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WASHINGTON NATURAL
HERITAGE PROGRAM

VEGETATION DYNAMICS AND DISTURBANCE HISTORY OF OAK PATCH PRESERVE, MASON COUNTY, WASHINGTON

by

Jane Kertis

February, 1986

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In partial fulfillment of contract obligations with the Department of Natural Resources

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ACKNOWLEDGEMENTS

Many people contributed to this study. A few deserve special mention. Thanks go to Dave Sims and Kenna Hoyser, who showed genuine interest in the project, and provided logistical support. Joel Dodge provided invaluable assistance with falling trees and cutting stumps. Irene Davis of the Mason County Historical Society, and Mrs. Alice Pope Gilbert supplied me with an abundance of interesting ideas and memories. Dr. Linda Brubaker was responsible for all pollen calculations. Special thanks go to Janet Hall, Rachel Friedman-Thomas, Ted Thomas, Deb Naslund and Mark Huff for assistance with field work, and to Peter Cole for his help with graphics. I gratefully acknowledge Debbie Lev, who helped collect "pre-dawn" moisture values, and gave me full use of her computer facilities. Mark Sheehan and Reid Schuller made this project possible, and I thank them for spending numerous hours with me discussing ideas and lending support. Finally, I would like to thank Dr. James K. Agee for his help in every aspect of this project, and for his support and encouragement.

This project is the result of a contract with the Department of Natural Resources.

INTRODUCTION

The present geographic range of Quercus garryana[1] (Oregon white oak) extends from southern Vancouver Island, British Columbia to the Santa Cruz Mountains of south-central California (Figure 1). In Washington and Oregon it generally occurs in a thin belt between the Coast Range and Cascade Mountains, although isolated stands are found east of the Cascade crest in both states (Fowells,1965). It is the only native oak of Washington and British Columbia, and the most extensive oak in Oregon. Q. garryana is a constituent of several community types within its range. It occurs in open savanna-like groves, as dense, pure stands and intermixed with conifers and other broadleaf trees.

In the Puget Sound area of western Washington, Quercus garryana woodlands occur within the Tsuga heterophylla (western hemlock) zone, on more extreme sites created by edaphic and climatic factors. The Olympic Mountains form an effective rainshadow for the area. Annual precipitation ranges from 25-40 inches, with only 4-10 inches falling during the April-September growing season. Coarse-textured, nutrient poor soils of these sites are developed in glacial drift and outwash from the Vashon glaciation, and are excessively drained. These conditions combine to create droughty microsites of marginal to poor

[1] all scientific nomenclature follows Hitchcock and Cronquist,1973

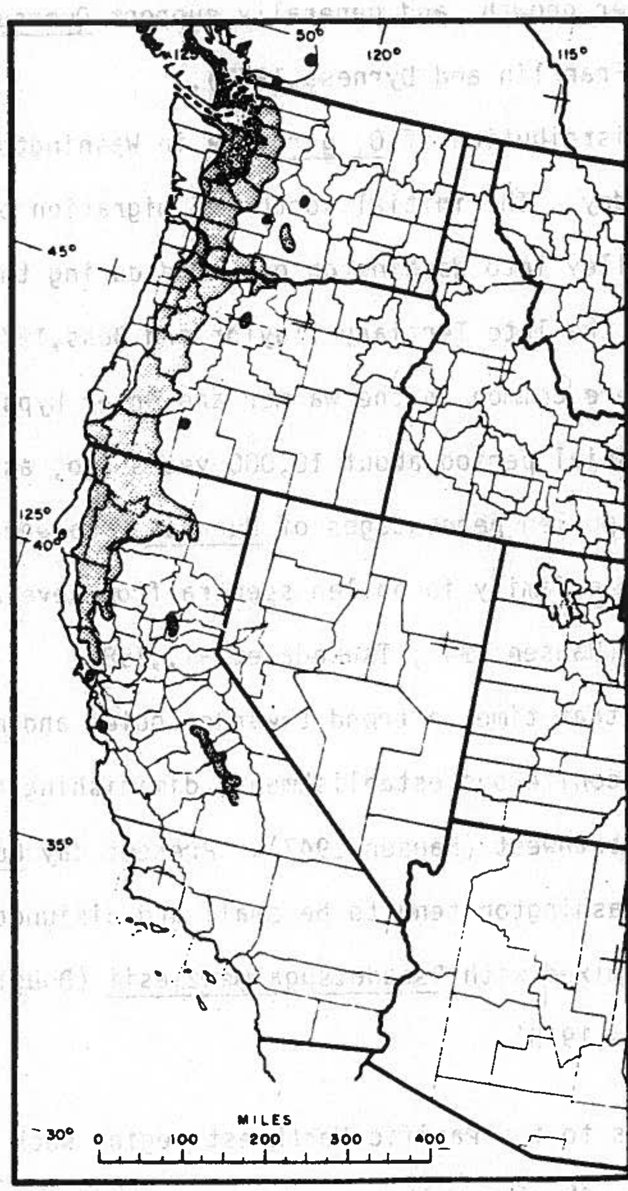


Figure 1. Range of Quercus garryana (from Fowells,1965)

site quality for conifer growth, and generally support Quercus garryana communities (Franklin and Dyrness,1973).

The prehistoric distribution of Q. garryana in Washington was more extensive than today. The initial northward migration of Quercus from the Willamette Valley into Washington occurred during the drying and cooling periods of the late Tertiary (Taylor and Boss,1975). Q. garryana communities were common in the warmer and drier Hypsithermal Interval of the postglacial period about 10,000 years ago, as evidenced by increased pollen percentages of Quercus, Poaceae and members of the Asteraceae family in pollen spectra from several Puget Lowland lake sediments (Hansen,1947; Tsukada et al.,1981; Barnosky,1983). Since that time, a trend towards cooler and moister conditions has favored coniferous establishment, diminishing the extent of oaks in the Northwest (Hansen,1947). Present day Quercus garryana woodlands in Washington tend to be small and disjunct, often surrounded by and intermixed with Pseudotsuga menziesii (Douglas-fir) forests (Taylor and Boss,1975).

The first explorers to the Pacific Northwest region such as David Douglas, William Tolmie, Charles Wilkes, and John Jeffrey mention stands of Q. garryana located in openings of more heavily forested areas. Frequent fires ignited by local Indian tribes were proposed as the reason for the savanna-like quality of these communities. Once settlement occurred, however, burning was prohibited and all naturally ignited fires were suppressed. In 1859, Dr. J.G. Cooper, a botanist on a survey trip of the 48th parallel, noted the changes in the composition of the Quercus communities, possibly due to fire suppression by stating "they belong to the prairies and are being crowded out by the extension of the spruces over them" (Cooper and Suckley,1859).

The few modern Quercus garryana communities in existence today in the Puget Sound area are being encroached upon by Pseudotsuga menziesii to varying extents. Fire suppression, grazing and agricultural land clearing are thought to be causative factors in the coniferous movement into Q. garryana dominated sites (Lang,1961; Franklin and Dyrness,1973; Taylor and Boss,1975).

In 1984, the Department of Natural Resources established Oak Patch Preserve to guarantee the continuation of the oak woodland type in the Puget lowland area. Post settlement activities have altered compositional and structural characteristics of the preserve, with P. menziesii invasion actively occurring on the site. The objectives of this study were to:

1) investigate present community dynamics and distribution on the preserve.

2) reconstruct preserve vegetation to pre-settlement (circa 1860) conditions.

3) document disturbance regimes responsible for both past and present composition and structure of the vegetation on the preserve and adjacent lands.

4) propose management recommendations for the restoration and maintenance of pre-settlement vegetation dynamics on the preserve.

BACKGROUND INFORMATION

Biogeography of Quercus garryana

Within its range (Figure 1), *Q. garryana* communities often occupy a narrow subzone between prairie and coniferous forest (Sprague and Hansen,1946; McDonald et al.,1983). *Quercus* is generally confined to the most arid microsites within conifer zones. In British Columbia, Washington and northwestern Oregon this species forms open groves and dense stands under edaphic and climatic conditions too stressful for establishment of *P. menziesii* (Krajina,1970; Franklin and Dyrness,1973). Woodlands and savannas are scattered in northern California, occupying ridgetops, tablelands and rocky forest openings up to 1600 m elevation (Griffin,1977; Sugihara et al.,1983).

Quercus garryana has a broad edaphic tolerance, growing in gravelly to heavy clay soils. It is common on excessively drained outwash soils, but reaches optimum development in the deep loams of southwestern Washington and the Willamette Valley in Oregon (Silen,1958).

Vegetation of Quercus garryana Communities

Quercus forms open savannas, dense woodlands and is a component of hardwood-conifer mosaics within its range. Quercus is the dominant overstory species within these types, and the sole constituent of closed canopy, younger stands scattered throughout British Columbia, Washington, Oregon and California (Thilenius,1964; Sugihara et al.,1983). Pseudotsuga is the most common associate, invading open savannas, and achieving co-dominance in more mesic woodland communities (Sprague and Hansen,1946; Silen,1958). Acer macrophyllum (bigleaf maple), Cornus nuttallii (Pacific dogwood), and Fraxinus latifolia (Oregon ash) are constituents in moist sites, with Arbutus menziesii (Pacific madrone)and Pinus ponderosa (ponderosa pine) associates under more xeric conditions. In southern Oregon and northern California, Lithocarpus densiflorus (tanoak), Quercus kelloggii (California black oak) and Umbellularia californica (California-laurel) become important in woodland and savanna vegetation types (Fowells,1965).

Understories are diverse in Quercus garryana communities. Present components in this stratum consist of many introduced and increaser species that have invaded or increased in density and extent after European settlement, making it impossible to describe pre-settlement understory conditions. Modern savannas are dominated by grasses and graminoids, the most common of which are Holcus lanatus , Festuca californica, F. viridula, F. rubra, Dactylis glomerata , Poa pratensis , Carex fracta, C. tumilicola and Elymus glaucus . Forbs include native species such as Camassia quamash, Vicia americana, Galium nuttallii, G. aparine, Fragaria vesca, as well as exotics such as Hypericum perforatum and Plantago lanceolata. A well developed shrub layer is supported by woodland types, with Symphoricarpos albus, Holodiscus discolor, Rosa pisorcarpa, R. gymnocarpa, R. nutkana, R. eglanteria , Amelanchier pallida, A. alnifolia, Rubus vitifolius and R. ursinus common components (Thilenius,1968; Sugihara et al.,1983; Sugihara et al.,in press).

Life History of Quercus garryana

Flowering of Q. garryana occurs during April-May, with large seed crops produced every few years. Acorns mature through the growing season and fall in September or October. Dispersal distance is generally short, due to the heavy nature of the fruit. Dissemination by animals, such as Tamiasciurus douglasii, Citella beecheyi douglasii (squirrels) and Tamias townsendii (chipmunks) is thought to be the major long-distance dispersal mechanism (Silen,1958).

Numerous destructive agents are responsible for the negligible natural reproduction by seed. Acorns are attacked by insect larva, and are eaten by rodents, birds and deer before germination can occur (Fowells,1965).

Successful germination rates of healthy acorns are high throughout most of the range of Q. garryana. Acorns germinate in late fall or early spring. Optimum seedbeds consist of moist soil covered with a thick leaf litter. Long taproots penetrate the soil rapidly, allowing establishment to occur prior to summer drought conditions, although some mortality from desiccation does take place.

Browsing, trampling, competition from other plants and fire are other factors causing mortality (Silen,1958).

Natural reproduction occurs most commonly through vegetative propagation. Root, stump and epicormic sprouting is activated by stem or crown injury (Plumb and McDonald,1981). Sprouting vigor is directly related to the diameter and age of trees in the stand. Larger diameter trees produce more sprouts, with an increase in both number and vigor apparent with increasing age. Only very old, decadent trees are incapable of sprout production (Roy,1955; McDonald,1969).

Seedling and sprout height growth is rapid, but decreases sharply in saplings and mature trees. Shade tolerance is higher in the juvenile than the mature stage, with older trees unable to withstand low light intensities created by overtopping (Silen,1958). Trees growing on optimum sites may reach heights of 15-25 m, diameters of 60-90 cm., and ages up to 500 years (Franklin and Dyrness,1973).

Disturbance History of Quercus garryana Communities

Early settlers and explorers of the northwest region mention the open character of the Quercus savanna, as well as the denser more forested quality of the Quercus woodland type. Charles Wilkes, on an exploring expedition to Washington in 1841, describes the area around Ft. Vancouver as dominated by open prairie scattered with Quercus, Pinus and Fraxinus. Narrow wooded belts of hardwoods (including Q. garryana) formed transition zones between prairie and coniferous forests (Wilkes,1844).

The frequent burning of prairies and Quercus communities was noted by several early travellers in the northwest. The botanist David Douglas, in his journeys throughout Oregon and Washington from 1823-1827, made numerous mention of the recently burnt-over prairie land he encountered. He attributed this to the deliberate setting of fires by Indians. Charles Wilkes notes extensive fire damage while travelling in northwestern Oregon by stating, "the country is overrun by fire, which had destroyed all the vegetation, except the oak trees, which appeared to be uninjured (Wilkes,1844).

The purpose for preservation of prairie and open Quercus savanna by frequent Indian burning was to increase food reserves and create more effective hunting practices. Acorns were a foodstuff for all Indians in the northwest (Gunther,1973; Norton,1979), and were the major subsistence resource for all Californian tribes (Lewis,1973). Many Indian villages in Washington were located near Quercus communities (Taylor and Boss,1975). Fern rhizomes, tubers and berries were prolific in newly burned sites. In speaking with local Indians around Fort Vancouver in 1826 about burning practices, David Douglas states, "Some of the natives tell me it is done for the purpose of urging the deer to frequent certain parts to feed, which they have left unburned and of course they are easily killed. Others say that it is done in order that they might the better find wild honey and grasshoppers, which both serve as articles of winter food" (Douglas' journal,1823-1827).

With settlement, frequent fires deliberately set by Indians were prohibited, and naturally ignited lightning fires were immediately extinguished. Land clearing activity for farming and ranching was extensive. Sheep and cattle grazing in prairies and open Q. garryana savannas was common throughout the northwest (Thilenius,1968; Sugihara et al.,1983). These combined activities served to decrease the extent of prairie and Quercus garryana types.

Disturbance Effects on Quercus garryana Vegetation Dynamics

A frequent-fire regime is thought to be the major disturbance factor that maintained Q. garryana communities in the past (Thilenius,1964; Taylor and Boss,1975; Griffin,1977; Sugihara et al.,1983). Fires served to decrease invasion of coniferous species, especially P. menziesii, into Quercus dominated sites. Frequent burning controlled the density of the stand, and initiated sprouting in trees that experienced injury or mortality due to higher intensity fires. An herbaceous understory was favored, rapidly dominating ground cover by establishing an inpenetrable sod layer.

The removal of Indian burning and suppression of naturally ignited lightning fires within the Quercus type has changed vegetation structure and composition. The presence of dense, even-aged younger Quercus intermixed with large relict open grown trees indicates present stands are shifting from savanna to forest structure (Habeck,1961; Thilenius,1964; Sugihara et al.,1983). Conifers, such as Pseudotsuga, are establishing in previously open Quercus communities, and are increasing in density in woodland types (Sprague and Hansen,1946).

The effects of grazing on Q. garryana communities are not widely known. The general trend in grazed systems is the replacement of herbaceous with woody species. Disturbance of the sod layer allows shrub and seedling establishment to occur (Thilenius,1964), with eventual conifer-hardwood woodland development probable.

SITE DESCRIPTION

Location

Oak Patch Preserve is located adjacent to the west shore of Oak Patch Lake on the Tahuya Peninsula in northeastern Mason County (Figure 2). The seven hectare tract occupies portions of the SE 1/4 and SW 1/4 of Section 15 in Township 23 North, Range 2 West of the Willamette Meridian, and is accessible by the gravel surfaced Elfendahl Pass Road.

Geology

The preserve is located in a flat outwash channel, created by the retreating Puget Lobe of the Vashon Stade of the Frasier Glaciation. This was the most recent continental ice sheet advance into the Puget Lowland region, and occurred approximately 14,000 years B.P. (Crandell 1965).

Soils

Soils of Oak Patch Preserve are of the Everett gravelly sandy loam series. They are coarse textured, excessively drained, gravel dominated soils derived from glacial till and outwash material. Soils are droughty due the inability of the sand and gravel constituents to capture and hold water (U.S. SCS,1951).

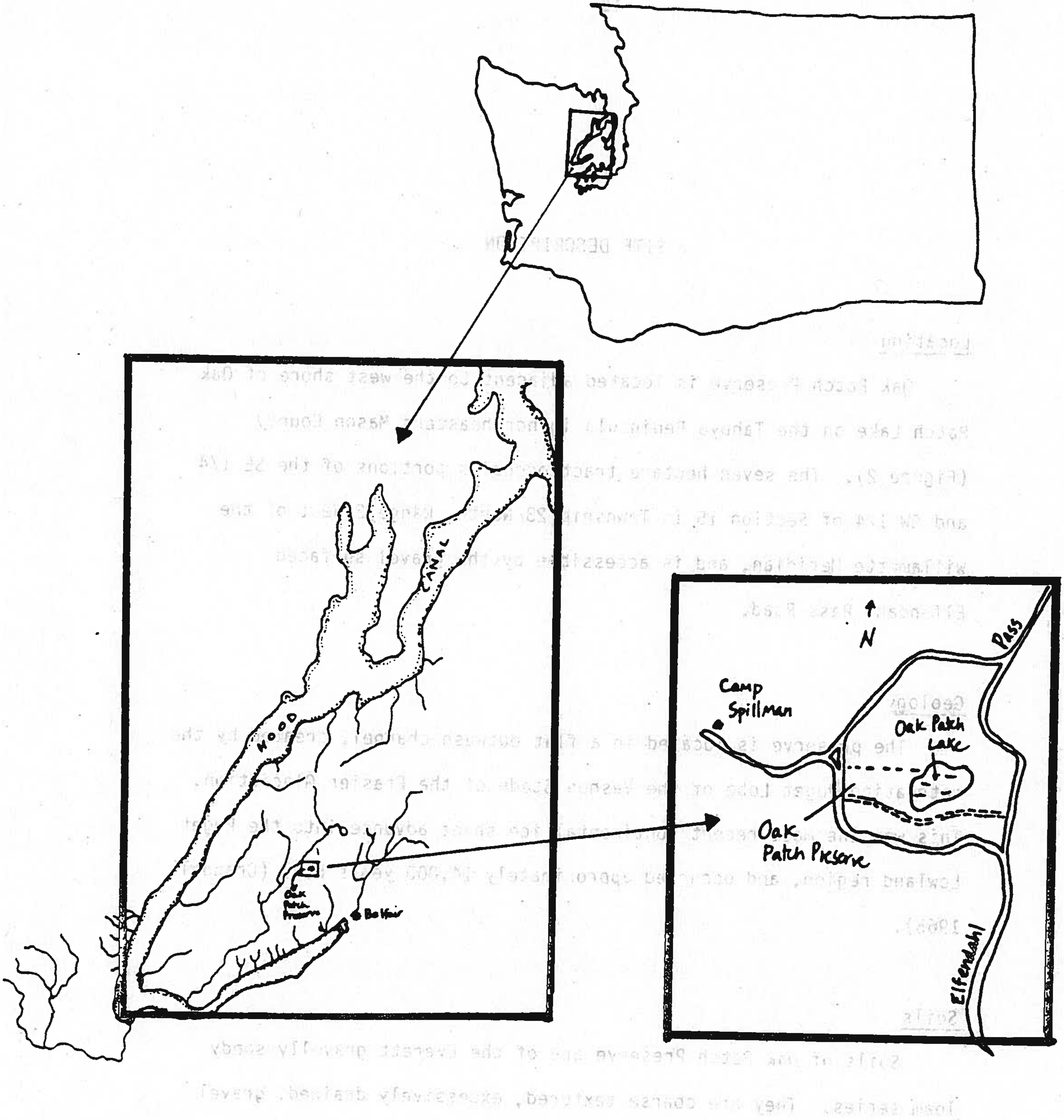


Figure 2. Location of Oak Patch Natural Area Preserve, Mason County, Washington.

