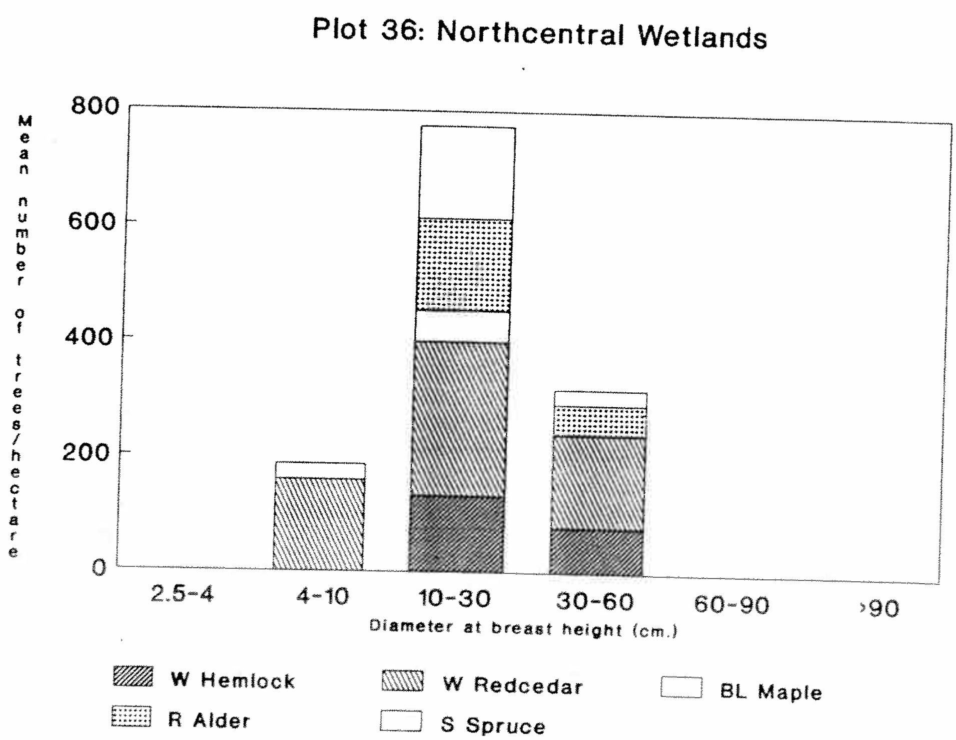


Figure 15. Size-class distribution for trees in Group III plots containing Sitka spruce.

Group IIIA2. Old-growth western redcedar. This group contained flat or low-slope plots. Western redcedar was dominant and bigleaf maple and/or red alder had the second highest density and basal area in three of the four plots (Fig. 14). All plots fit Franklin and Spies' (1991) definition of western redcedar old-growth, with redcedar, western hemlock, or bigleaf maple the shade-associate; and all fit the western hemlock/sword fern-foamflower association of Henderson, et al. (1992), except for part of plot 30 which was western hemlock/skunk cabbage.

Mean total understory cover was 102% (Table 5). Sword fern, lady fern, wood fern, Plagiomnium insigne, salmonberry, foamflower, miner's lettuce, and wall lettuce were were present in all plots.

Plot 4 straddled a low draw that contained seasonal standing water. Plot 30 was on a bench also straddling a wet area. Both understories were dominated by a combination of sword fern and lady fern or wood fern and contained skunk cabbage (Lysichitum americanum), an indicator of wet and very wet soils. Plot 30 contained the two largest western redcedars found in the NRCA.

Plot 7, on the south side of the beaver pond, was flat. Its understory was dominated by almost equal coverage of spreading wood fern, lady fern, and sword fern, and it also contained more than 5% cover of elderberry, salmonberry and stink currant (Ribes bracteosum). The latter two species are indicators of very moist and wet soils.

Plot 46, which included a section of trail and old roadbed and was located close to the entrance to the NRCA, had the greatest species diversity of any area sampled (28 understory species). The most abundant understory species was Plagiomnium insigne with 30% cover, the highest recorded for that species at the study site. Lady fern, sword fern, salmonberry, youth-on-age, Eurynchium oreganum, and wall lettuce all had more than 5% cover. Species found in no other plot included Indian plum or osoberry (Oemleria cerasiformis), goatsbeard (Aruncus sylvester), largeleaved avens (Geum macrophyllum), and two exotics, creeping buttercup (Ranunculus repens) and creeping Charlie (Glecoma hederacea).

Group IIIB. Alder/sword fern/vine maple/devil's club. East of the beaver pond along the south boundary of the conservation area was a dense stand of red alder (Fig. 16). Stumps in the stand appeared to be cut more recently than stumps found in other areas of the site. One of the plots contained the highest density of red alder and the highest cover of devil's club on the site. Total vascular understory coverage averaged 155%, with vine maple and sword fern, combined, accounting for approximately three-fourths of that amount (Table 5). Devil's club, Eurynchium praelongum, and Plagiumnium insigne each had more than 5% cover in the community, and stinging nettle was abundant in one plot.

Group IV: Bottoms

Bottom plots occupy the right extremes of the TWINSPAN and DECORANA outputs. Stands were located at topographic low points, with slopes ranging from 0 to 7% (Table 1). Red alder had the highest density and basal area, except in plot 34, although the largest trees were western redcedars (Fig. 17). Small western hemlocks were present in half the plots, either growing on downed logs or on "hummocks" above the mucky soil. Although average tree density and basal area were the lowest of any plots on the site, alder density in the 30-60 cm diameter class

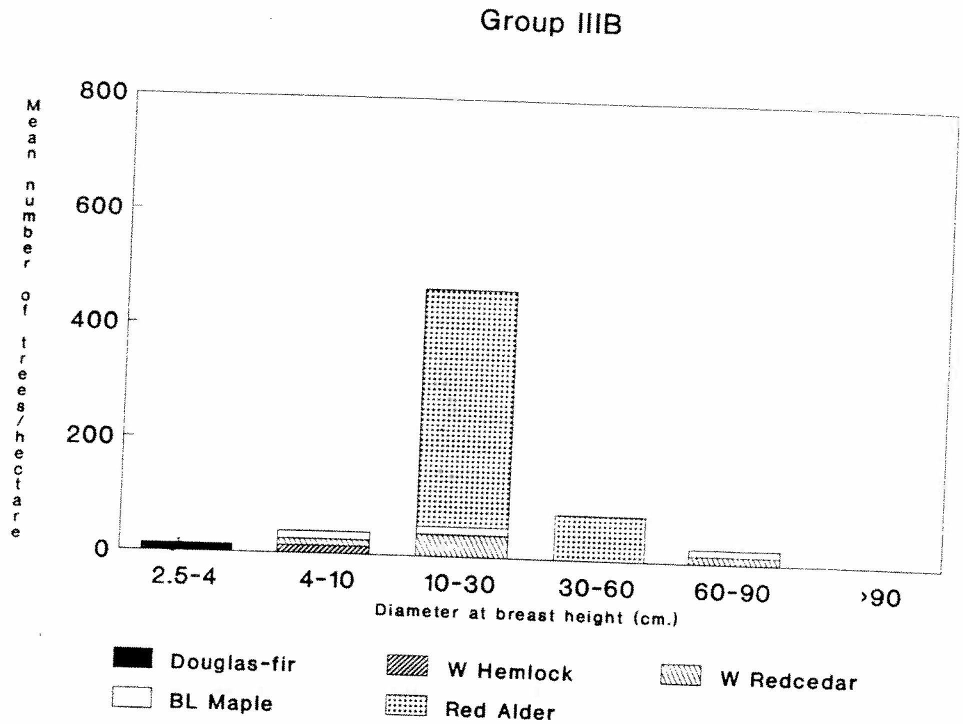


Figure 16. Size-class distribution of trees in Group IIIB.