Climate

The mid-latitude maritime climate of this region is affected by the presence of the Olympic Mountains. The range moderates weather trends, and forms a rainshadow, blocking precipitation from inland areas. Summers are generally cool and dry, with wet and mild winters. Summer drought conditions are common, with less than 10% of annual precipitation falling in the April-September growing season (U.S. Weather Bureau,1969).

Weather records from the Grapeview weather station in eastern Mason County represent more local climate trends. Mean annual temperatures from 1931-1960 was 52°F, with temperatures ranging from 40°F (January) - 65°F (July, August). Mean monthly precipitation ranged from .75"
(July) - 9.29" (December), with approximately 18% falling during the growing season (April-September) (Phillips,1968).

Vegetation

The preserve contains a mosaic of vegetation types. Quercus garryana dominates the area, with the stand reputed to be the largest of its kind on the Tahuya Peninsula (Department of Natural Resources, unpublished information). Structure ranges from dense, younger, closed canopy trees to scattered, mature individuals. Pseudotsuga menziesii occupies the lower stratum of the overstory over approximately 75% of the preserve. There are a few trees that are presently sharing co-dominance with Q. garryana, even overtopping them in portions of the preserve. Pseudotsuga is the sole arboreal constituent in the southern preserve boundaries. Pinus contorta and

Rhamnus purshiana are infrequent associates of Q. garryana on the preserve as well.

Understory dominants vary across the preserve. The site is dominated by shrubs over most of its area. Common species include Symphoricarpos albus, Holodiscus discolor, and Berberis aquifolium. Patches of herb dominated understories exist in forest openings. Poaceae and Cyperaceae dominate, with Fragaria vesca var. crinita, Viola adunca, Vicia americana and Lonicera ciliosa common as well. Introduced weeds, such as Chrysanthemum leucanthemum, Hypericum perforatum, Senecio jacobaea and Plantago lanceolata are evident in the herb layer throughout the site.

METHODS

An integrated approach was used to determine past and present vegetation dynamics, as well as relevant environmental and disturbance processes affecting floristic distribution at Oak Patch Preserve. This section is divided into four topics: Present Vegetation, Soils, Past Vegetation and Disturbance History. Each subsection encompasses a distinct aspect of the research plan, but when used in conjunction with one another produces a more complete picture of community components and dynamics present at Oak Patch Preserve.

PRESENT VEGETATION

Permanent Macroplots

A general field reconnaissance of the seven ha site revealed four communities, based on species dominance throughout the preserve. A 15x25m permanent macroplot was positioned within each type to represent the most homogenous sample. Sampling followed a modified system devised by Fonda and Bernardi (1976)(Figure 3). Four 8m transects were placed at 5m intervals perpendicular to a 25m centerline tape. Sampling proceeded as follows:

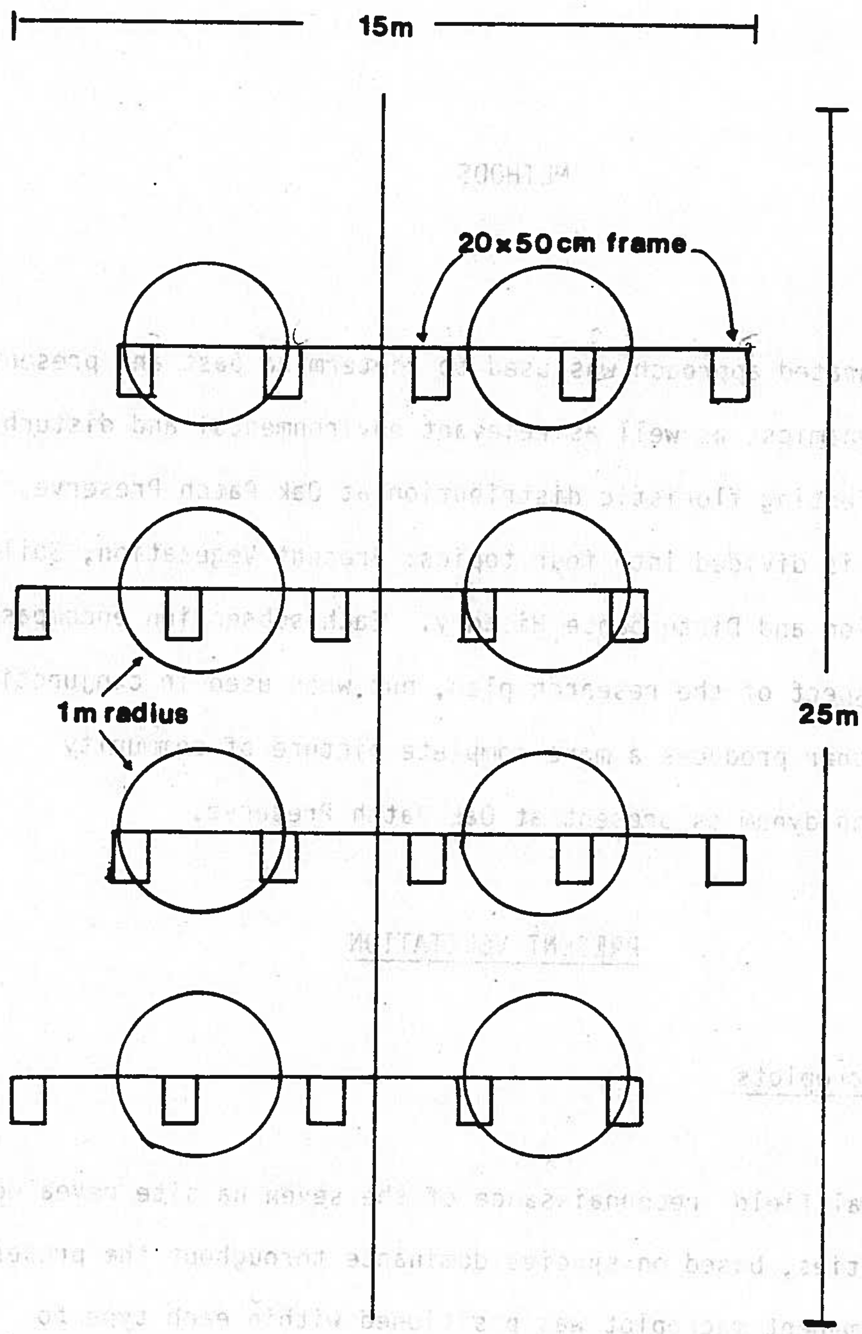


Figure 3. Macroplot design.

1)Twenty 20x50 cm frames were systematically placed along the transects. Percent cover of herbs and low growing shrubs were estimated. Density and percent cover of all seedlings up to .5 m in height were recorded as well.

2) Two 1 m radius circular plots per transect were used to sample tall shrub percent cover and .5-2 m tall and less than 5 cm diameter at breast height (dbh) seedling/sapling cover and density.

3) All trees greater than 5 cm dbh located within the 15x25m macroplot were tagged. Height and dbh were recorded, and densities tabulated for each species. Increment cores were extracted as close to the base as possible for each tree. Cores were mounted and sanded, and ages determined. Estimations of tree ages were necessary for those cores not intersecting the pith. Correction factors were developed to estimate growth from tree base to core height as well.

Vegetative similarity between macroplots was examined via a quantified version of Sorensen's similarity index (Mueller-Dombois and Ellenberg 1974), using percent cover data for herbs and shrubs, and relative density data for tree species. A community coefficient was calculated for each possible pair of plots using the following formula:

$$cc = 2*minV/V1+V2 * 100$$

cc=community coefficient
minV=smallest quantitative value (relative density or cover) common to both plots
V1=cover or density value for plot A
V2=cover or density value for plot B

A matrix was then developed based on pairwise community coefficient values.

Transect Plots

Vegetation

A systematic vegetation sampling scheme was chosen as an amendment to the macroplot design in order to refine reconnaissance results and utilize floristic data to infer forces responsible for distribution of species throughout the preserve. Eight north-south oriented transect lines were systematically run through the site, and into the adjacent *Pseudotsuga menziesii* forest (Figure 4). Vegetation plot centers were placed at 30m intervals along each transect, with a total of seven plots per transect. Tree percent cover and density by species were recorded in a 100 sq m plot. A 25 sq m subplot was used to estimate percent cover of shrub species, with herbaceous vegetation percent cover sampled in a 4 sq m subplot.

Two complimentary multivariate techniques were chosen for organizing transect vegetation data. Ordination analysis arranges species and samples along floristic gradients based on similarities between variables. Classification, or clustering analysis, groups related samples or species. Used together, these methods can effectively summarize ecological data, and aid in interpreting environmental and successional interactions with community structure, composition, and distribution.

Ordination - Detrended correspondence analysis (DCA) is an improved eigenvector ordination technique employed in the FORTRAN program DECORANA (Hill,1979a.), and was chosen to analyze transect vegetation data. It was considered the most sophisticated and objective means of

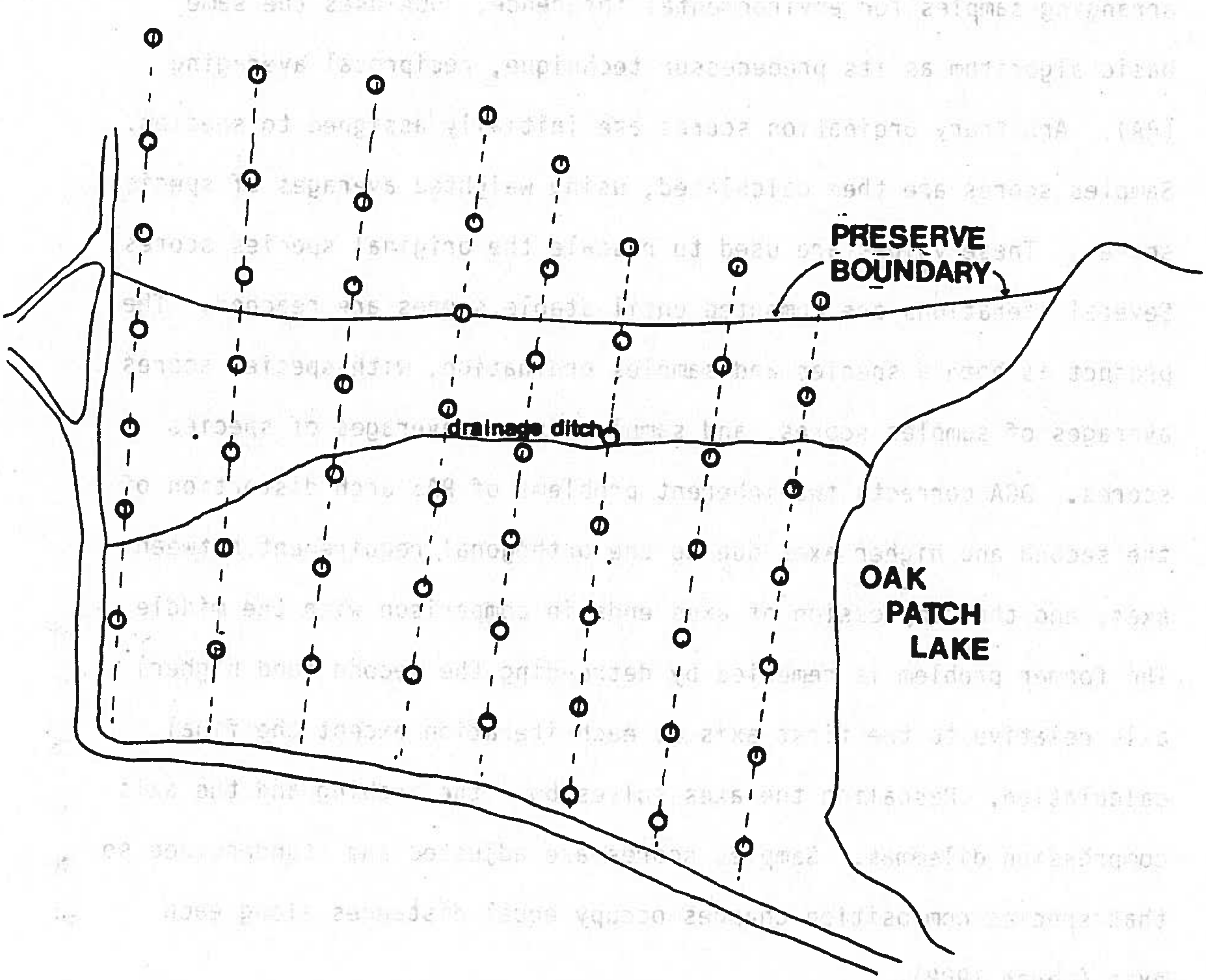


Figure 4. Location of transect plots at Oak Patch Preserve.

arranging samples for environmental inference. DCA uses the same basic algorithm as its predecessor technique, reciprocal averaging (RA). Arbitrary ordination scores are initially assigned to species. Samples scores are then calculated, using weighted averages of species scores. These values are used to rescale the original species scores. Several iterations are computed until stable scores are reached. The product is both a species and samples ordination, with species scores averages of samples scores, and samples scores averages of species scores. DCA corrects two inherent problems of RA: arch distortion of the second and higher axes due to the orthogonal requirement between axes, and the compression of axes ends in comparison with the middle. The former problem is remedied by detrending the second (and higher) axis relative to the first axis at each iteration except the final calculation. Rescaling the axes solves both the arching and the axis compression dilemmas. Samples scores are adjusted and standardized so that species composition changes occupy equal distances along each axis (Gauch 1982).

Cover data for all species with greater than two percent cover in each of the transect plots was entered and analyzed by DECORANA. Species and samples ordination diagrams were produced.

Community type composition and distribution information utilized by multivariate analysis was used to infer environmental and successional gradients across the landscape (Waring and Major,1964; Zobel et al, 1976). Indirect gradient analysis was employed; environmental inferences were based solely on floristics, with no data gathered on physical parameters (such as temperature and moisture).

Classification - Two-way indicator species analysis, a polythetic divisive classification method was chosen to analyze the floristic data from transect plots. It was considered to be the most objective technique for organizing floristic data into community types. The FORTRAN program TWINSPAN (Hill,1979b.) utilizes this hierarchical technique. Samples data are initially ordinated by reciprocal averaging using all of the species data. Species that occupy the axis extremes are used to separate samples data, and the ordination axis is broken in the middle to create the original two clusters. These differential species are used to further divide the clusters until no more than the predetermined number of samples are contained within each group (Gauch,1982).

All species with greater than two percent cover in each of the plots were used in the TWINSPAN classification scheme. Default parameters were computer chosen in all cases, rather than individually selected by the experimenter. Output consisted of a dendrogram, with differential species identified in the selection of each cluster.

Pre-dawn moisture stress

Transect plots were utilized for pre-dawn moisture stress analysis on September 24, 1984. Moisture stress should be at the lowest value at this time, only limited by soil moisture conditions surrounding the root system (Waring and Cleary,1967). Fourteen 2-4m tall *P. menziesii* saplings, and five *Q. garryana* from a range of heights were randomly selected within vegetation plots. Two *Pseudotsuga* twigs from the north side of each tree were clipped at approximately 2m height and placed in a pre-moistened polyethylene bag. Quercus leaves and twigs were collected in the same fashion. No more than five minutes elapsed between collection and measurement.

Samples were prepared for measurement following standard methods (Ritchie and Hinckley,1975). A Scholander pressure chamber was used to determine water potential of sample twigs and leaves. Two values were obtained for most trees. These were averaged in most cases, except when spurious values were obtained due to equipment failures.

Correlations between TWINSPAN identified community types and pre-dawn moisture stress values were calculated. Comparisons between Q. garryana and P. menziesii water potential were made.

Seedling Establishment

One 4 sq m plot was placed within the preserve to observe establishment patterns of both Quercus and Pseudotsuga. Only one plot was selected, due to the destructive nature of the sampling scheme. Plot location was subjectively chosen to include both species of seedlings. All seedlings were mapped, and heights recorded. Basal discs were cut from each of the four P. menziesii seedlings on the plot. Discs were sanded, polished and ages assigned using a dissecting scope to count annual rings. Scars were observed on three discs, and disturbance dates were determined. An additional 24 Pseudotsuga seedlings randomly selected from adjacent areas were clipped, measured for height, and aged.

Quercus garryana sprout and seedling regeneration were sampled as follows: The 29 sprouts were measured for height and clipped below the root collar. Height and age was recorded, and a basal disc obtained from the one true seedling. Individual sprouts, as well as the seedling disc were sanded, polished, and aged. Twenty five additional Quercus seedlings/sprouts randomly selected from an adjacent site were basally clipped, heights recorded, and aged following the above techniques.

Height/age relationships of Q. garryana and P. menziesii regeneration were examined via least squares regression. This statistical method has been used successfully to evaluate and characterize relationships between independent and dependent variables (Kleinbaum and Kupper,1978). Age was considered the independent variable, with height as the dependent variable. Ninety five percent mean confidence intervals were calculated as well.

Tree Growth Dynamics

A Q. garryana and P. menziesii from a small diameter class (<17 cm dbh) and a large diameter class (>17 cm dbh) were selected. The larger diameter Quercus was one of a clump of trees, and was presently overtopped by the larger diameter Pseudotsuga. The smaller diameter Quercus and Pseudotsuga were located at the edge of a shrubby clearing, and were partially shaded by conifers. Each tree was felled and sectioned at the base, as well as every 1.5m up the bole. Discs were sanded and aged.

Ages from sectioned discs were used to construct growth rate diagrams for each tree. This aided in interpretation of past interaction between the two species, and in understanding any influences one species may exert on the other.

SOILS

Macroplots

A soil pit was dug adjacent to each of the four macroplots in order to compare soil characteristics under different present day communities. An additional pit was opened under herbaceous vegetation next to a 200 year old Q. garryana to get soil samples under a mature Quercus/Poaceae community. Soils were described, and samples taken from each horizon for laboratory analysis. Percent cobble content by volume was recorded for each horizon.

Comparisons between horizon depths and A horizon color was qualitatively analyzed. Cobble content between plots was examined.

The organic matter content of the A and B horizons from each of the five sites was analyzed via the loss on ignition technique. Two replicates of each horizon were taken. Loss on ignition was calculated by the following formula:

$$\%\text{loss on ignition} = \frac{\text{oven dry wt} - \text{ignited soil wt}}{\text{oven dry wt of sample}} * 100$$

Comparisons were made between community values.