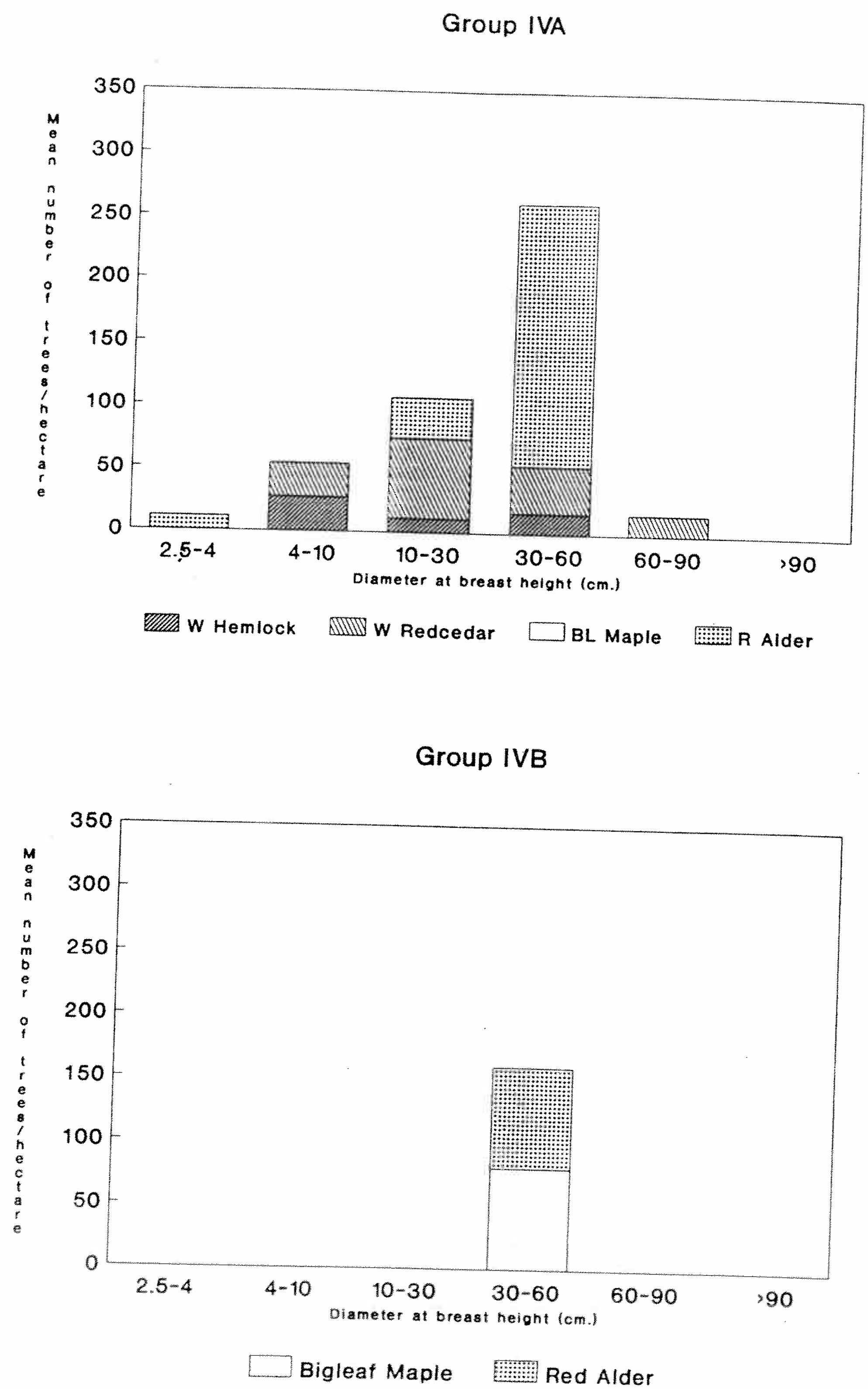


Figure 17. Size-class distribution of trees in Group IV.

and alder basal area were the highest. These plots represent the "cedar and alder swamps" of Franklin and Dyrness (1973:68). According to Franklin and Dyrness, red alder may be a climax species in these "swamps".

Understory cover, highest of any group, averaged 216% (Table 6). Although many species had high cover values, the only understory species with more than 5% cover in all six plots was Eurynchium praelongum. Species found only in Group IV plots included giant horsetail (Equisetum telmateia), crabapple (Pyrus fusca), American brooklime (Veronica americana), duckweed (Lemna minor), water parsley (Oenanthe sarmentosa), marsh violet (Viola palustris), bittercress (Cardamine oligosperma), the largest thalloid liverwort in our area, Conocephalum conicum, and the only peat moss found at the study site, Sphagnum squarrosum. Many of these species are indicators of wet and very wet soils.

Even on the wettest sites, downed logs provided a substrate for some plant species that were characteristic of drier areas. But species most typical of Group I were completely absent from Group IV.

Group IVA1. Alder/ferns/skunk cabbage (creekside plots). Two plots (23, 24), located adjacent to the creek that forms the northeast boundary of the NRCA, were classified together. Both were dominated by red alder, contained small and medium-sized western redcedar and western hemlock, and cut stumps. Both would be classified in the western hemlock/skunk cabbage association of Henderson et al. (1992).

Understory vegetation was dense and diverse. Each plot contained 23 understory species, the third highest diversity found on the site.

Table 6. Mean composition of the understory for plant communities classified in TWINSPAN Group IV. Cv = % cover; F = % frequency; Cn = constancy; + = <0.05%.

	Cedar/Alder "Swamp" IVA			Alder/Maple Bottom IVB		Group IV (n=6)		
	Cv	F	Cn	Cv	F	Cv	F	Cn
Shrubs								
Salmonberry	38.2	76	100	41.3	90	38.7	78	100
Vine maple	15.6	42	100	38.0	80	19.4	48	100
Elderberry	8.1	52	100	3.8	20	7.4	47	100
Stink currant	5.1	22	60	1.5	10	4.5	20	67
Red huckleberry	2.2	14	20			1.8	12	17
Devil's club	2.2	8	40			1.9	10	50
Crabapple	0.7	8	20	0.4	20	0.6	7	17
Fool's huckleberry	0.8	4	20			0.6	3	17
Swamp gooseberry	0.3	2	20			0.3	2	17
Trailing blackberry	0.3	2	20			0.3	2	17
Ferns and fern-allies								
Lady fern	24.8	74	100	24.6	80	24.7	75	100
Spreading wood fern	10.6	48	80	3.3	30	9.4	45	83
Sword fern	9.2	36	80	11.4	60	9.6	40	83
Giant horsetail	3.7	15	60	27.5	90	7.6	28	67
Licorice fern	1.4	20	80	1.9	30	1.5	22	83
Forbs								
Water parsley	22.6	49	80			18.9	41	67
Skunk cabbage	21.1	42	100			17.6	35	83
Foamflower	5.5	29	100			4.6	24	83
Youth-on-age	2.6	8	40	38.7	83	8.7	21	50
Northern starwort	1.2	6	20	2.3	17	1.4	8	33
Marsh violet	1.2	2	20			1.0	1	17
Duckweed	1.1	9	20			0.9	8	17
False lily-of-the-valley	1.0	6	40			0.8	5	33
American brooklime	0.8	4	40			0.7	4	33
Angelica sp.	0.8	2	20			0.6	1	17
Crisped starwort	0.6	5	60			0.5	4	50
Wall lettuce	0.5	2	60	0.6	4	0.5	3	67
Hedge nettle	0.4	3	60	1.6	4	0.6	3	67
Stinging nettle	0.3	2	40	20.5	60	3.7	12	50
Sweet bedstraw	0.1	2	40	1.3	8	0.3	3	50
Mosses and liverworts								
Eurynchium praelongum	13.1	74	100	7.5	92	12.2	77	100
Rhytidiadelphus loreus	4.4	18	100	0.9	17	3.8	18	100
Plagiomnium insigne	3.9	32	100	1.3	46	3.5	34	100
Hylocomium splendens	1.9	6	100			1.6	5	83
Rhizomnium glabrescens	0.4	9	80	0.8	8	0.5	9	83
Plagiothecium undulatum	0.6	8	100			0.5	7	83
Isothecium stoloniferum	0.2	4	20			0.3	4	17
Rhizomnium spp.	+	4	20	1.1	38	0.2	10	33
Leucolepis acanthoneuron	0.1	8	60	7.8	54	1.4	15	67
Neckera sp.	+	1	20	1.9	13	0.3	3	33
Hookeria lucens	0.2	2	20			0.1	1	17
Dicranum sp.	0.2	2	40			0.1	1	33
Eurynchium sp.	+		20	1.0	21	0.2	4	33
Moss spp.	0.5	5	100	1.8	25	0.8	8	100
Liverwort spp.	+	6	100	2.2	21	0.4	8	100
Muck	33.4	46	100	22.2	42	31.5	45	100
Log	8.2	13	100			6.8	11	83
TOTAL PLANT COVER	209.7			248.8		216.2		

Lady fern, sword fern and skunk cabbage accounted for more than 20% of the cover on each plot, and foamflower and Eurynchium praelongum accounted for at least 10%. Plot 23 also had almost 60% cover of salmonberry and 30% of vine maple.