Transects

Depth and color (designated by the Munsell color chart) of the A horizon were recorded in each of the 56 transect plots. Understory and litter components were noted, as well as textural characteristics.

Modification of a soil development index (SDI) (Harden,1982) was used to standardize A horizon soil color components from the 56 transect plots, and incorporate these data, along with organic horizon depth data into a single variable for use in vegetation-soil interaction analysis and environmental interpretation. Soil color is composed of three components: hue, chroma and value. Hue and chroma variables are associated with the amount of weathering and the age of the soil; whereas the value of a soil is closely related to the amount and distribution of organic matter in the solum (Buntley and Westin,1965). The age and weathering processes of the soils of Oak Patch were considered uniform across the site, so hue and chroma variables were not incorporated into the SDI.

Melanization, the darkening of the soil due to organic matter accumulation is contained in the value color component and was quantified as follows:

$$Xv=10[(\text{value}\,\Delta\, X_a)]$$

Xv= quantified color value associated with organic matter content
ΔX_o= (value of C horizon) - (value of A horizon)

(from Harden,1982)** An average of C horizon values from the four macroplot soil pits was used, as C horizon colors were unavailable for the 56 transect plots.

The "Xv" measure was then multiplied by the horizon depth to obtain the final soil development index value for the A horizon (Harden,1982).

Mean SDI values for each community type were calculated and comparisons between types were made.

PAST VEGETATION

Palynological Evidences

A sediment core of Oak Patch Lake (see Figure 2) was taken using a Phleger-type gravity sampler (Phleger,1951). Subsamples of upper (0-2 cm), mid (10-12 cm) and lower (18-20 cm) portions of the 20 cm long sediment core were selected for pollen analysis. Samples were prepared and processed according to standard techniques (Faegri and Iverson,1975). Pollen residues were mounted in silicon oil, identified and counted at 400X and 1000X magnifications. No less than 300 pollen grains were counted at each level.

Pollen counts from each of the three sediment depths were used to develop a pollen diagram. Pollen percentages were calculated based on the total terrestrial pollen at each sampling depth.

Biological Information

Twenty increment cores were extracted from randomly selected larger diameter *Pseudotsuga* (> 55 cm dbh) and *Quercus* (> 25 cm dbh) on the site. Cores were brought back to the laboratory, mounted and sanded and aged.

Age classes were determined for all larger diameter trees collected on the site. A diagram was produced to illustrate past stand composition throughout time, including both pre-settlement and post settlement situations.

Tree age data collected from macroplots was used to examine stand initiation and development patterns, within each community. A diagram was produced to illustrate age class distribution by species.

Historical Information

Land survey records from 1874 were examined for Oak Patch Preserve and the adjacent area. Information on section and quarter section tree markers, such as species and their accompanying diameter class, as well as summary descriptions of site quality, soils and disturbances was used to produce a qualitative vegetation reconstruction of the area.

A history of ownership was developed for the site. Mason County title records provided specific information on both formal land leasing and deeded ownership of the site from 1892 to the present.

Mrs. Alice Pope Gilbert, a Belfair resident whose family homesteaded within two miles of Oak Patch, was interviewed. Qualitative information requested concerned stand composition of Oak Patch, site use, and disturbance frequency. The Mason County Historical Society also provided pertinent information concerning the area.

DISTURBANCE HISTORY

Fire History

Information collected from Oak Patch Preserve, as well as three clearcuts in a two mile radius from the site were used to determine fire history in the area. Both live and dead tree material provided evidence of past fire frequency and intensity.

Ten live scarred *P. menziesii* trees located within or directly bordering the preserve, and 11 trees at the three clearcuts were cored. A mininum of two cores were extracted per tree to determine actual scar dates. Germination dates were calculated as well.

Two multiple scarred live *Pseudotsuga* seed trees in one clearcut were selected and felled. Basal discs were sanded, and scar dates assigned.

A general reconnaissance of *P. menziesii* stumps at each of the three clearcuts was performed. Six scarred stumps were sectioned and brought back to the laboratory where they were sanded, aged and scar dates assigned. Department of Natural Resources records provided logging dates. Five stumps were examined in the field, and approximate scar and germination dates were determined.

Numerous *Pseudotsuga* stumps were discovered on the preserve. Several attempts to obtain discs were unsuccessful, however, due to the advanced stages of decay that had set in. One stump was partially intact because of the high quantity of resin surrounding numerous scars. The sapwood was rotted, however, so chronological dates could not be obtained for these scars. Scar frequency was examined in this case. Portions of another stump was salvaged as well. These samples were sanded, and scar frequencies were determined.

Department of Natural Resources records were examined for the Oak Patch and clearcut locations. Historical records provided regional information on large fires that may have burned in the area.

Fire frequencies and chronological fire dates were determined from stump and live tree core information. These data were checked against any pertinent historical evidence, and a fire history of the area was determined.

Germination dates of stump samples, as well as live tree ages of _P. menziesii_ and _Q. garryana_ were utilized to produce an age class distribution diagram. This aided in fire history and past fire frequency determinations.

Logging

The two _Pseudotsuga_ stump sections used in fire history sampling at Oak Patch Preserve were also used to determine logging history. However, due to stump age and advanced decay, exact logging dates could not be determined from these samples. Increment cores from live _P. menziesii_ and _Q. garryana_ on the site were utilized for this purpose.

Twenty increment cores extracted from selected _Quercus_ and _Pseudotsuga_ on the site were aged. Ring widths were measured with the Bannister incremental measuring table, and graphed in a chronological sequence. Suppression-release patterns were examined, and correlated with fire history and historical information. Age class data were also used.

Historical information was employed to substantiate biological data. Legal lease records to logging companies, survey records, and Department of Natural Resources records were all used to determine logging history of the site.

Other Disturbances

Disturbances such as grazing and hunting were only examined peripherally. Historical records and a personal interview with a Belfair resident were used to determine if these disturbances played and important role in the vegetation history of the preserve.

RESULTS AND DISCUSSION

PRESENT VEGETATION

Community Descriptions

FIELD RECONNAISSANCE RESULTS

Four communities were identified by field reconnaissance: 1)open herbaceous, 2)*Pseudotsuga menziesii/Gaultheria shallon*, 3)*Quercus garryana/Symphoricarpos albus*, 4)*Quercus garryana - Pseudotsuga menziesii/Symphoricarpos albus* (Figure 5,Plate 1). Plant composition of the four types (Table 1) exhibit few similarities among communities, with *Symphoricarpos albus*, *Amelanchier alnifolia*, *Rubus ursinus* and *Quercus garryana* the only species common to all four plots.

Very low densities of juvenile *Rhamnus purshiana* (26/ha) and *Pseudotsuga menziesii* (80/ha) characterize the open herbaceous commumity (Figures 6,7). This community occupies approximately one hectare, and is found in the northwestern section of the preserve (Figure 5). *Q. garryana* seedlings are very scattered throughout the area, with densities of 26/ha. Shrub cover is moderate, with *Berberis aquifolium* and *Holodiscus discolor* dominating. A diverse herb layer

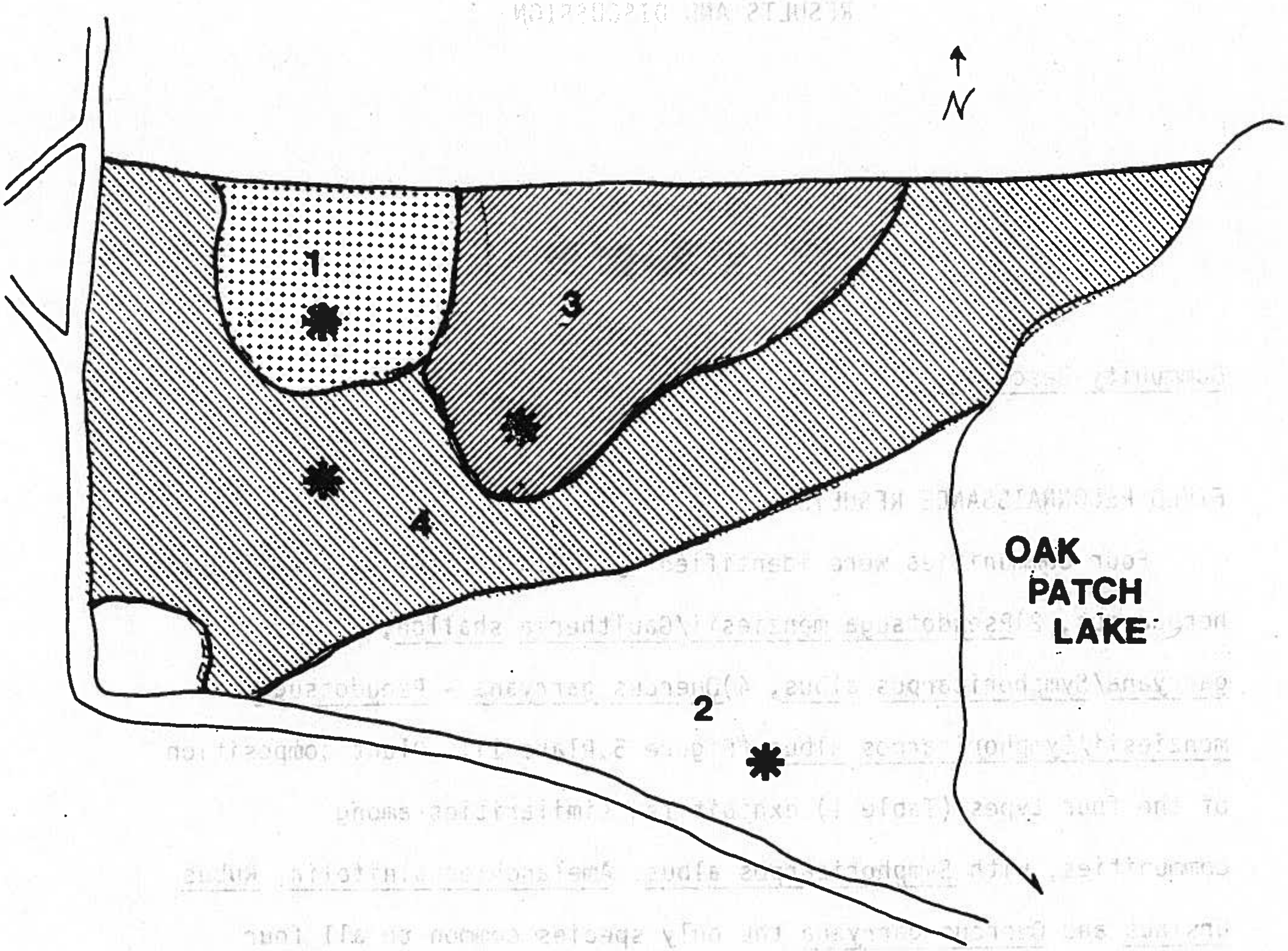


Figure 5. Location of communities at Oak Patch Preserve.

1 = open herbaceous
2 = Pseudotsuga menziesii/Gaultheria shallon
3 = Quercus garryana/Symphoricarpos albus
4 = Quercus garryana - Pseudotsuga menziesii/Symphoricarpos albus

Table 1. Species composition of the four communities identified by field reconnaissance methods:

1 = open herbaceous
2 = Pseudotsuga menziesii/Gaultheria shallon
3 = Quercus garryana/Symphoricarpos albus
4 = Quercus garryana - Pseudotsuga menziesii/Symphoricarpos albus

	COMMUNITY			
	1	2	3	4
TREE STRATUM *				
Quercus garryana		1	25	11
Pseudotsuga menziesii	3	20		6
Rhamnus purshiana	1		3	
Salix lasiandra		2		
Pinus contorta var. contorta		2		
SEEDLINGS *				
Quercus garryana	1	1	8	18
Pseudotsuga menziesii				1
SHRUB STRATUM +				
Berberis aquifolium	16			11
Berberis nervosa		11		
Symphoricarpos albus	7	3	64	38
Holodiscus discolor	12			3
Rosa gymnocarpa	5		8	
Rosa nutkana				7
Amelanchier alnifolia		2		
Pyrus fusca	2			
Gaultheria shallon		68		
Corylus cornuta var. californica		6		
Spiraea douglasii			9	
Arctostaphylos uva-ursi	2			
HERB STRATUM +				
Fragaria vesca var. crinita			5	7
Carex sp.	14			
Holcus lanatus			2	
Poa pratensis			3	
Rubus ursinus	2		2	4
Lonicera ciliosa			3	
Pteridium aquilinum		10		
Chrysanthemum leucanthemum	4			
Hypericum perforatum	4			
CRYPTOGAMS +				
moss	16	12		26

* density/macroplot

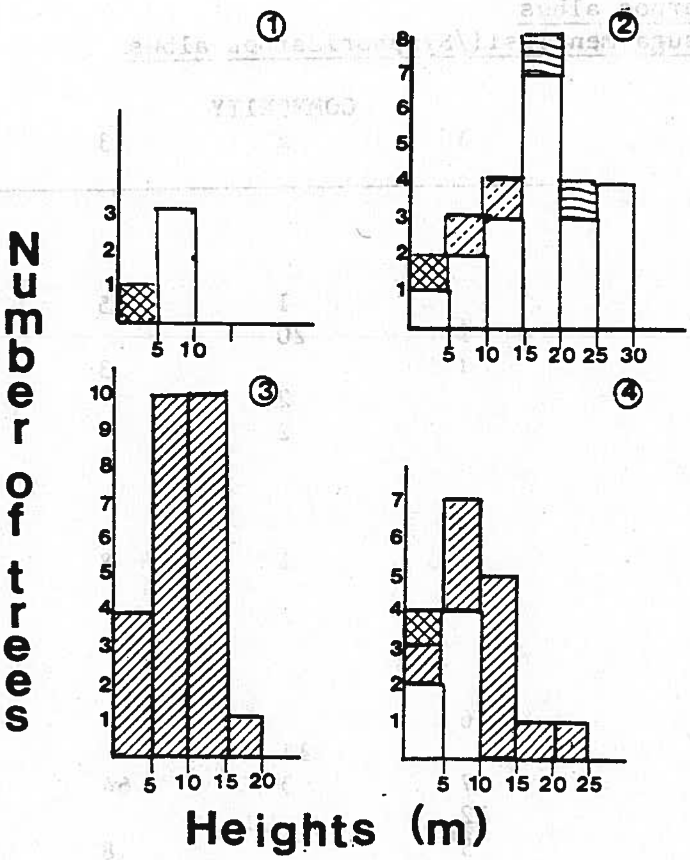


Figure 6. Number of trees by height class within macroplots

= Quercus garryana

= Rhamnus purshiana

= Pseudotsuga menziesii

= Salix lasiandra

= Pinus contorta

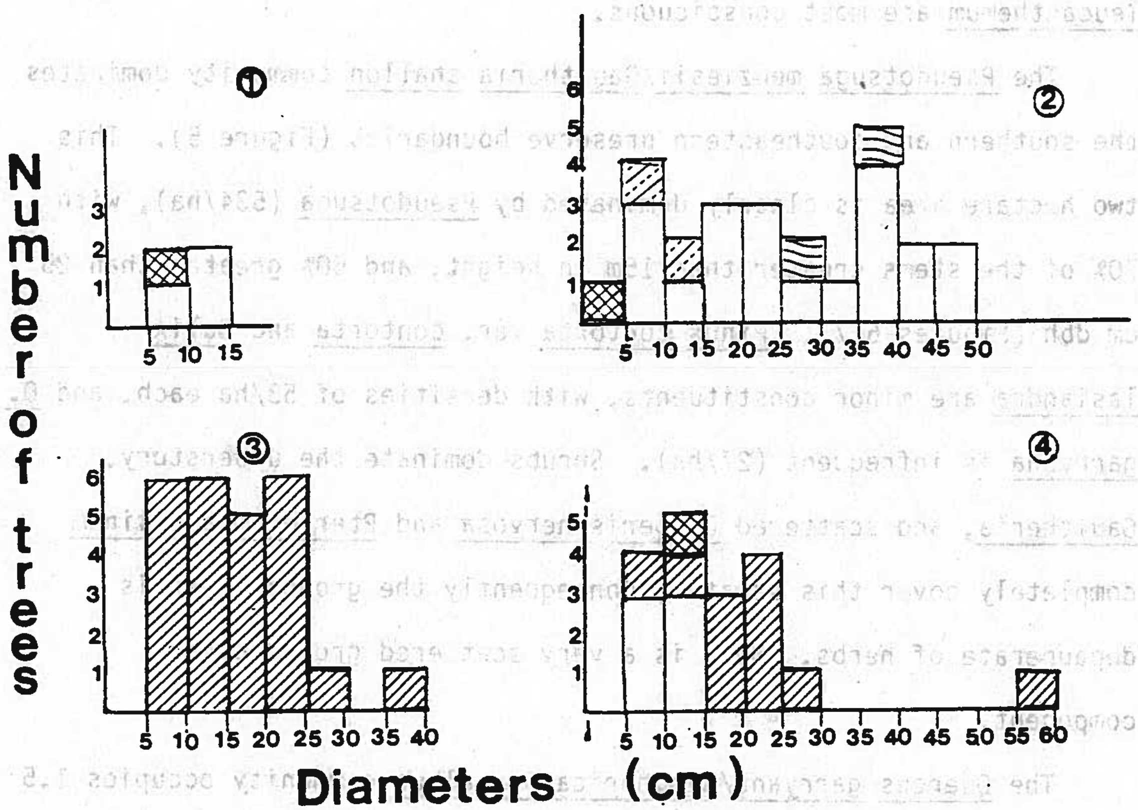


Figure 7. Number of trees by diameter class within macroplots.

= <u>Quercus</u> <u>garryana</u>

= Rhamnus purshiana

= <u>Pseudotsuga</u> <u>menziesii</u>

= <u>Salix</u> <u>lasiandra</u>

= <u>Pinus</u> <u>contorta</u>

carpets the understory. Carex pensylvanica var. vespertinum, Carex spp. and weedy species such as Hypericum perforatum and Chrysanthemum leucanthemum are most conspicuous.

The Pseudotsuga menziesii/Gaultheria shallon community dominates the southern and southeastern preserve boundaries (Figure 5). This two hectare area is clearly dominated by Pseudotsuga (534/ha), with 70% of the stems greater than 15m in height, and 50% greater than 25 cm dbh (Figures 6,7). Pinus contorta var. contorta and Salix lasiandra are minor constituents, with densities of 53/ha each, and Q. garryana is infrequent (27/ha). Shrubs dominate the understory. Gaultheria, and scattered Berberis nervosa and Pteridium aquilinum completely cover this stratum, consequently the ground layer is depauperate of herbs. Moss is a very scattered ground cover component.

The Quercus garryana/Symphoricarpos albus community occupies 1.5 hectares of Oak Patch Preserve (Figure 5). Tree densities are highest within this site (747/ha), dominated by Quercus. Eighty percent of the Quercus are in the 5-15m height class, and range from 5-40 cm. dbh. (Figures 6,7). Rhamnus purshiana is a minor associate. Q. garryana regeneration is high (213/ha), due to the proximity of seed source and the sprouting ability of this species. Shrub cover is high, with Symphoricarpos clearly dominant. Poa spp., Holcus lanatus, Fragaria vesca var. crinita and Lonicera ciliosa are the major components of the diverse herb layer.

The most extensive community is the Quercus garryana-Pseudotsuga menziesii/Symphoricarpos albus community (2.5 hectares) (Figure 5). Total tree densities (453/ha) are lower than both the pure Quercus and the pure Pseudotsuga communities. Q. garryana is the most conspicuous species (294/ha), occupying the largest diameter (greater than 15 cm) and height (greater than 10m) classes (Figures 6,7). Quercus regeneration is highest in this community (480/ha). P. menziesii seedlings are also present in small quantities (26/ha). The shrub layer is well represented. S. albus is the most important species, but Berberis aquifolium and Rosa nutkana var. nutkana are common associates. Herbaceous cover, although low, is diverse. Species include Fragaria vesca var. crinita, Rubus ursinus, Lathyrus nevadensis var. pilosellus, Vicia americana and Lonicera ciliosa.

Community coefficients indicate overall similarity between plots is relatively low (Table 2). High similarity does exist between Quercus/Symphoricarpos and Quercus - Pseudotsuga/Symphoricarpos communities.

CLUSTER ANALYSIS

Cover data for the original 56 transect plots were examined, and three outlier plots were identified, based on their vegetation composition and proximity to the disturbed microsites. Two plots were located in small, anomalous shrub patches associated with the drainage ditch. Another plot contained the only Thuja plicata on the site, and thus was discarded.

Classification resulted in the identification of four forest community types: 1) Pseudotsuga menziesii/Gaultheria shallon/Linnaea borealis, 2) Pseudotsuga menziesii - Quercus garryana/Holodiscus discolor/Chrysanthemum leucanthemum, with two shrub phases: a) Gaultheria shallon b) Arctostaphylos uva-ursi, 3) Quercus garryana -

Table 2. Community coefficients of similarity between communities identified by field reconnaissance:

1 = open herbaceous
2 = *Pseudotsuga menziesii*/*Gaultheria shallon*
3 = *Quercus garryana*/*Symphoricarpos albus*
4 = *Quercus garryana* - *Pseudotsuga menziesii*/*Symphoricarpos albus*

	COMMUNITY PERCENT SIMILARITY			
	1	2	3	4
1	--	46.9	14.4	40.7
2	--	--	4.4	28.3
3	--	--	--	73.2
4	--	--	--	--

Pseudotsuga menziesii -Rhamnus purshiana/Symphoricarpos albus - Berberis aquifolium/Fragaria vesca var. crinita, 4) Quercus garryana - Rhamnus purshiana/Rosa nutkana - Symphoricarpos albus/moss.

The community types identified by cluster analysis are similar to the four communities recognized by field reconnaissance. Q. garryana and P. menziesii dominated types are recognized by both techniqes. Cluster analysis refined the Quercus garryana - Pseudotsuga menziesii/ Symphoricarpos albus community, which is the most extensive of the four communities identified by field methods, and was observed to be the most variable in composition and structure. The open herbaceous community was not large or homogeneous enough to be identified as a separate community type. It was identified as an ecotone between the Pseudotsuga menziesii - Quercus garryana/Holodiscus discolor/Chrysanthemum leucanthemum and the Quercus garryana - Pseudotsuga menziesii - Rhamnus purshiana/Symphoricarpos albus - Berberis aquifolium/ Fragaria vesca var. crinita community types.

ORDINATION ANALYSIS

Community types identified by cluster analysis were used to categorize transect plots in ordination space (Figure 8). Eigenvectors representing axis one and two accounted for the majority of variance in the data (73.1%), so further analysis of higher order axes was discontinued.

Distribution of community types along axis one suggest a moisture gradient is evident within the preserve. The Pseudotsuga/Gaultheria/Linnaea community type occupies the lower, most mesic end of the axis, followed by the Pseudotsuga -

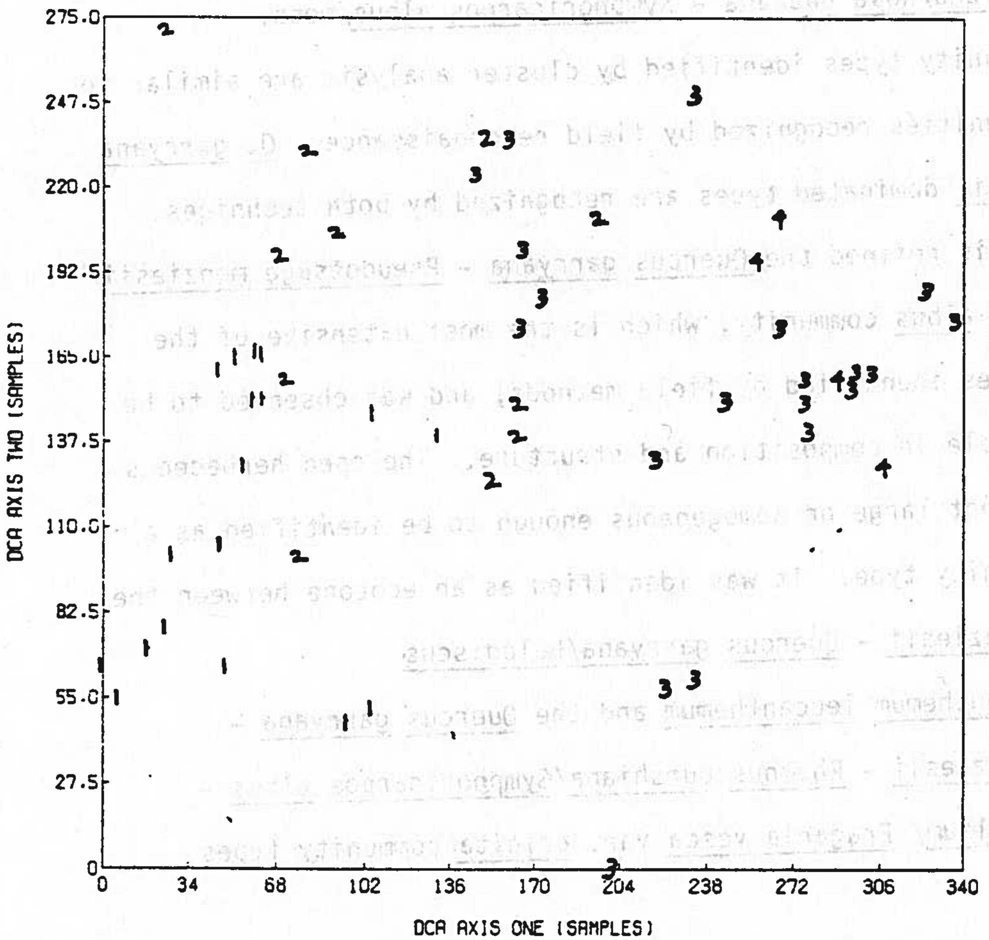


Figure 8. Ordination of transect plots.

1 = Pseudotsuga menziesii/Gaultheria shallon/Linnaea borealis
2 = Pseudotsuga menziesii - Quercus garryana/Holodiscus discolor/ Chrysanthemum leucanthemum
3 = Quercus garryana - Pseudotsuga menziesii - Rhamnus purshiana/ Symphoricarpos albus - Berberis aquifolium/Fragaria vesca var. crinita
4 = Quercus garryana - Rhamnus purshiana/Rosa nutkana - Symphoricarpos albus/moss

Quercus/Holodiscus/Chrysanthemum community. Quercus -Pseudotsuga - Rhamnus/Symphoricarpos - Berberis/ Fragaria indicates more droughty microsites, with Quercus - Rhamnus/Rosa - Symphoricarpos/moss nested within this community types's ordination space.

Pre-dawn water potential values for selected Quercus and Pseudotsuga at Oak Patch are listed by community type in Table 3. Sample size is small and variation within community type is high in most cases, but a general trend is apparent. Q. garryana is consistently less moisture stressed than P. menziesii in all three community types sampled. Moisture stress values for both species decrease from Pseudotsuga dominated community types to Quercus community types. This trend seems to run counter to the hypothesis that Pseudotsuga should exist on less water stressed sites. It is important to note that a water potential value is not a purely physical measure. Root competition for moisture will deplete soil water reserves, and increase moisture stress. Shallow rooted Pseudotsuga, especially seedling and saplings are competing with shrub and herb vegetation for soil moisture, thus draining the available moisture in surface horizons. Pseudotsuga may be occupying more mesic microsites, but competition for water reserves could be artificially creating more xeric conditions.

Edaphic conditions can create droughty microsites, limiting water availability, especially in upper soil horizons. Soils of the Oak Patch Preserve vicinity developed from gravelly glacial till and outwash material. The site and surrounding valley appears to be a continuous outwash channel from aerial photographs (USDA SCS,1951), and presently lies near the Tahuya River channel area. Variation in

Table 3. Pre-dawn water potential values for selected Quercus garryana and Pseudotsuga menziesii saplings/trees located within TWINSPAN identified community types. All values are in bars.

	COMMUNITY TYPE *			
	1	2	3	4
Quercus garryana				
mean value	3.5	1.0	0.9	--
range	--	--	.8-1.5	
sample size	1	1	3	
Psuedotsuga menziesii				
mean value	7.5	5.9	5.2	--
range	3.5-9.5	3.0-9.0	2.5-7.0	
sample size	5	4	5	

* 1 = Pseudotsuga menziesii/Gaultheria shallon/Linnaea borealis
2 = Pseudotsuga menziesii - Quercus garryana/Holodiscus discolor/ Chrysanthemum leucanthemum
3 = Quercus garryana - Pseudotsuga menziesii - Rhamnus purshiana/ Symphoricarpos albus - Berberis aquifolium/Fragaria vesca var. crinita
4 = Quercus garryana - Rhamnus purshiana/Symphoricarpos albus - Rosa nutkana/moss

coarse fragment content could account for differing water availability, thus creating a moisture gradient throughout the site (see Soils section).

Dyrness et al.(1974) state that a temperature gradient was responsible for stratifying forest zones in their vegetation classification of the central portion of the western Cascades Province in Oregon. Moisture stress variations were concluded to be the driving force in intrazonal distribution. Zobel et al.(1976) validated this hypothesis by correlating temperature index values with zonal differentiation and moisture index values with distribution within a vegetation zone. The influence of moisture in vegetation distribution at Oak Patch Preserve is thus consistent with the aforementionned research, as the preserve lies within the Tsuga heterophylla zone (Franklin and Dyrness,1973).

Past research indicates that Quercus garryana communities commonly occupy the driest, more exposed microsites in the Pseudotsuga menziesii range (Fowells, 1965; Krajina,1970; Franklin and Dyrness,1973). The presence of Holodiscus, in addition to Quercus signifies more xeric conditions in P. menziesii dominated stands (Franklin and Dyrness,1973; Zobel et al.,1976). In Quercus garryana vegetation types of the Willamette Valley, Oregon, Thilenius (1968) ranked four Quercus communities along a moisture gradient. A community resembling community type 3, with Rhamnus and Pseudotsuga in the overstory and Symphoricarpos in the shrub layer was considered more mesic than a community resembling community type 4, with Rosa nutkana as a dominant understory component. There is not a strong differentiation between distribution patterns of Quercus - Pseudotsuga

- Rhamnus/Symphoricarpos - Berberis/Fragaria and Quercus - Rhamnus/Rosa - Symphoricarpos/moss at Oak Patch Preserve, which may indicate these community types are too similar in composition and moisture requirements to separate using this technique.

Water relations research corroborates the inferred available moisture gradient. Minore (1979) listed *Q. garryana* as the most tolerant of moisture stress of the northwest trees, with *Pinus contorta* less resistant, followed by *Pseudotsuga menziesii*. On a scale of 0 (dry) to 100 (wet) the ecological optimum for *Quercus garryana* was ranked at 10, as compared with 17 for *Pseudotsuga*, in moisture relations studies done in the coastal redwood region (Waring and Major,1964). *Quercus* species have long taproots that are able to utilize deeper water reserves. In a study comparing *Juniperus virginiana* (eastern redcedar) and *Quercus alba* (white oak), researchers found that soil water potential decreased more in shallow horizons than at depth for *J. virginiana* but not for *Q. alba* (Ginter-Whitehouse et al.,1983). This rooting characteristic is important in western Washington, especially in summer when drought conditions prevail.

The moisture gradient is refined in the second axis, with indicator understory species evidently spreading the community types. This is especially apparent in the *Quercus* - *Pseudotsuga* types. This trend is coupled with the effect of past disturbances (such as fire and logging) on the site, creating various seral stands, thus complicating the available moisture gradient.

The lower ordination space of axis two is occupied by *Pseudotsuga* or *Pseudotsuga* - *Quercus* community types dominated by moist site indicators. Gaultheria is present in P. menziesii community types, with Corylus cornuta a component of Quercus - Pseudotsuga stands. Pteridium aquilinum is common in these community types. This species is known as an early invader into Pseudotsuga sites (Franklin and Dyrness,1973).

Pseudotsuga stumps were noted in several mid-range plots of axis two. Both Q. garryana and P. menziesii are present and dominant in the 3-10 m height class, with P. contorta and R. purshiana more important constituents. Symphoricarpos is dominant in the understory. Sugihara et al. (submitted for publication) recognized dense stands of Quercus garryana/Symphoricarpos albus as a mesic seral community; the result of a past fire.

More open or younger stand structure characterizes the upper scale of the second axis. Arctostaphylos uva-ursi, a dry site indicator, is important in the Pseudotsuga type understory, and Rosa nutkana and R. gymnocarpa are common xeric indicators of the Quercus garryana communities (Thilenius,1968). Introduced weedy species such as Chrysanthemum leucanthemum, Senecio jacobaea and Prunella vulgaris, known as invaders following disturbance, are components of the herb layer.

Researchers have noted the effects of disturbance on Quercus - Pseudotsuga communities. In more mesic microsites, Q. garryana communities are considered seral to P. menziesii stands (Lang,1961; Fowells,1965; Krajina,1970). In the past, repeated fires have maintained Quercus woodlands and kept conifer populations to a minimum (Taylor and Boss,1975; Plumb and McDonald,1981). Logging in mixed conifer-Quercus stands can also favor Quercus (McDonald et al.,1983).

Q. garryana is able to invade newly disturbed areas, either by acorn germination or stump or root sprouting (Taylor and Boss,1975; McDonald et al.,1983; Sugihara et al.,1983). At Oak Patch, where Quercus openings are small and Pseudotsuga seed source is abundant, conifer encroachment is rapid. The result is a vegetation mosaic whose distribution is influenced not only by moisture differences but by the type and severity of past disturbances.

Distribution of present vegetation at Oak Patch Preserve is thus a result of complex forces. The inferred moisture availability trend, coupled with logging and fire effects have created a mosaic of plant communities across the preserve.

Stand Establishment Patterns

Both Quercus garryana and Pseudotsuga menziesii were found reproducing on Oak Patch Preserve. The 4 sq m seedling establishment plot contained four Pseudotsuga menziesii seedlings, ranging from 42 - 107 cm in height, and 6-14 years of age. Quercus regeneration consisted of one true seedling and three clusters of root sprouts totalling 29 stems. Suckers were found sprouting below root collars of large diameter roots. Many sprouts grew parallel to the ground before attaining any vertical height, and made it difficult to determine actual cluster sizes. Heights ranged from 23-145 cm, and ages from 1-10 years. Within-clump density varied from 5-15 (Table 4).

Browsing was apparent for both species. Multiple leaders existed in all Pseudotsuga seedlings, and current year needles were browsed. Scars were apparent in two seedlings and may have been the result of

Table 4. Ages and heights of species found in seedling establishment plot.

Pseudotsuga menziesii height (cm)	Pseudotsuga menziesii age	Quercus garryana height (cm)	Quercus garryana age
107	14	46	5
94	6	145*	9*
63	13	52*	7*
42	9	104*	7*
		40*	5*
		64*	7*
		52*	10*
		32*	4*
		59*	5*
		52*	5*
		81#	6#
		48#	5#
		50#	4#
		25#	1#
		27#	1#
		70'	5'
		45'	5'
		53'	5'
		34'	4'
		42'	5'
		45'	4'
		41'	8'
		34'	4'
		41'	5'
		41'	5'
		25'	2'
		54'	3'
		37'	3'
		44'	4'
		23'	4'

* = root sprouts from clump 1
\# = root sprouts from clump 2
' = root sprouts from clump 3

animal damage. Injury to terminal buds and current year leaves in 75% of Quercus sprouts indicated browsing had occurred.

Q. garryana seedlings and suckers and P. menziesii seedlings from the seedling establishment plot and adjacent areas were used in least squares regression to examine height/age relationships for the two species (Figure 9). No attempt was made to force the regression line through the origin, as first year height growth is very non-linear when compared with later growth, and would overly bias the regression equation. No data was collected to be able to accurately predict this first year relationship, so scatter diagrams are examined only within the data ranges common to both species. Correlations between height and age were strong in Pseudotsuga seedlings (.722), and regression results (r squared = 52.1%) indicate a linear relationship exists between the two variables. Quercus height/age correlations (.677) and coefficient of determination (r squared = 45.8%) indicates linearity as well, although the relationship is not quite as strong as that of Pseudotsuga.

The clumped sprouting nature of many of the Q. garryana regeneration accounts for the high variability present in the scatter diagram (Figure 9). Numerous stems sprout from an established root system of the same tree in one year; however, height varies according to initial dominance acheived by the individual sprouts. Horizontal stem growth influences height as well. Some sprouts from each clump were growing parallel to the ground surface before achieving any vertical height. This growth form may be the response to low light intensities in the understory.