Group IVA2. Alder/salmonberry/water parsley. This group consists of two plots (25, 26) that were located in the northwest corner and one (34) located in a narrow ravine. All were flat with standing water most of the year. In the summer an average of 56% of the ground surface was muck (thick organic layers of decomposed plant material). Total understory cover was high, and plot 34 had the highest vascular plant understory coverage of any plot - 232%.

Trees were not abundant, but plant life forms were diverse, including shrubs, ferns, herbs and mosses, which all had high cover values. Salmonberry was the dominant understory species in two plots, and water parsley in one. Skunk cabbage, lady fern, vine maple, spreading wood fern and stink currant each had more than 20% cover in at least one plot. In plot 34, salmonberry, skunk cabbage, water parsley, vine maple and stink currant each had at least 20% cover, and elderberry, giant horsetail and Eurynchium praelongum had over 10% cover.

Group IVB. Alder/salmonberry/youth-on-age. TWINSPAN separated plot 35, the highest-slope plot in this group (7%), from the rest of Group IV. The plot was located in a northwest-facing "bowl" at the base of a draw, and the canopy was relatively open - only three bigleaf maples and three red alders occurred within the plot (Fig. 17). Abundant light and moisture undoubtedly contributed to the high understory cover which was nearly as great as that of plot 34 (Table 6). The plot contained about 23% cover of muck and had the highest cover values of salmonberry, youth-on-age, giant horsetail, and stinging nettle at the study area. These species, plus vine maple and lady fern, accounted for 192% of the coverage on the plot.

Old-growth

Old-growth Douglas-fir and western redcedar forest covers much of the Beaver Creek NRCA. Twenty of the 46 plots sampled met the definition for old-growth forest under the revised definition (Franklin and Spies, 1991) and another eight under the interim definition (Old-growth definition task group, 1986), based on the size criteria for living trees.

Most of the 28 old-growth plots are old-growth Douglas-fir, but six of the "revised" old-growth and four of the "interim" stands are old-growth western redcedar. Only one plot (22) fit the definition of old growth western redcedar/western hemlock. Five other plots, all in Group I, had large Douglas-firs, but lacked sufficient smaller trees to satisfy the definition of old-growth. In some cases this may have been due to the 1895 fire which, if only moderate in intensity, could have destroyed subcanopy trees while only scarring mature Douglas-fir that had thicker bark (Agee, 1991).

Sixty-eight percent of the plots in Group I, 100% in Group II, and 40% in Group III met live tree criteria for one of the definitions of "old growth".

Floristics

During the 1992 season, 137 vascular plant species were found at the Beaver Creek Natural Resources Conservation Area (Appendix 1). The rose family (Rosaceae) was represented by the largest number of species (13), most of them shrubs or small trees. However, only salmonberry (17 plots) and trailing blackberry (15 plots) were common on the site. The heath family (Ericaceae) and sunflower family (Asteraceae) were each represented by nine species. Red huckleberry and wall lettuce were the only common and abundant representatives of their respective families found throughout the site. Five of the composites found are not native to western Washington.

In an examination of a number of descriptions of vegetation, del Moral and Denton (1977) found that some plant families may be characteristic of particular environments or geographic conditions. The pine family (Pinaceae) dominates stable, forested vegetation in mesic conditions. The ferns (order Filicales) show strong preference for moist forest habitats and for certain deciduous, successional sites. Members of the rose family (Rosaceae) occur in a variety of habitats including wet sites, drier coniferous forests, and successional deciduous forests. The ericads characteristically occur on acid soils in cool, mesic, dark forests, and are rarely found in seral communities. The composites (Asteraceae) may be common in dry, open forests.

Members of the pine and cedar (Cupressaceae) families were the dominant overstory species at Beaver Creek NRCA. Douglas-fir had the highest basal area of any species, western hemlock the highest density, and western redcedar was found in all but two plots (Table 7). Among the understory plants, ferns had the highest cover values. Sword fern, the most abundant understory species on the site, averaged 32% cover and 77% frequency. In 30 plots, it had the highest cover of any understory species, and in six more, it had the second highest cover. In the bottoms, it was less abundant, growing only on fallen logs or impounded soil. Sword fern was found in 44 plots and spreading wood fern in 39.