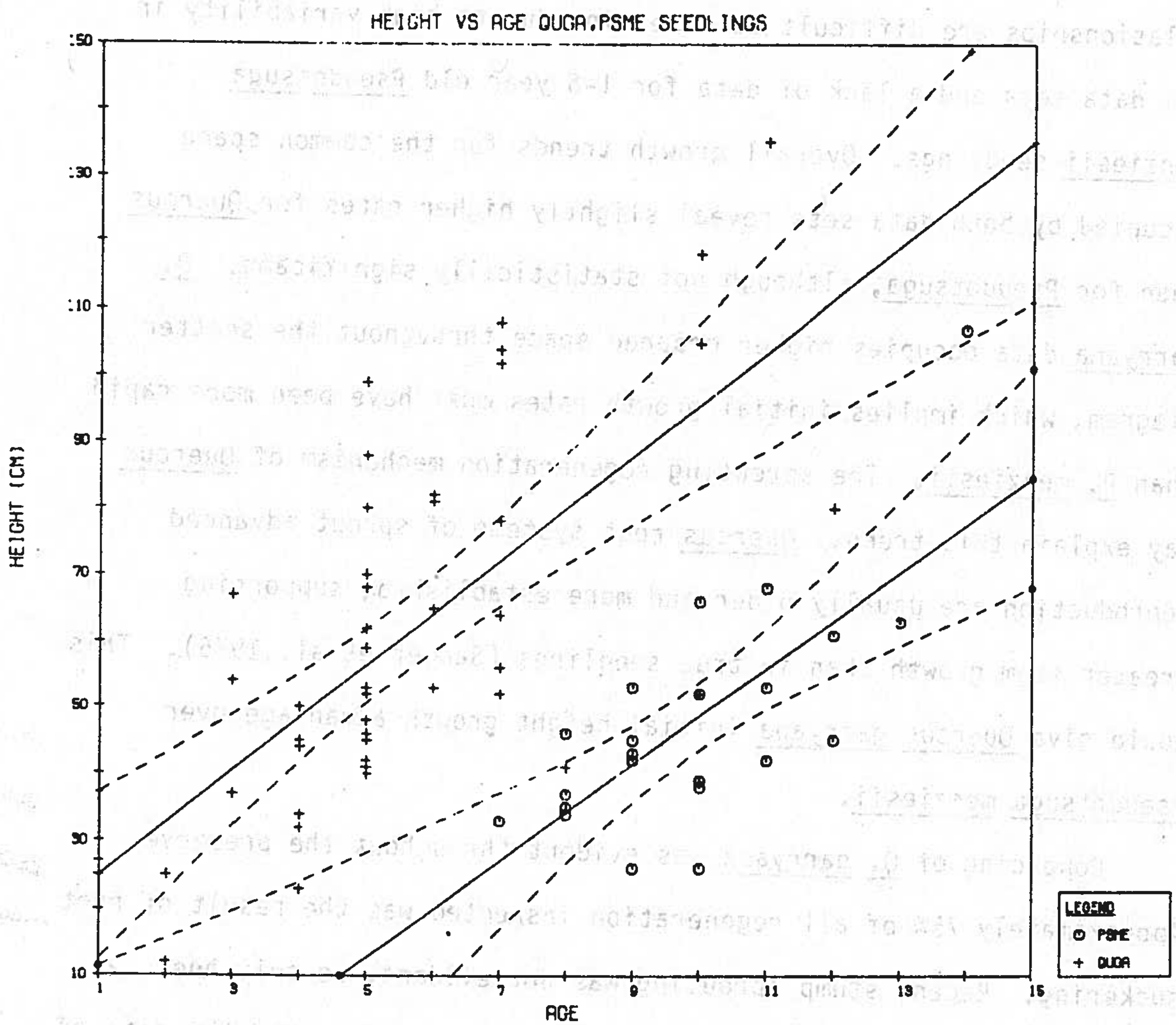


Figure 9. Least squares regression lines and 95 percent mean confidence intervals of seedling and sprout height vs. age.

Comparisons between Pseudotsuga and Quercus height/age relationships are difficult to determine due to high variability in the data sets and a lack of data for 1-6 year old Pseudotsuga menziesii seedlings. Overall growth trends for the common space occupied by both data sets reveal slightly higher rates for Quercus than for Pseudotsuga, although not statistically significant. Q. garryana data occupies higher graphed space throughout the scatter diagram, which implies initial growth rates must have been more rapid than P. menziesii. The sprouting regeneration mechanism of Quercus may explain this trend. Quercus root systems of sprout advanced reproduction are usually older and more established, supporting greater stem growth than in true seedlings (Sander et al.,1976). This would give Quercus garryana initial height growth advantage over Pseudotsuga menziesii.

Coppicing of Q. garryana was evident throughout the preserve. Approximately 75% of all regeneration inspected was the result of root suckering. Recent stump sprouting was not evident, as only one relatively intact Quercus stump was found on the site, and the date of cutting could not be determined.

Sprouting as a means of reproduction in Quercus has been studied by numerous researchers, and results are consistent with those at Oak Patch. Plumb and McDonald (1981) state that suckering from the root crown is the most important survival adaptation of California oaks. Three year old Quercus garryana sprouts in northern California were 2.8m in height (McDonald et al.,1983), indicating rapid vertical growth. Root suckers developing from scorched Oregon white oak in Humboldt County, California averaged 2m height in 2 years, and 2.79m height in 3 years (Roy 1955). Sprague and Hansen (1946) attributed stump and root sprouting as the major form of regeneration of _Q. garryana_ in the McDonald forest of the central Willamette Valley in Oregon.

The role of acorn germination as a reproductive measure has not been thoroughly investigated. Seed crops are variable, with heavy seed producing years estimated at 2-3 years for southwestern Oregon and northern California _Quercus_ species in general (McDonald et al.,1983). Acorns mature in one season, dropping in early fall, with germination occurring at that time or in the following early spring. Germination success varies. Fowells (1965) reports low success rates when acorns fall in heavy sod because penetration by the radicle is hindered, while McDonald et al. (1983) estimate 77-100% germination success, but stress that environmental factors (such as temperature, light and moisture) highly influence germination. _Curculio uniformis_ (filbert weevil) and _Melissopus latiferreanus_ (white moth) larvae infect acorns and render them sterile (Scheffer,1959). A high percentage of acorns that fall to the ground are eaten by deer, mice, chipmunks, squirrels and birds (Silen,1958). If germination is successful, heavy browsing of young seedlings, and root damage (caused by pocket gophers) may cause high mortality.

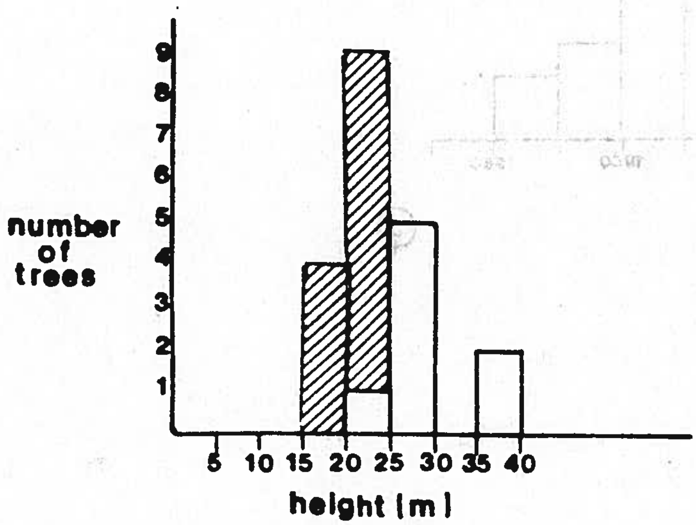
Stand Structure

Present arboreal composition at Oak Patch Preserve varies over space, with dominance of _Pseudotsuga menziesii_ in some areas, and _Quercus garryana_ dominance evident in other sections; co-dominance exists in mosaics throughout. An examination of height, diameter, and age relationshins (from data collected on macroplots and additonal trees on the site), and growth rate analysis investigate present stand structure dynamics on the site.

Quercus and Pseudostuga are represented in a wide variety of height and diameter classes (Figures 6,7,10). Pseudotsuga occupies larger height (25-40m) and diameter (55-75cm) classes, but is also present in smaller classes as well. Distribution of larger trees is concentrated in the northern, southern, and southeastern preserve boundaries, however several considerable sized individuals are scattered within the Q. garryana - P. menziesii community. Several Pseudotsuga stumps are found scattered throughout the northwestern and southern portions of the site, which may bias the data toward smaller trees, due to the removal of larger trees from the site.

Quercus garryana is also well represented; heights range from 4-25m, and diameters vary from 5-80 cm. The largest trees are widely spaced within the Quercus - Pseusdotsuga community. Pinus contorta var. contorta and Salix lasiandra are minor constituents, occupying mid range height and diameter classes, with Rhamnus purshiana present only in the smallest divisions.

A wide age range exists on the site (Figures 11,12). Young (10-20 year old) Pseudotsuga menziesii are invading the open herbaceous community, as well as the Quercus garryana - Pseudotsuga menziesii community. Older trees (up to 200 years of age) are represented throughout the area, but are concentrated within the northern and southeastern preserve boundaries. Past logging has eliminated the older age classes. Q. garryana dominates the oldest age classes (180-



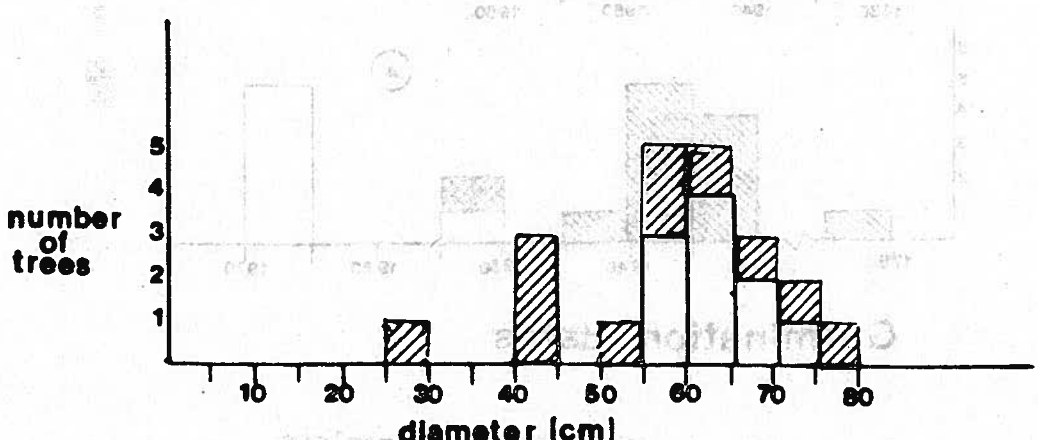


Figure 10. Number of selected trees by height and diameter classes from Oak Patch Preserve and adjacent areas.

= *Quercus garryana*

= *Pseudotsuga menziesii*

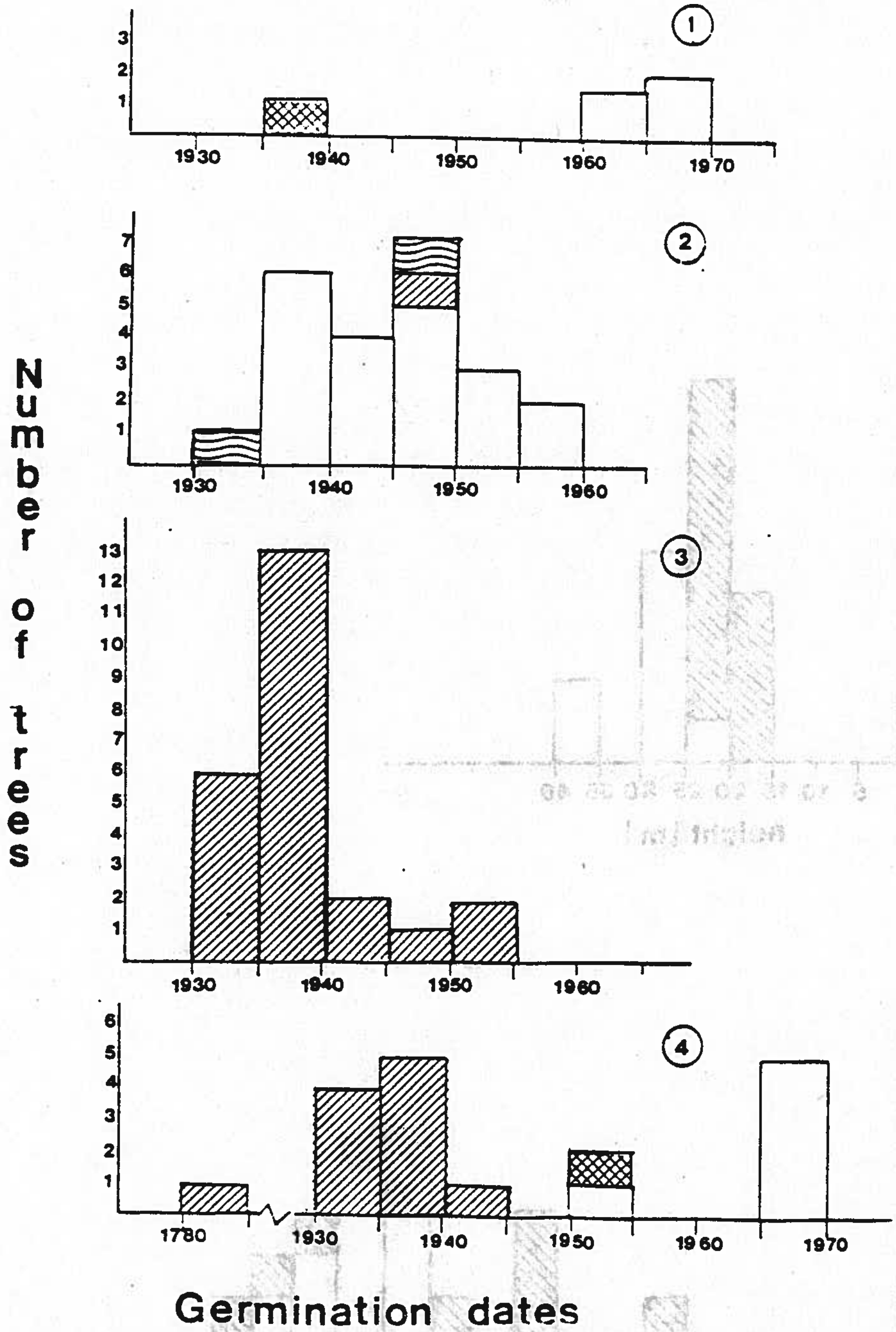


Figure 11. Number of trees by age class within macroplots.

1 = open herbaceous
2 = Pseudotsuga menziesii/Gaultheria shallon
3 = Quercus garryana/Symphoricarpos albus
4 = Quercus garryana - Pseudotsuga menziesii/Symphoricarpos albus

= Quercus garryana

= Pseudotsuga menziesii

= Rhamnus purshiana

= Pinus contorta

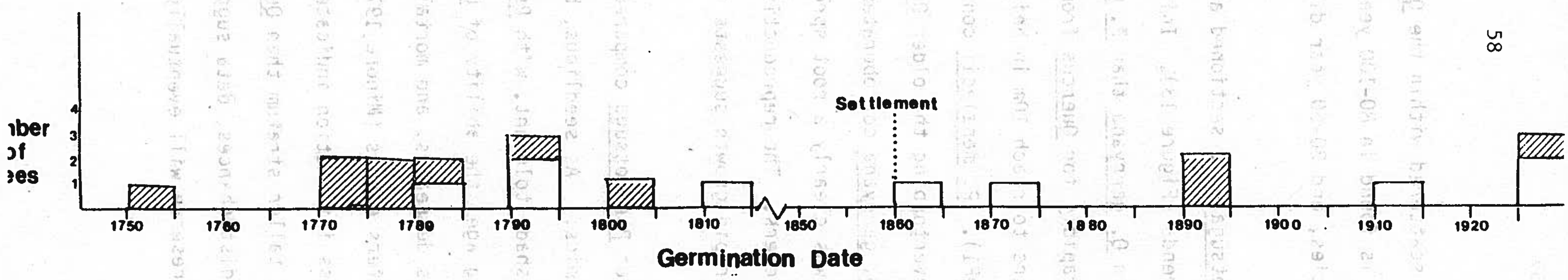


Figure 12. Number of trees by age class from Oak Patch Preserve and adjacent areas.

= *Quercus garryana*

= *Pseudotsuga menziesii*

240 years old), with most trees scattered within the Quercus - Pseudotsuga community. Quercus is found in 80-100 year classes in Q. garryana - P. menziesii communities, and 30-60 year divisions in the Quercus garryana community.

Two Quercus and two Pseudotsuga were sectioned at various heights to reconstruct growth trends (Figure 13). Initial growth rates (first 1.5m) were faster in Q. garryana than P. menziesii, however growth rates decreased rapidly for Quercus from that point on. It took Quercus (tree 01) 38 years to reach 10m in height, compared with 19 years for Pseudotsuga (DF1). P. menziesii continues its more rapid growth, and is presently overtopping the older Quercus garryana.

Initial growth release of Q. garryana corroborates seedling establishment results. Tree 01 was clearly a root sprout, located in a coppice of smaller diameter suckers. The reproductive mode of tree 02 was not obvious, but initial rapid growth suggests it may have been a sprout as well.

The more rapid growth rate of Pseudotsuga compared to Quercus creates the following stand dynamics: As seedlings, both Q. garryana and P. menziesii are moderately shade tolerant, with Pseudotsuga more so than Quercus. With increasing age, the ability of Quercus garryana to tolerate low light intensities decreases, and mortality eventually results once overtopping by conifers occurs (Minore,1979; McDonald et al.,1983). Oak Patch height class information indicates that Pseudotsuga presently occupies a taller stratum than Quercus in some areas of the preserve. Barring disturbances, data suggests the future stand composition of Oak Patch Preserve will eventually consist of a

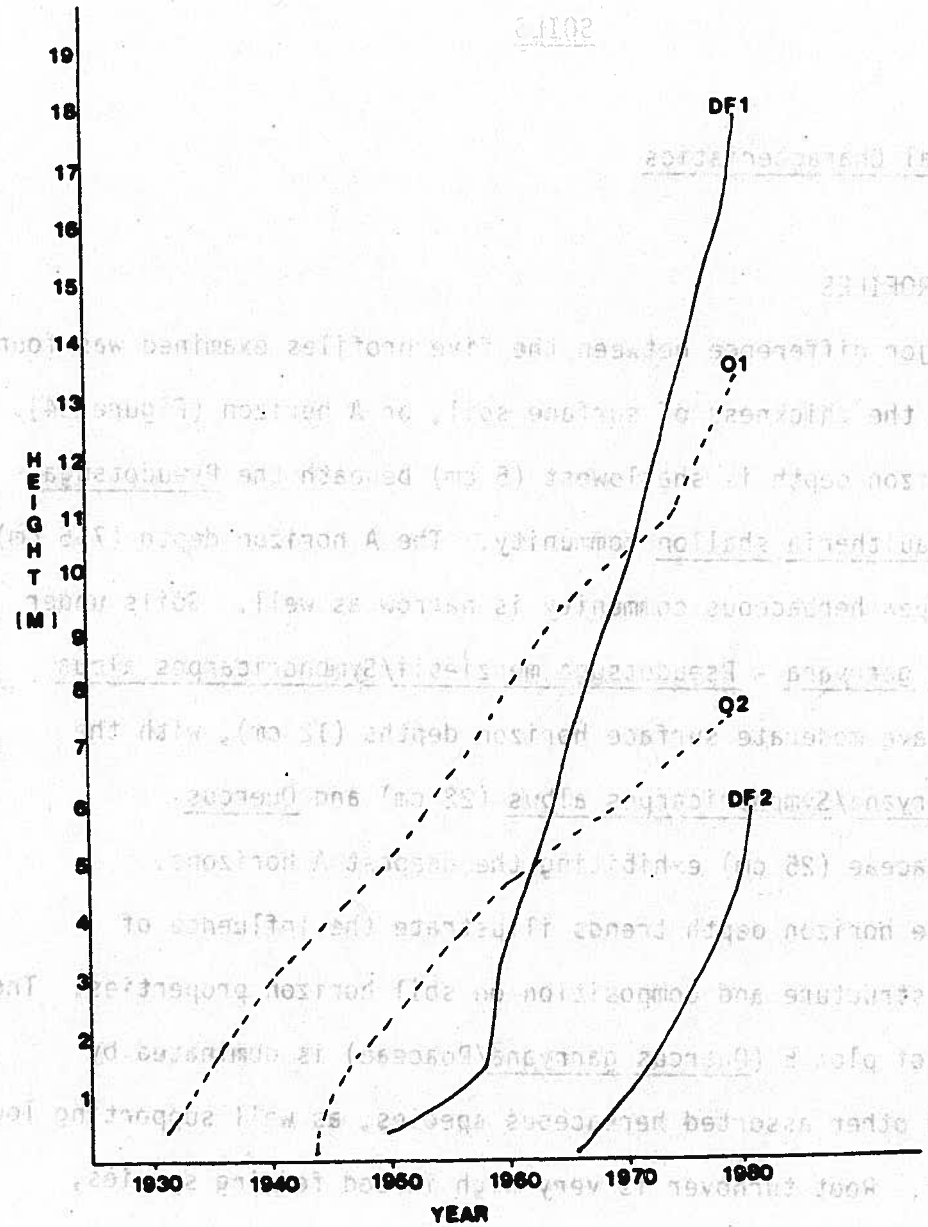


Figure 13. Growth rate trends for selected Quercus garryana and Pseudotsuga menziesii

O1, O2 = Quercus garryana
DF1, DF2 = Pseudotsuga menziesii

pure Pseudotsuga menziesii forest, with Quercus garryana eliminated from the site.