The trees

Size parameters of common tree species are summarized in Table 7. Douglas-fir was abundant on much of the site and often had the highest average diameter and basal area, particularly on upper slopes, benches and broad ridgetops. The largest tree measured was a Douglas-fir found uphill from the northeast corner of the site (plot 20); it had a diameter of 213.9 cm. No other Douglas-fir over 150 cm dbh was found, but trees of that species between 100 and 120 cm in diameter were not uncommon. On "better" sites in the Pacific Northwest, Douglas-fir typically attains an age of 750+ years and a diameter of 150-220 cm (Franklin and Hemstrom, 1991).

Western hemlock had the highest density of any tree species at the conservation area, but in plots in which it was found, its mean basal area was only one-tenth that of Douglas-fir. The average western hemlock was one-fourth the diameter of the average Douglas-fir. The largest western hemlock found (plot 40) was 83.6 cm.

Western redcedar was ubiquitous. Tolerant of a wide edaphic range (Klinka, et al., 1989:229), the species was found in almost all cover

Table 7. Size parameters of the most common tree species at Beaver Creek NRCA. Mean values are averages for all trees within plots in which the species occurs.

Species	Occurrence (# of plots)	Maximum Diameter (cm)	Mean Diameter (cm)	Mean Density (trees/ha)	Mean Basal Area (m^2/ha)
Douglas-fir	27	213.9	87.4	165	99.0
Western redcedar	44	145.0[1] 118.4[2]	33.3	218	20.9
Western hemlock	37	83.6	22.0	239	9.1
Bigleaf maple	23	79.5	42.1	82	11.4
Red alder	23	54.4	34.9	204	19.5
All common species		213.9	41.6	191	30.1

[1]Measured on flared trunk
[2]Largest individual measured with straight trunk

types. It was dominant on some narrow ridgetops, in draws and ravines, and on poorly-drained benches. Large individuals were present (only Douglas-fir and Sitka spruce were larger), but mean diameter of western redcedar was only 11 cm larger than that of western hemlock.

Red alder was less common than the coniferous species, but its density was high in the plots in which it was dominant. It is a pioneering species that does best in full sun and at the conservation area was found in locations where logging, wind, or a high water table have provided a canopy opening.

Bigleaf maple was found in exactly one-half of the plots. Mean diameter was second only to that of Douglas-fir, but density was low, as it usually occurred as solitary or scattered individuals. The large size and wide canopy of many specimens made bigleaf maple a conspicuous element of the overstory.

Scattered, large Sitka spruce trees were found along creek bottoms. The largest measured was 130.8 cm dbh. Sitka spruce is a long-lived species (700 or 800 years) (Fowells, 1965) that may have escaped fire in the bottoms. Communities containing smaller Sitka spruce were found near each of the two major wetlands.

Paper birch was only occasionally seen in the study area. The largest measured individual, 32.5 cm dbh, was found near the north wetlands in plot 27, and the second largest, 25.1 cm dbh, was growing on top of a stump in a redcedar/alder community south of the beaver pond (plot 7). Downed trunks of the species were more commonly seen. Perhaps a number of birch became established after the most recent fire, and died out in recent years.

Cascara seedlings (Rhamnus purshiana) were occasionally seen, but the only larger specimen (15 cm dbh) was found in the mixed community containing Sitka spruce in the north wetland (plot 36). Seeds, disseminated widely by birds and mammals (Arno and Hammerly, 1977:202), obviously germinate on the forest floor, but the shade-tolerant species occurs most frequently on very moist to wet, nitrogen-rich soils and tolerates fluctuating groundwater levels (Klinka, et al., 1989:198). It is likely that growth in the upland coniferous communities, where only seedlings were seen, is prevented by the lack of soil moisture.

Only three Pacific yews (Taxus brevifolia), all about six feet tall and less than 2.5 cm diameter, were seen, and all in areas dominated by Douglas-fir and western redcedar.

Listed, Rare or Unusual Species

Wool-grass (Scirpus atrocinctus), found on the edge of the beaver pond, is listed as a Group 3 Monitor species (Washington Natural Heritage Program, 1994). The plant is a bulrush, a member of the sedge family. No other listed plants were seen, although a few rather unusual species were found on the Beaver Creek conservation area.