SOILS

Morphological Characteristics

MACROPLOT PROFILES

The major difference between the five profiles examined was found to exist in the thickness of surface soil, or A horizon (Figure 14). Surface horizon depth is shallowest (5 cm) beneath the Pseudotsuga menziesii/Gaultheria shallon community. The A horizon depth (7.5 cm) under the open herbaceous community is narrow as well. Soils under the Quercus garryana - Pseudotsuga menziesii/Symphoricarpos albus community have moderate surface horizon depths (12 cm), with the Quercus garryana/Symphoricarpos albus (22 cm) and Quercus garryana/Poaceae (25 cm) exhibiting the deepest A horizons.

Surface horizon depth trends illustrate the influence of vegetation structure and composition on soil horizon properties. The understory of plot 5 (Quercus garryana/Poaceae) is dominated by grasses and other assorted herbaceous species, as well supporting low shrub cover. Root turnover is very high in sod forming species, adding organic matter to surface soil, thus increasing A horizon depths. The Q. garryana growing in plot 5 is 200 years old, and exhibits a growth form (such as a short bole, and spreading horizontal branches) associated with open stand characteristics. Open grown Quercus stands in this region typically develop a grass and herbaceous

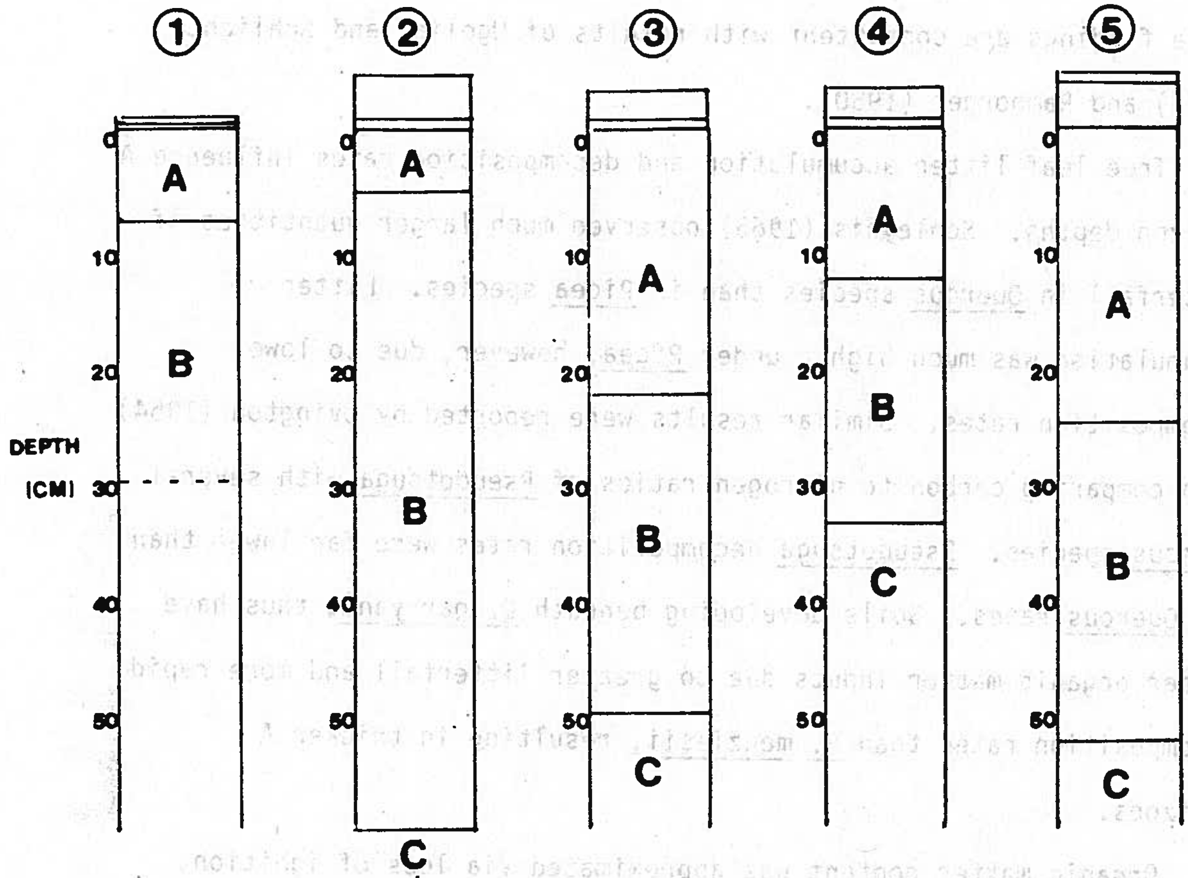


Figure 14. Soil horizon thicknesses for macroplots and an additional community.

1 = open herbaceous
2 = _Pseudotsuga menziesii/Gaultheria shallon_
3 = _Quercus garryana/Symphoricarpos albus_
4 = _Quercus garryana_ - _Pseudotsuga menziesii/Symphoricarpos albus_
5 = _Quercus garryana_/Poaceae

dominated understory (Lang,1961; Thilenius,1964). Root turnover in the Pseudotsuga dominated site was minimal due to a depauperate herbaceous layer, and may account for shallow surface horizon depths. These findings are consistent with results of Ugolini and Schlichte (1973) and Ramborger (1980).

Tree leaf litter accumulation and decomposition rates influence A horizon depths. Schleynis (1965) observed much larger quantities of litterfall in Quercus species than in Picea species. Litter accumulation was much higher under Picea, however, due to lower decomposition rates. Similar results were reported by Ovington (1954) when comparing carbon to nitrogen ratios of Pseudotsuga with several Quercus species. Pseudotsuga decomposition rates were far lower than the Quercus rates. Soils developing beneath Q. garryana, thus have higher organic matter inputs due to greater litterfall and more rapid decomposition rates than P. menziesii, resulting in thicker A horizons.

Organic matter content was approximated via loss of ignition. Soils under Pseudotsuga cover exhibited the lowest A horizon percent losses, while soils under Quercus incurred the greatest loss on ignition (Table 5). Overall carbon losses were lower in the B horizon, with soils under P. menziesii displaying lowest values, and soils under the Quercus garryana - Pseudotsuga menziesii community exhibiting greatest organic matter decreases.

The loss on ignition findings corroborate horizon depth data. Surface horizon organic matter content, as approximated by loss on ignition is greatest in the thicker soil horizons. These are found under Quercus garryana sites.

Table 5. Soil organic matter percent loss on ignition* under different communities.

	COMMUNITY **				
Soil horizon	1	2	3	4	5
A	14.2	5.0	16.6	12.1	19.4+
B	10.2	3.5	6.8	11.6	6.2

* n = 2

** 1 = open herbaceous
2 = Pseudotsuga menziesii/Gaultheria shallon
3 = Quercus garryana/Symphoricarpos albus
4 = Quercus garryana - Pseudotsuga menziesii/Symphoricarpos albus
5 = Quercus garryana/Poaceae

\+ n = 1

Table 6. Soil horizon percent coarse fraction by volume under different communities.

	COMMUNITY*				
Soil horizon	1	2	3	4	5
A	5	0	40	35	50
B	50	10	80	70	80

* 1 = open herbaceous
2 = Pseudotsuga menziesii/Gaultheria shallon
3 = Quercus garryana/Symphoricarpos albus
4 = Quercus garryana - Pseudotsuga menziesii/Symphoricarpos albus
5 = Quercus garryana/Poaceae

The influence of organic matter content in horizon color determinations reveals similar trends. The presence of organic matter in surface horizons may darken soil color; higher organic input is reflected in blacker values. Plots 3 (*Quercus garryana*/*Symphoricarpos*) and 5 (*Quercus garryana*/Poaceae), display black A horizon color, with brownish black designations given to *Pseudotsuga menziesii*/*Gaultheria shallon*, *Quercus garryana* - *Pseudotsuga menziesii*/*Symphoricarpos albus*, and open herbaceous surface soil horizons. Color differences are not as evident in the B horizon.

Soil texture was also examined in this study. Cobble content was estimated for each horizon at each site. The *P. menziesii* plot is located on silty loam soil, with very low cobble content (Table 6). The presence of cobbles increases in *Q. garryana* sandy loam soils, with content as high as 80% cobbles by volume encountered. Since the preserve is located in a glacial outwash channel, the high silt content in the *Pseudotsuga* soils may have developed from a silt bar deposited in that area.

TRANSECT PLOT SOIL CHARACTERISTICS

Trends indicate lowest soil development index (SDI) values for the A horizon under *Pseudotsuga* dominated sites, with increased values associated with soils under *Quercus* (Table 7). These results are consistent with macroplot surface soil findings. Similar results were noted by Ugolini and Schlichte (1973) and Ramborger (1980) in their comparisons between soils under *Pseudotsuga*, *Q. garryana*, and prairie vegetation.

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Table 7. Soil development index (SDI) values for different community types.

Community type*	sample size	mean	range
1	18	.067	.029-.203
2	14	.239	.057-.406
3	17	.406	.232-1.00
4	4	.427	.174-.867

* 1 = Pseudotsuga menziesii/Gaultheria shallon/Linnaea borealis
2 = Pseudotsuga menziesii - Quercus garryana/Holodiscus discolor/ Chrysanthemum leucanthemum
3 = Quercus garryana - Pseudotsuga menziesii - Rhamnus purshiana/ Symphoricarpos albus - Berberis aquifolium/Fragaria vesca
4 = Quercus garryana - Rhamnus purshiana/Symphoricarpos albus - Rosa nutkana/moss

PAST VEGETATION

Paleological,biological and historical information used to reconstruct vegetation at Oak Patch Preserve indicate Quercus garryana and Pseudotsuga menziesii as being historically present on the site. A quantitative reconstruction to pre-settlement stand conditions could not be developed, due to past logging of Pseudotsuga, and a high incidence of heart rot in larger Quercus.

Paleological Evidences

Results of the pollen anlaysis from Oak Patch Lake are detailed in a pollen percentage diagram (Figure 15). The three levels are discussed below, beginning with the oldest subsample.

LEVEL 1 18-20 CM

This sample is characterized by high percentages of coniferous species and low occurrences of herbs and other understory components. Cupressaceae, most likely Thuja plicata (western redcedar) dominates the pollen spectrum, accounting for 28% of total terrestrial pollen. Pinus (16%), Tsuga heterophylla (western hemlock) (16%) and Pseudotsuga menziesii (13%) are conspicuous as well. An abundance of Alnus rubra (red alder) (24%) is evident. Only 1% of total pollen at this level is attributed to Quercus garryana. A paucity of shrubs and herbs are evident in this zone, with only small percentages of Poaceae and Cyperaceae pollen deposited.

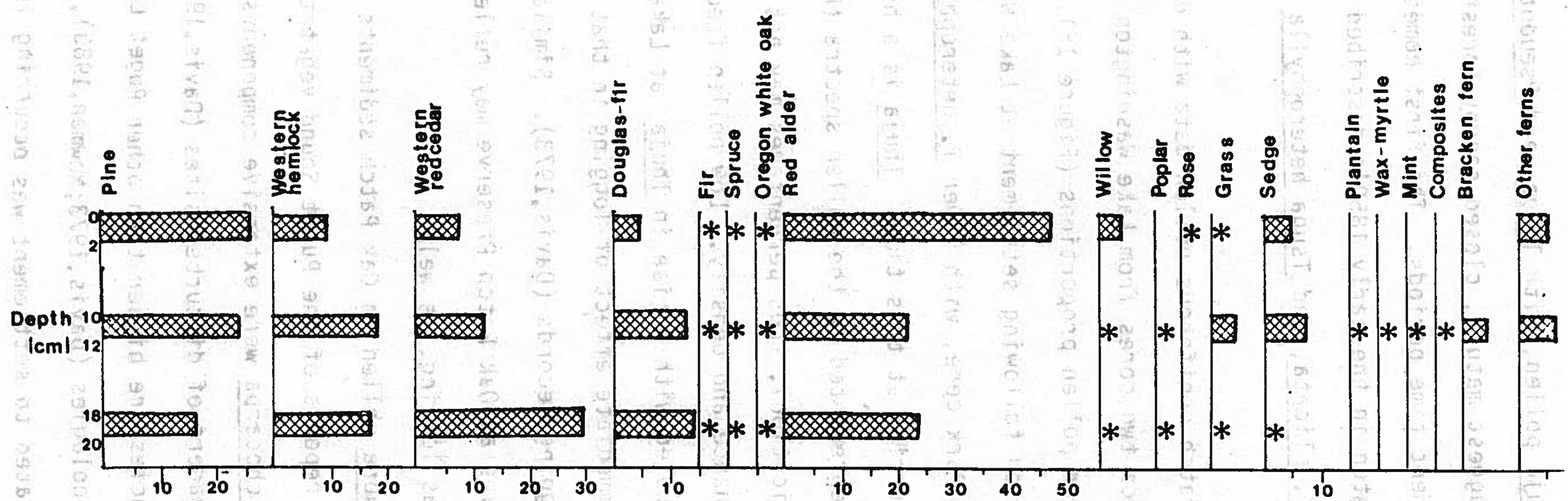

Figure 15. Pollen percentage diagram from Oak Patch Lake. Pollen percentages are plotted against depth.

* = less than 2%

The dominance of Thuja pollen, with Tsuga and Pseudotsuga as important contributors suggest mature, closed canopy forest conditions indicative of pre-settlement time periods. The first homesteaders to arrive in western Washington in the early 1850's described impressive stands of P. menziesii, T. plicata, and Tsuga heterophylla (Scott,1962).

Comparisons of Oak Patch coniferous pollen data with dated early settlement pollen data from two cores from Lake Washington sediments (Davis,1973) reveal similar pollen proportions (Figure 16). Thuja pollen frequencies increased following settlement at Lake Washington, especially in the Madison Park core, with lower T. heterophylla and P. menziesii percentages occurring at this time. Thuja is a heavy pollen producer and may be overrepresented in the pollen spectra (Dr. L.B. Brubaker, personal communication), thus percentages may not actually reflect actual stand dominance and density. Low pollen frequencies of Pseudotsuga and Tsuga, coupled with a rise in Thuja at Lake Washington indicate the immediate effect of logging in that area, as verified in historical logging records (Davis,1973). Similar pollen proportions of these species at Oak Patch Preserve may reflect a recent disturbance, such as logging, as well.

The presence of A. rubra pollen in Oak Patch sediments is consistent with settlers' reports of the Puget Sound vegetation, as both Alnus and Populus trichocarpa were extensive components of floodplains, and early invaders of disturbed sites (Davis,1973). Oak Patch Alnus pollen frequencies are higher than other Puget Lowland pre-settlement pollen chronologies (Davis,1973;Newman,1983), suggesting disturbance related to settlement was occurring in the Oak

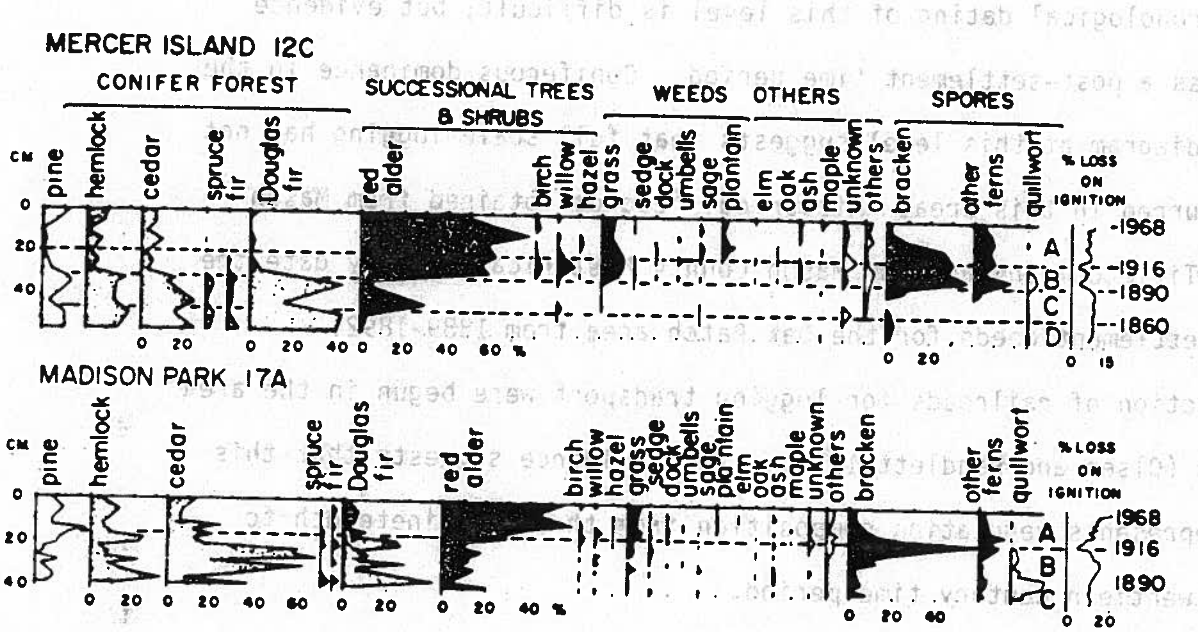

Figure 16. Pollen percentage diagram from two sediment cores from Lake Washington. Pollen percentages are plotted against depth. (from Davis,1973)

Patch vicinity. Charcoal fragments were found in Oak Patch Lake sediments at the 18-20 cm depth, indicating disturbances such as naturally ignited fires or slash burning following logging may have occurred as well.

Chronological dating of this level is difficult, but evidence indicates a post-settlement time period. Coniferous dominance in the pollen diagram at this level suggests that full scale logging had not yet occurred in this area. Historical records obtained from Mason County Title Company and the Mason County Historical Society date the first settlement deeds for the Oak Patch area from 1889-1892. Construction of railroads for logging transport were begun in the area in 1888 (Olsen and Randlett,1978). This evidence suggests that this zone represents vegetation composition from the late nineteenth to early twentieth century time period.

LEVEL 2 10-12 CM

Arboreal pollen dominates this level. <u>Pinus</u> (24%) and <u>A. rubra</u> (22%) are the most frequently occurring pollen, with significant percentages of <u>T. heterophylla</u> (17%), <u>P. menziesii</u> (12%) and <u>T. plicata</u> (11%). <u>Q. garryana</u> is found at very low freqencies.

Herbaceous pollen contributes significantly to the pollen spectrum. Cyperaceae are dominant (8%), with Poaceae (2%) and spores from <u>Pteridium aquilinum</u> (bracken fern) (2%) and other ferns (6%) contributing significantly. Small amounts of <u>Plantago</u> (plantain), <u>Myrica</u> (wax-myrtle), Laminaceae and Tubiliferae are components of this stratum.

This zone is characterized by a marked decrease in _Thuja_ pollen from level 1, accompanied by an increase in _Pinus_ pollen frequencies. _Tsuga_, _Pseudotsuga_ and _Alnus_ pollen remain unchanged. Because _Thuja_ is such a prolific producer of pollen, decreasing the population size by logging alters pollen proportions. Logging of _T. heterophylla_ and _P. menziesii_ decreases pollen frequencies of these species, but not enough to offset the decrease in pollen production by _T. plicata_. Consequently, _Tsuga_ and _Pseudotsuga_ pollen percentages remain the same, or even increase. Since total pollen productivity decreased due to logging of the above species, proportions of _Pinus_, a mobile and prolific pollen producer, increased . This rise may be accentuated at Oak Patch due to local populations of _P. contorta_ in the area. These effects could be reflected in the pollen spectra immediately after a disturbance such as logging or fire occurs.

The herbaceous component of the pollen rain at this level indicates recent disturbance as well. _Pteridium aquilinum_ often accompanies _Alnus rubra_ as pioneer species after perturbations, and is evident in the pollen diagram only at this level. _Plantago_, found in small quantities only at this depth, and used in Europe as an indicator of agricultural disturbance (Davis,1973), may be reflecting similar conditions at Oak Patch Preserve. The highest percentages of Poaceae and Cyperaceae occur at this depth as well, and may reflect herbaceous invasion following a recent disturbance. Charcoal was also evident, and may indicate slash burning immediately following a logging operation.

Precise historical logging records were not available for the Oak Patch vicinity, so reliance was made on biological data from live trees and stumps to estimate heavy logging periods in this area (results of this aspect will be discussed in the Disturbance History section). Timber removal was heaviest in the 1920's to early 1930's in this area. Davis (1973) noted that logging increased dramatically in the Puget Sound area in the 1920's, due to an elevated timber market in eastern United States. A Civilian Conservation Corps camp (CCC camp) was located on the banks of the Tahuya River, approximately one half mile northwest of Oak Patch, at this time. A berm was constructed on the western shore of Oak Patch Lake at approximately this time to increase water levels (see the Disturbance History section for details). It was seeded with species of Poaceae and Cyperaceae, which could account for the rise in pollen percentages of the two types at this depth.

LEVEL 3 0-2 CM

Pollen from broad-leaved species dominate surficial sediments. <u>A. rubra</u> (48%) reaches its peak at surface levels. <u>Pinus</u> (25%) is the dominant gymnosperm, with <u>T. heterophylla</u> (9%), <u>Thuja</u> (7%) and <u>Pseudotsuga</u> (4%) frequencies at a minimum. <u>Quercus</u> and <u>Salix</u> are uncommon.

Herbaceous components occurring in the surficial pollen spectra include Cyperaceae and spores from other ferns. Small percentages of Rosaceae and Poaceae are evident as well.

Modern pollen rain from Oak Patch Lake surficial sediments illustrates the effect of repeated perturbations on the landscape. Gymnosperm percentages are at their minimum, with a decrease in <u>Pseudotsuga</u> and <u>Tsuga</u> most evident. <u>Pinus</u> proportions remain constant, perhaps offset by a dramatic increase in *A. rubra* percentages. Understory species have decreased as well.

These trends are consistent with modern pollen rain from other sites in the Puget Sound Lowland (Hansen,1938; Davis,1973; Heusser,1978a,b,c; Barnosky,1981; Newman,1983). Continued timber harvesting and fire activity have decreased gymnosperm populations, while increasing *Alnus* and other early successional species.

SUMMARY

An accurate interpretation of pollen and spore frequency data for the purpose of reconstructing vegetation in an area depends on knowledge of pollen production, deposition and preservation mechanisms. Pollen is produced at varying amounts by different species, and this will influence frequencies calculated in pollen percentage diagrams. Mobility of pollen is a factor that makes it difficult to discern truly local plant assemblages from more regional vegetation components (Faegri and Iverson,1975).

Pollen sampling from Oak Patch Lake was designed to obtain a crude picture of changing vegetation dynamics over time. Subsample frequencies of 10 cm. intervals are very low, as compared with .5-1 cm. intervals from a short core from Lake Washington (Davis,1973). The infrequent sampling regime, as well as no available radiocarbon dates and lack of information concerning sedimentation rates of Oak Patch Lake make it difficult to accurately date changes in vegetation composition, and the disturbances responsible for these shifts.

The Oak Patch Lake pollen percentage diagram reflects regional shifts in vegetation history throughout the Puget Sound area. A general decrease in modern Tsuga, Pseudotsuga, and Thuja pollen percentages, accompanied by increasing Alnus pollen frequencies is seen in many Puget Lowland pollen spectra (Hansen,1938; Davis,1973; Heusser,1978; Newman,1983). Increased Pinus percentages and consistent, though low, Quercus proportions add a more localized aspect to the Oak Patch Lake pollen spectra, although quantitative changes in stand structure are impossible to decipher from these data.

Pre-Settlement Vegetation (Prior to 1860)

The presence of numerous older Quercus garryana (180-240 years old) on the site suggests its role as a major component of pre-settlement stands (Figure 12). Residual Pseudotsuga occupies slightly younger age classes, with oldest trees germinating 180-200 years ago. Commercial logging of P. menziesii since settlement occurred may have eliminated older trees, however, thus biasing age class data.

Further evidence of the existence of a Quercus dominated area is found in land survey records from 1874. Reports mention intersecting a "...grass swale covered with scattering scrub oaks and containing about 25 acres" (Land Survey Office, Department of Natural Resources), while setting the 15 and 22 section lines for Township 23N Range 2W, which is the present location of Oak Patch Preserve. Surveyors selected "witness" or "bearing" trees at each section and quarter-section corners, in order for homesteaders to locate their land claims (Habeck,1961). Witness trees surrounding the oak swale were dominated by fir (presumedly P. menziesii) of larger diameter classes, with scattered smaller diameter pines (probably _P. contorta_) to the north of the preserve.

An interview with Mrs. Alice Pope Gilbert, whose family homesteaded in 1889 in the Twin Lakes area, located approximately 1 mile west of Oak Patch, reveals additional historical vegetation information. Mrs. Gilbert stated that the area was always known as the Oak Patch, and she remembers it as an open, dry site, with only scattered larger _Quercus garryana_ in the overstory (Plate 2). Even after her family moved to Seattle in 1905, they would return to Oak Patch to pick _Erythronium oregonum_ (adder's tongue lily) and _Cypripedium_ sp. (lady's slipper). The open nature of the patch made it a favorite browse site for deer, and people would hunt there extensively. Mrs. Gilbert remembers a cabin at the edge of the open _Quercus_ stand, where hunters would camp until a timber company burned it down to discourage use of the area.

The open stand structure of past vegetation at Oak Patch Preserve is evident in the morphological characteristics of the oldest _Quercus_ on the site. A few old trees display open growth forms, indicating development under more savanna-like conditions (Thilenius,1964). Understories of open stands are often rich in herbaceous species. Survey records of 1874 describe the Oak Patch understory as a "grassy swale". Mrs. Gilbert, in her accounts of Oak Patch vegetation in the early 1890's, mentions an abundance of spring flowers growing under the large scattered _Quercus_.

Post Settlement Vegetation

The first homesteaders arrived in the Belfair area in 1859 (Deegan,1971). Settlement of Oak Patch did not occur until a later date, according to Mason County title records, with the first deed approved by the United States government land offices in 1892. Most land staking in the area was for the purpose of farming, although soil conditions proved unfavorable for profitable crop production. Mrs. Gilbert's family raised Angora goats for their wool, and another family had a large hog ranch in the vicinity.

Eventually, logging companies leased or bought the land from unsuccessful farmers, and timber became a more lucrative cash crop in the area. An agreement with Riverside Timber Company and the owner of Oak Patch occurred in 1903 according to title records, however detailed logging information was not available. Oak Patch was sold to McCleary Timber Company in 1925, and sold again to Stimpson Timber Company in 1931. Continued timber removal agreements were recorded until the land was deeded to Mason County in 1940. The State Forest Board acquired the land in 1941.

Age class data reflect the effects of settlement on overstory composition of the preserve, however insufficient data concerning early settlement (pre-1920) events makes it impossible to infer overstory interactions at that time. Logging may have eliminated *Pseudotsuga menziesii* in this age class. Germination of *Quercus garryana* prior to 1920 is evident only in 1890-1895, and may be an indication of disturbance at that time (see Disturbance History section).

A flush of reproduction occurs after 1925. Ring width patterns of living trees on the site reveal a sharp release after 1932 (see Disturbance History section). Ring width pattern data, historical deed and title information, and the presence of Pseudotsuga stumps on the site imply the area was logged in the early 1930's.

The reproduction following timber removal on the site is found in the four macroplots (Figure 11). Quercus garryana was first to regenerate, and coppicing is apparent in 72% of reproduction, suggesting root sprouting as the most common regeneration mode. Quercus regeneration occupies a 25 year age class (1930-1955), with no reproduction apparent in younger age classes. Post logging germination dates for P. menziesii lag Q. garryana by approximately 5 years, with earliest seeding occurring in 1935-1940. Reproduction is continuous, however, and extends into the present.

DISTURBANCE HISTORY

Landscape perturbations may arrest or accelerate succession, depending on the disturbance type, frequency and severity. Frequent disturbance regimes usually favor early seral species over climax species (Wright and Bailey,1982). Adaptations to disturbance events allow some species to compete more effectively for recently cleared areas. Disturbance frequencies have influenced past and present composition and structure of communities at Oak Patch Preserve.

Fire History

Precise dating of fire occurrences on the preserve and adjacent area was impossible to calculate. Extensive logging removed older *Pseudotsuga* containing possible scar information and age data. The remaining stumps were often too rotted to extract precise information. Minimal destructive sampling was allowed on the preserve, so wedges were not cut from trees exhibiting scars to get accurate fire dates. Reliance was made on increment cores from older aged trees. Scarring often occurs only on one side of a tree. Immediately following a tissue injury, cambial activity increases, producing tissue to cover the wound. Over time, bark completely covers the scar. Increment coring of the unscarred side of the tree would not reveal any scar information. If coring successfully encounters the scar tissue, but is angled incorrectly, exact dating of a disturbance occurrence is impossible. Multiple cores of a scarred surface help to decrease this inaccuracy, but may still not always produce an exact disturbance date.

Scar and age class information collected from three clear cuts in a two mile radius from Oak Patch Preserve, and from the preserve itself, was pooled for all sites to derive an estimated fire history for the immediate area (Table 8). Approximate scar dates were correlated with germination dates to determine fire occurrence periods. The resulting fire history is only an approximation of actual fire activity in the area. More intensive sampling is necessary to accurately identify fire dates.

Table 8. Estimated fire history for Oak Patch Preserve and surrounding area.

Estimated fire occurrence date	Fire-free interval (yrs)
	52+
1932	
	30
1902	
	16
1886	
	18
1868	
	14
1854	
	11
1843	
	12
1831	
	29
1802	
	34
1768	

PRE-SETTLEMENT FIRES (PRIOR TO 1860)

An estimated mean fire frequency of 20 years was calculated for Oak Patch and the surrounding area for the 1768-1868 time period (Table 8). Fire frequencies prior to 1750 could not be estimated, due to an insufficient number of samples in the 240+ age class. Other fire history research is lacking in this immediate area, so direct comparisons are limited to similar environments elsewhere in this region. Fire frequencies for the dry Pseudotsuga menziesii zone of the coastal valley of Oregon and Washington were roughly estimated at 40 years (Wright and Bailey,1982), but it was noted that variation exists due to topography and other microsite factors. Hot, dry summer weather coupled with light fuel loadings create conditions conducive to low intensity surface fires. This could impair ability to discern fire frequency from fire scars, as light fires often do not generate enough heat to cause injury to a mature tree.

Historical accounts from the Pacific Northwest indicate Indian burning as a common practice in pre-settlement periods in prairie and open Quercus garryana communities. Morris (1934) cites reports from David Douglas, Jessie Applegate and S.A. Clark in which annual Indian burning was observed; its purpose to drive game, enhance browse and food reserves, and create more open conditions for greater ease in travel and hunting. William Tolmie (1833, cited in Lang,1961) made mention of prairies burned by the Nisqually Indians to create fresh feed to attract deer. Lang (1961) and Ugolini and Schlichte (1973) cite mention of frequent fires set by Indians as one of the major forces maintaining prairie and open Quercus stands.

The Duhlelap branch of the Twana Indians established a permanent winter settlement at the head of Hood Canal near present day Belfair State Park, approximately 5 miles east of Oak Patch. They travelled extensively in spring through fall, gathering food for winter use. There is evidence they traded with the Upper Chehalis and Nisqually tribes for acorns, which they ate fresh or ground into a mush. Ptertidium aquilinum rhizomes and berries were common food items, with mention made that groups would travel great distances to burnt over areas where berries were abundant (Elmendorf,1960).

There is no concrete evidence that the Duhlelap Indians visited Oak Patch, or burned it to maintain more open conditions. One Pseudotsuga menziesii stump, located at the southern boundary of the preserve, assumed to have resulted from early 1930's logging in the area, did reveal a very frequent scarring pattern. The initial scar, occurring when the tree was 39 years of age was extensive. Before the tree had completely healed over with bark, less severe injuries may have initiated scarring. Sapwood rot was extensive, so actual disturbance and germination dates could not be determined. Other scars were noted at 42,45,48 and 50 years of age. Although it is impossible to prove, these scars may be the result of more frequent low intensity surface fires in the Oak Patch Preserve.

POST SETTLEMENT FIRES

Fire frequencies for post settlement periods decrease after 1860, with mean fire-free intervals estimated at over 30 years (Table 8). Scarring frequency was high in the initial settlement period (1868-1902), but decreases sharply after that time, with no fires recorded after 1932. It is impossible to distinguish naturally ignited fires from those that are human caused. Land clearing activities and other disturbances may account for higher early settlement fire frequencies, and slash fires following logging may have ben responsible for the 1932 scars. An effective fire suppression policy was instituted in the early twentieth century which has resulted in lower fire frequencies throughout the region (Wright and Bailey,1982).

FIRE EFFECTS

The effects of different fire regimes on _Quercus garryana_ - _Pseudotsuga menziesii_ communities has not been extensively researched. Volland and Dell (1981) note that thick bark plates develop in juvenile _Quercus garryana_ and serve to protect the cambium from reaching lethal temperatures. _Psuedotsuga_ develops thick bark at a later date, with seedling and sapling stages more susceptible to damage and mortality from even low intensity fires. The vegetative reproductive mode (by root,stump and epicormic sprouting) of _Quercus_ is effective in taking immediate advantage of a post fire situation. Sprouts are produced immediately after a fire, and due to the already established root system, can obtain initial height dominance. _P. menziesii_ relies solely on seed germination for reproduction, thus can not gain initial dominance (Volland and Dell,1981). Griffin (1980) and Roy (1955) noted heavy root, stump and epicormic sprouting immediately after moderate ground fires and more severe crown fires in different _Quercus_ species in California.

The more frequent surface fires of the pre-settlement time period at Oak Patch Preserve served to initiate sprouting in _Quercus_ garryana. Surface fires may have killed some sprouts and young seedlings, but mortality was patchy, as light fuel loads prevented high heat levels over much of the area. Pseudotsuga seed source was available, and germination did occur on the site; however, frequent fire may have eliminated some of the less tolerant seedlings and saplings. Some Pseudotsuga no doubt survived, and were scattered throughout the site. The pre-settlement understory, dominated by grasses,graminoids and herbs, was perpetuated by this regime, creating thick sod layers that prevented shrubs from establishing dominance. There probably were scattered shrubs throughout the site, especially those with sprouting abilities following fire. These include Symphoricarpos, Holodiscus, Berberis, Rosa and Arctostaphylos (Wright,1972).

Many researchers have postulated that frequent low intensity surface fires, possibly set by Indians, are responsible for maintaining pre-settlement Quercus stands. Sprague and Hansen (1946) and Thilenius (1968) note that Willamette Valley Quercus garryana stands were more open in the past, with annual ring studies from Pseudotsuga menziesii stumps indicating frequent surface fires controlling density and species composition. Clark (1970) states that many eastern Quercus stands in Wisconsin are no less than 100 years old, and date back to the cessation of Indian burning in the area. Griffin (1977) credits frequent fire regimes as the major disturbance maintaining the open Quercus savannas of northern California.

Logging History and Effects

Historical records indicate extensive timber removal occurred in the Oak Patch area. Construction of railroads to transport timber was begun as early as 1888 (Olsen and Randlett,1978). Logging agreements for timber on the Oak Patch Preserve and adjacent area were continuous from 1903-1940 when the land was awarded to Mason County.

Specific logging dates for the early twentieth century were unavailable. Legal timber agreements were made in 1903, 1906, 1925, 1929 and 1931, according to Mason County title records, but no files exist to document actual logging of the site. P. menziesii stumps on the preserve were too rotted to cross date the year of cutting.