The only peat moss seen was Sphagnum squarrosum, present in a small patch on the edge of the northwest wetland. In January, 1994, it was submerged, but in the summer of 1992 it was above water level. It is a woodland species that prefers high nutrient levels and is found close to water level (McQueen, 1990).

Ground-pine (Lycopodium clavatum) is the only clubmoss found on the site, in a small population on the shore of the beaver pond. The species is "frequent in moist, open woods in the mountains" (Muenscher, 1941:53).

A small population of leathery grapefern (Botrychium multifidum) was also found near the beaver pond, the only members of the adder's-tongue family (Ophioglossaceae) seen at the NRCA. Although not considered rare, the species is infrequently found, and only in moist to wet locations in the lowlands (Muenscher, 1941:53; Hitchcock and Cronquist, 1973:45). The Beaver Creek NRCA population straddles an informal trail at the south end of the Beaver pond, and is subjected to some trampling.

Creeping snowberry (Symphoricarpos mollis), not included in the 1941 flora of Whatcom County (Muenscher, 1941), was seen only on the highest ridge. It was one of the few indicators of dry soils found at the study area.

Pyrola chlorantha (green wintergreen) and several saprophytes, including the white-flowered form of Corallorhiza maculata (spotted coralroot) were found in coniferous forest stands.

Non-Native Plant Species

Fifteen of the 137 species of vascular plants found at the Beaver Creek NRCA are not native to the Pacific Northwest. Some were found only as seedlings sprouted from seeds dropped by birds and are unlikely to reproduce in the shady forest environment. Others are shade-tolerant species that are becoming serious problems in northwest forests.

Wall lettuce. By far the most abundant non-native (exotic) species is wall lettuce, which is well-established throughout the NRCA. It was present in 34 of the 46 plots, including all of Group I. In Group I wall lettuce had an average cover of 5.5%, making it a major component of the understory. This contrasts with the situation only 20 years ago when Hitchcock and Cronquist (1973:534) stated that wall lettuce is a "European weed of wet places, occasional west of the Cascades".

English holly. The second most prevalent exotic species is English holly, which was found in over two-thirds of Group I and II plots and in all areas of the site. Its mean cover in the two groups was less than 1%, but small shoots were common, often connected by an extensive network of rhizomes. A few plots contained a network of such shoots covering several square meters. Only a few individuals with diameters greater than 6 cm were found, but some were too large to remove by hand.

Holly is not listed in the 1973 Flora of the Pacific Northwest (Hitchcock and Cronquist, 1973), indicating that 20 years ago it was unknown outside of cultivation in our region. Today it is common, becoming a serious pest in some forests (Olson, 1992).

English ivy. English ivy (Hedera helix) was found in four locations: near the north wetland, at the base of plot 45, and in plots 34 and 46. Ivy is a shade-tolerant evergreen vine that eventually crowds out leaves and suppresses growth of deciduous trees and has destroyed forests in some areas of Europe and the former Soviet Union (Thomas, 1980). Plants can be eradicated by pulling or cutting (Olson, 1992).

Herb Robert. One patch of herb Robert (Geranium robertianum) was seen near the outlet creek on the south side of the beaver pond and several individual plants were found on the hillside above the southeast corner of the site. Herb Robert survives under widely diverse environmental conditions, maintains its leaves through most northwest winters, and reproduces in deep shade. In the past two decades, it has spread rapidly in some western Washington forests; once established, it quickly approaches 50-100% cover (Tisch, 1992).

Reed canarygrass. Reed canarygrass (Phalaris arundinacea), an aggressive invader of wetlands (Taylor, 1990:18), is present in the beaver pond between the DNR sign and the osprey nest.

Creeping buttercup. Creeping buttercup (Ranunculus repens) was found on the beaver pond dam, **below the osprey nest,** on the roadbed crossing the north wetland, **near the "Y" in the entrance trail,** and **below** plot 35. This species has supplanted most of our native buttercups (N. Buckingham, pers. comm.). Although it presently is restricted to small areas of moist, open or disturbed soil at the Beaver Creek NRCA, it can become a truly noxious weed in wet places (Taylor, 1990:56).

Other species. Two seedlings of evergreen blackberry (Rubus laciniatus) were removed, one near plot 4 and one from plot 38. Although a serious pest in the open, this species is not known to do well in shade (R. Taylor, 1994, pers. comm.). Canada thistle (Cirsium arvense), a "cosmopolitan noxious weed from Eurasia" (Hitchcock and Cronquist, 1973:503) that spreads from deep rhizomes, was seen in only a few locations at the conservation area, primarily above the northeast boundary. Plot 16, in a coniferous forest community on a bench above the northeast corner, contained a Canada thistle 2 m tall. This species is also unlikely to become a serious pest under the forest canopy, although it may do well in openings.

Laurel (Prunus laurocerasus), hairy cat's-ear (Hypochaeris radicata), common dandelion (Taraxacum officinale), curly dock (Rumex crispus), creeping Charlie (Glecoma hederacea), nipplewort (Lapsana communis) and foxglove (Digitalis purpurea) were also seen.

CONCLUSION

The Beaver Creek Natural Resources Conservation Area is topographically and floristically diverse. Hillsides and ridgetops support old-growth Douglas-fir and western redcedar forest communities interspersed with mixed deciduous/coniferous stands. Bottoms are occupied by red alder/western redcedar "swamp" communities, and a beaver pond and another small wetland provide habitat for aquatic and lakeshore species and for mixed stands containing Sitka spruce.

Distribution of community types appears to be a response to two factors, moisture content of the soil and disturbance history of the site. Microtopographic features of the NRCA - including narrow and broad ridgetops, steep and gradual slopes broken by benches and draws, and bottoms with standing water - were associated with various amounts of soil moisture. Species indicative of very dry moisture regimes were found on the highest ridgetops while species indicative of very wet regimes were found in the bottoms. On benches, species indicative of very wet soils grew in small pockets surrounded by species of moderately dry soils. Draws were more variable, with some containing abundant species of moist soils and others having little understory vegetation.

Natural disturbances such as fire, lightning, and windstorm have affected the study area just as they have affected stand development elsewhere. Anthropogenic disturbance, particularly logging, has also been influential at the Beaver Creek NRCA. Selective removal of large trees since the mid to late 1800s created an unusual distribution and number of light gaps in the canopy. Although such gaps can produce several effects, notably a release of understory trees from suppression, increased growth of understory plants, and/or a burst of tree regeneration (Franklin and Hemstrom, 1991; Connell and Slayter, 1977), the most conspicuous effect at Beaver Creek is that the old-growth forest is sprinkled with pockets of red alder, usually considered a species of younger stands, and large bigleaf maples.

At the present time, high-quality native plant communities cover the site. Trees, shrubs, herbs, mosses and liverworts represent the richness and diversity of the western Washington flora. But there are some serious threats to the ecological integrity of the conservation area. English holly is present in much of the forest, and its abilities to tolerate deep shade and develop extensive networks of rhizomes indicate that its influence will spread. Its impact on forest structure and composition are just beginning to be seen at Beaver Creek NRCA and in other western Washington forests. On the other hand, the damage that can be done by reed canarygrass, an aggressive invader along the north shore of the pond, is well-documented at other locales. Herb Robert and English ivy are present in only small numbers at the conservation area but also have well-known impacts. Substantial effort should be made soon to prevent the spread of these four species. At the present time, they appear amenable to mechanical control, although dousing cut stumps of holly with an herbicide may be necessary to prevent suckering of the larger plants (Olson, 1992).

The other immediate threat to the area is human recreational use. The roads and trails from Lake Whatcom should be closed to bicycles and motorized vehicles at the site boundary in order to prevent serious damage to the vegetation along the northern slopes of the site, and the Lake Louise Road access should be signed or controlled to prohibit access by all vehicles. The delineation of walking trails in potentially high-use areas is also recommended in order to avoid the damage caused by extensive networks of informal trails, already becoming evident on the south and east sides of the pond. This takes on particular urgency at locations in which rare or locally uncommon plants are found.

Given the proximity of the Beaver Creek Natural Resources Conservation Area to Bellingham and the WWU campus, its diversity of habitats and vegetation and its unique history, use of the area as an educational laboratory should prove rich and fruitful in the future. As human pressures on the surrounding area grow, its value as a preserve and as an example of a Pacific Northwest forest ecosystem will increase.

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