Examination of annual ring widths revealed a sharp increase in values in the early 1930's (Figure 17). Pseudotsuga menziesii's low growth prior to this date was due to high competition from other even-aged cohorts. Extensive drought conditions prevailed in the state from the mid 1920's through the 1930's, and could account for the low growth trends evident in ring widths in both Quercus and Pseudotsuga at that time (Governer's Ad Hoc Exec. Water Emergency Comm.,1977). The pronounced growth release varied from tree to tree, ranging from 1933-1936, but was apparent in all 20 trees examined. Fire or logging could have caused this release. A fire with enough intensity to kill dominant overstory tree species, however, would also have injured or killed most trees in the lower strata, and lower growth values would be expected as a result of this disturbance. But, logging of the dominant overstory stratum would eliminate competition and release unmerchantable individuals in the understory, thus immediately

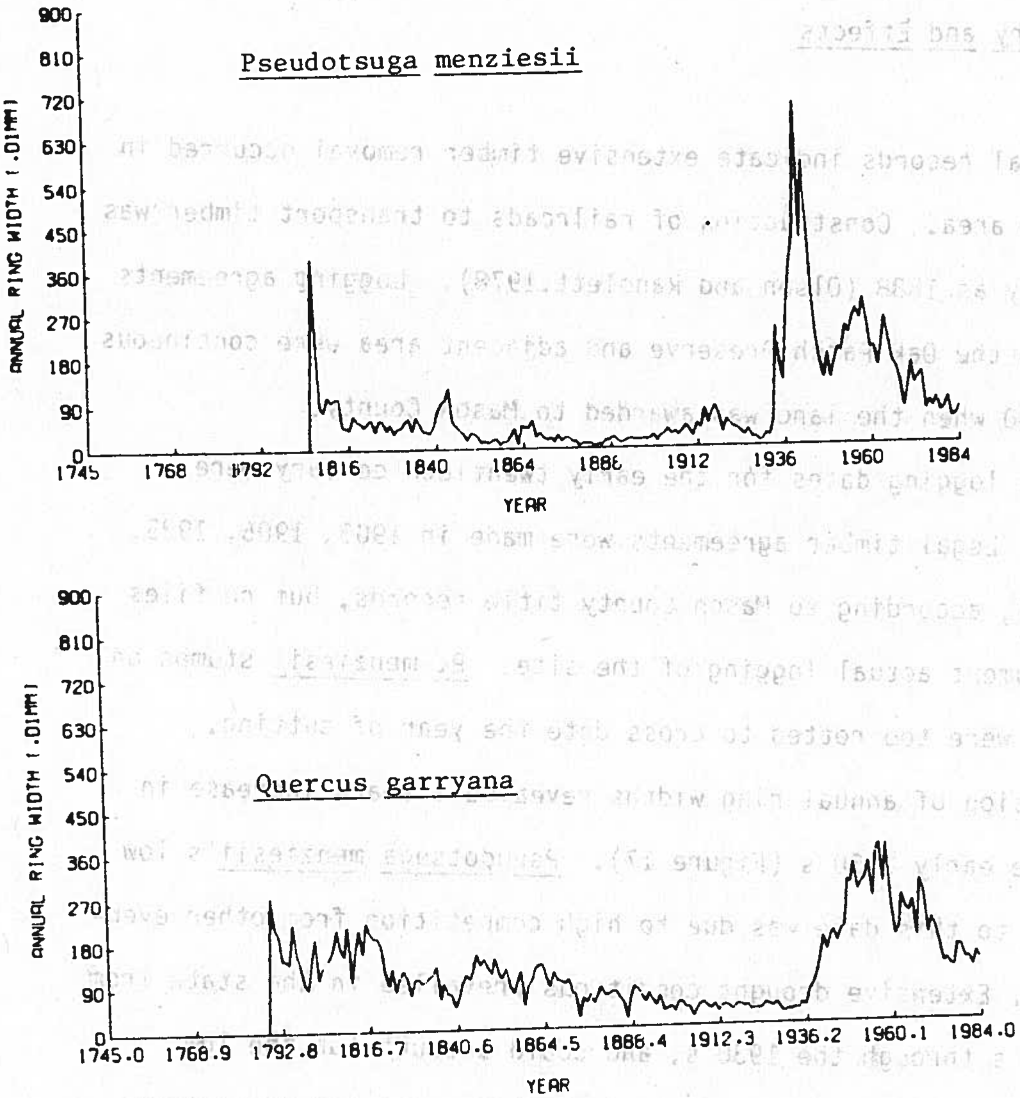

Figure 17. Ring width patterns of selected trees.

increasing growth rates. A light intensity slash fire may have followed logging operations, with little effects on growth rates. The increased growth could be exaggerated at Oak Patch, due to the previous low growth experienced during the drought period, and the suppressed growth due to competition. Growth trends vary after logging, and reflect drought and competition influences.

Vegetation response to logging was similar to fire. Root sprouting of Q. garryana immediately occurred after early 1930's logging on the site, as evidenced in the ages and clumped nature of the younger stand in the Quercus garryana/Symphoricarpos albus community (Figure 11). A few scattered Quercus stumps on the site suggest larger trees had been cut at this time, triggering sprout production. Injuries to live trees may also have initiated suckering. Advanced sprout regeneration may have served to increase density and the land area occupied by Quercus garryana on the preserve. Pseudotsuga reproduction germinated up to five years after Quercus, with heavy seeding in the southern preserve boundaries, where the most extensive logging had taken place. Regeneration was also evident in the Q. garryana dominated central portion of the preserve, as illustrated in age class analysis of macroplot four (Figure 11).

Sprouting shrubs that respond well to disturbance such as Symphoricarpos, Berberis, Rosa, Holodiscus and Gaultheria may have incresed in dominance and extent, invading areas that had been recently cleared. Pteridium aquilinun, Chrysanthemum leucanthemum, Senecio jacobaea and Hypericum perforatum were all able to establish in the newly disturbed areas. The open herbaceous site, with high shrub and weed cover has scattered P. menziesii stumps and decayed logs along the northern plot perimeter, suggesting it may have been more forested prior to logging. The remnants of a skid trail lead out from the plot, indicating it may have been a log landing at one time. This would explain the low density of trees on the site, as soil compaction may have prevented seedling germination to occur.

Other Disturbances

No documented information exists concerning grazing, hunting or fishing impacts on Oak Patch Preserve. Mrs. Gilbert, whose family homesteaded in the area, noted high hunter use in the preserve since the late 1890's. She indicated parties would remain on the site for weeks, either camping or staying in the cabin built at the edge of the *Quercus* patch. Wood cutting and other manual disturbances may have affected the site, although the extent appears to be minimal. No accounts of livestock grazing could be located for the site.

Berm and drainage ditch construction (to control water levels of Oak Patch Lake) (see Figure 4 for location) dates were not available, however were estimated to be just prior to logging in the area, according to age class information extracted from a *Pinus contorta* on the berm. Survey records of 1874 describe the area as a grassy swale, which may indicate portions of the site were in standing water for part of the year. Heavy shrub cover of *Physocarpus capitatus*, *Rosa* and *Symphoricarpos* line the drainage ditch, and may have resulted from this disturbance.

Summary

With settlement, fire suppression and logging have caused a change in vegetation structure and composition at Oak Patch Preserve. Stand density has increased, with even-aged clones of Q. garryana and P. menziesii creating more closed canopy conditions. Quercus garryana sprouting has declined, and suckers that are produced are often unable to establish due to low light intensities in the understory. Mortality will eventually ensue.

Understory composition has been altered by settlement activities as well. Sprouting shrubs, such as Symphoricarpos, Holodiscus, Rosa and Berberis presently dominate the understory, where as historical records indicate a grassy swale once existed. Patches of sedge, grass and herbs are now only found scattered beneath the shrub layer.

CONCLUSIONS

Present vegetation structure and composition of Oak Patch Preserve consists of a *Quercus garryana* - *Pseudotsuga menziesii* woodland, intermixed with pure, dense stands of younger *Quercus garryana* (*Quercus garryana/Symphoricarpos albus* community) and *Pseudotsuga menziesii* (*Pseudotsuga menziesii/Gaultheria shallon* community). Non-forested land occupies a portion of the preserve. Mature *Quercus* and *Pseudotsuga* are scattered throughout the preserve, with the conifer invading the *Quercus garryana* - *Pseudotsuga menziesii/Symphoricarpos albus* and open herbaceous communities. The shrub layer is well developed throughout the preserve, with scattered herbs, grasses and graminoids occupying low ground cover percentages.

Distribution of present communities is the result of moisture trends coupled with disturbance effects throughout the preserve. *Quercus garryana* dominated communities occupy more xeric microsites, with *Pseudotsuga menziesii* stands present in more mesic habitats. Edaphic regimes may be creating this gradient, as soils under *Quercus* communities exhibit higher coarse fragment content than soils under *Pseudotsuga* communities. Moisture site indicators consist of many invader species that establish following a disturbance.

Both *Q. garryana* and *P. menziesii* are found reproducing on the preserve. *Quercus* regeneration consists primarily of root sprouts, with scattered seedlings evident as well. Many sprouts are growing parallel to the ground before attaining any veritcal height, in response to lower light intensities in the understory.

Initial growth rates of Quercus garryana are faster than Pseudotsuga menziesii, but decrease rapidly with age. P. menziesii growth increases with age, and has the potential to eventually overtop Quercus in areas where both species are present.

Present vegetation conditions are different from pre-settlement communities on the preserve. Numerous 180-240 year old Quercus garryana suggest its role as a dominant component of pre-settlement stands. Morphological characteristics of a few older trees and 1874 land survey record observations indicate more open grown conditions prevailed in the past. Pseudotsuga forests surrounded the Quercus patch, and establishment of scattered individuals occurred. Logging of older P. menziesii in the southern and southeastern preserve boundaries has obscured the role of this species in that portion of the preserve, making reconstruction more difficult in that area.

Pre-settlement understory composition was impossible to reconstruct from present vegetation. 1874 land survey records and interviews with an area homesteader suggested pre-settlement understories were dominated by grass, sedge and herbaceous species.

A frequent fire regime was responsible for the pre-settlement communities existing on the preserve. Surface fires controlled density of Quercus garryana, as well as eliminating Pseudotsuga and other conifer species from establishing in great numbers. Frequent fires could have kept shrubs from dominating in the understory, and favored establishment of a thick herbaceous layer.

Fire suppression and logging have altered stand composition and structure on the preserve. Present density of Pseudotsuga menziesii has increased in the Quercus patch, especially within the Quercus - Pseudotsuga/Symphoricarpos community. Pseudotsuga height growth rate far exceeds that of Quercus, and it is presently overtopping Q. garryana within portions of the Quercus - Pseudotsuga/Symphoricarpos community. The present Quercus/Symphoricarpos community consists of a dense closed canopy stand, and is the result of heavy sprout production following the early 1930's logging and/or fire activity on the site. Continual soil disturbance has encouraged shrub establishment and sprouting, at the expense of the herb layer.

The present structure and composition of vegetation at Oak Patch Preserve has thus changed throught time. Frequent disturbances, such as fire, are responsible for past distribution, and need to be reinstated in order to reconstruct and maintain the Quercus garryana woodland that occupied Oak Patch Preserve in pre-settlement times.

OAK PATCH PRESERVE MANAGEMENT PLANS

The preservation of the Quercus garryana woodland community in Washington state is important, due to its unique attributes and disjunct distribution throughout the state. Protection of Quercus woodland vegetation involves management for disturbance processes, which have historically maintained the site. The absence of a frequent disturbance regime since settlement has altered community dynamics at Oak Patch Preserve, increasing Pseudotsuga menziesii density and extent into once Q. garryana dominated sites, thus threatening mortality of Quercus by overtopping.

The objectives of the proposed management plans are:

1) the restoration of vegetation to pre-settlement (circa 1860) conditions

2) the maintenance of the pre-settlement community's structural and compositional characteristics using disturbance processes

These objectives assume the inclusion of pre-European influences (such as Indian burning) as "natural processes" on the site. Reconstruction and maintenance plans tend toward management for more pure Quercus garryana stand characteristics than may have existed in 1860, due to the inpracticality and future heavy maintenance costs of mixed stand dynamics.

Manipulation of vegetation will concentrate primarily on overstory interactions. The pre-settlement status of Quercus garryana and Pseudotsuga menziesii is inferred from present site conditions and historical information. Understory components are not as easily reconstructed. Present understory constituents reflect more modern disturbances (e.g. increased weedy species cover), with little evidence of actual pre-settlement composition. Continued disturbance may serve to increase undesirable herb and shrub components. With this in mind, suggested management for the shrub and herb strata will be a minor consideration in these plans.

Initial Reconstruction Management Plan

The pre-settlement dominance of Quercus garryana over much of Oak Patch Preserve is evident from age class analysis and historical documents. The role of Pseudotsuga has been obscured by logging of older age class trees, but appears to have been minor prior to settlement activities in the present day Quercus garryan/Symphoricarpos albus and Quercus garryana - Pseudotsuga menziesii/Symphoricarpos communities (Figure 7). The open herbaceous site may have been more forested prior to 1860, but present day high herbaceous cover suggests it may have been an ecotone between Quercus and Pseudotsuga communities.

Manipulations are necessary in these communities (open herbaceous, Quercus - Pseudotsuga/Symphoricarpos) to reconstruct pre-settlement species composition. The presence of numerous Pseudotsuga stumps in the present day Pseudotsuga/Gaultheria community suggests this species has dominated the southern boundary of the preserve for some time. No manipulations are recommended for this community.

The faster growth rate of _Pseudotsuga_ over _Quercus_ necessitates selective removal of the former species from areas where the latter is present. Due to potentially significant disturbance to both overstory and understory plants, it is recommended that all larger sized (greater than 10m in height) _P. menziesii_ and _Pinus contorta_ remain on the site, however all seedlings and saplings .5m-10m located within the open herbaceous and _Quercus_ - _Pseudotsuga_/_Symphoricarpos_ communities should be hand clipped and carried off the site. A brief field check of the _Quercus_/_Symphoricarpos_ community is suggested as well. Smaller seedlings will be destroyed in the initial prescribed burn so will not need to be clipped. All _Quercus garryana_ seedlings and saplings should be left undisturbed on the site.

The current high density of _Q. garryana_ in both _Quercus_/_Symphoricarpos_ and _Quercus_ -_Pseudotsuga_/_Symphoricarpos_ communities may exceed that of the pre-settlement community. Frequent fires may have served to naturally thin the stand when trees were smaller. Due to the high incidence of rot in this species, thinning of present _Quercus_ clones is not recommended.

Manipulation of present understory structure and composition is necessary in order to recreate pre-settlement conditions inferred from land survey records and historical accounts. High shrub density and invasion of introduced weedy species have altered the primarily herbaceous ground stratum of pre-settlement times. Tall shrubs (.5m and taller) should be clipped. Uprooting of shrub species should be avoided, as it will disturb the soil and may induce sprouting. A "weed eater" would sufficiently reduce shrub height, and scatter foliage, thus increasing fine fuel loadings for the prescription burn.

Prescribed burning of the entire site is recommended after manual manipulations have been performed. The objective of the burn is to reduce surface fuels with minimal overstory effect. Autumn burning is suggested, after the rains have wetted the site, but before the next year's grass and herb layer is apparent. A backing fire should be used, or a narrow strip head fire if necessary. Flame length should not exceed 1 ft.

Immediate seeding of native grass and sedge species may be necessary, in order to give them initial advantage and to decrease invasion by noxious weeds. Sprouting of shrubs, especially *Symphoricarpos*, may be a problem. Monitoring of the site is suggested, and if sprout density and extent has increased dramatically, a second restoration burn may be necessary in two to three years to decrease dominance of *Symphoricarpos* on the site. All *Pseudotsuga* and *Pinus* seedlings not killed by the burn will be visible and should be cut at this time.

Stand Maintenance Management Plan

A frequent disturbance regime is necessary in order to maintain *Quercus garryana* dominance on the preserve. A combination of manual manipulation and prescription burning is recommended to fulfill these requirements. Financial constraints must be balanced with requisite biological characteristics to produce the most effective and least costly maintenance plan for the preserve.

The objectives of the maintenance plan are to keep *Pseudotsuga menziesii* and *Pinus contorta* establishment to a minimum, as well as preserving the dominance of herbs in the understory. Resistance to low intensity fires in Pseudotsuga does not develop for approximately 10 years, and by 20 years the tree is able to withstand moderate intensity ground fires. Until a thick sod layer develops, shrub encroachment may continue to be a problem on the site.

Several disturbance frequencies are examined in Table 9. Although annual manipulations of seedlings would effectively guarantee the future desired condition on the preserve, continual soil disturbance may cause shrub and weed invasion into the herbaceous layer. Yearly fuel accumulation is not enough to carry surface fires through the site without a continuous herbaceous layer supplying fine fuels. Logistics are difficult, as fire conditions must be perfect to produce the desired effect. Labor intensive hand manipulation, and fire equipment and personnel are costly requirements of this disturbance frequency.

A five year frequency interval would be sufficient to manipulate Pseudotsuga and Pinus seedlings on the site. Fuel loadings may be adequate to carry surface fires, destroying some seedlings, initiating sprouting in some Quercus, and keeping shrubs from dominating the understory. Some shrub sprouting may occur, however. Perennial grasses and herbs are able to establish in newly disturbed areas, and maintain their dominance in areas where they had previously established. Undesirable weedy species may also invade after disturbances. Costs are moderate in maintaining this frequency interval, and logistic requirements not as difficult as the annual disturbance interval.

Table 9. Disturbance frequency/management considerations matrix for maintenance of pre-settlement conditions at Oak Patch Preserve.

	Disturbance Frequency Interval (yrs.)			
	1	5	10	20
Items to be considered				
Cost	High	Med.-Low	Med.-Low	High+
Logistics	Difficult	Moderate	Moderate	High+
Tree density control	Good	Good	Moderate	Bad
Shrub control	Good	Moderate	?	?
Perrenial grass cover	Low	High	?	Low
Exotics/annuals establishment	High	High	Moderate	Low

+ due to potentially high fire damage

Tree establishment of all species in the preserve after a ten year disturbance-free period may be extensive, requiring both manual manipulation and prescribed fire to recreate desired conditions. Surface fires will be more intense, and may necessitate additional personnel, thus increasing costs. Shrub invasion into herbaceous areas after a ten year disturbance free interval may be a problem, however this is unknown and will need to be monitored.

A twenty year disturbance frequency interval will necessitate intensive costly manipulation of tree species. _P. menziesii_ and _P. contort_ reproduction will have sufficient time to establish throughout the preserve, and may be shading the slower growing _Q. garryana_ regeneration. Fuel accumulation will be high, increasing fire intensity and potential damage to established _Quercus garryana_, perennial grasses and herbs, while encouraging invasion of sprouting shrubs. Vigorous root sprouting of _Quercus_ may create undesirable future dense, closed canopy forest conditions.

A five year disturbance frequency appears to be the most cost effective and biologically sound frequency for maintenance of the _Quercus garryana_ woodland community on the preserve. Monitoring is necessary to substantiate this frequency interval. Manual manipulations may be necessary to thin _Pseudotsuga menziesii_ and _Pinus contorta_ encroachment and eradicate invasive weeds from the site on a more frequent basis. Prescription burning every five years should keep arboreal, shrub and herb strata in the desired compositional and structural states.

FUTURE RESEARCH RECOMMENDATIONS

Quercus garryana communities have not been extensively researched in the Northwest. There is a great need for future studies in all scientific areas (ecology, genetics, physiology, etc.) in order to better understand, and more effectively manage this species. Listed below are future research ideas I have developed from my study of the Oak Patch Preserve.

I. Regeneration mechanisms

A. Sexual reproduction

1. A detailed examination of crop cycles and acorn viability.

2. Greenhouse experiments involving acorn germination under various light regimes and seedbed conditions.

3. An examination of germination rates and mortality rates of young Quercus garryana seedlings on the preserve.

4. An investigation into the impact of browsing on regeneration.

B. Vegetative propagation

1. An examination of how severe a disturbance is necessary to induce sprouting in Quercus.

2. A more detailed investigation of coppice structure-- growth differences, mortality rates, etc.

II. Disturbance Effects

A. Fire

1. After visiting Fort Lewis Querucus garryana stands, it appears Quercus is more tolerant to more intense surface fires than proposed in literature. Small experimintal prescription burns under various fire intensities could produce a detailed account of fire tolerance. The personnel at Fort Lewis are very cooperative, and would be willing to let a researcher use their land, records, and accompany them on prescribed burns.

2. A comparison of fire histories of the Oak Patch area with those of other Quercus garryana communities in Washington state. An investigation of the effects of different fire regimes on community structure and composition.

B. Other disturbances

1. The response of Querucs to logging--- stump and root sprouting potential.

2. The effects of manual clipping of sprouts, or logging of selected clones from a coppice. Special note should be made of decay potential resulting from this action.

BIBLIOGRAPHY

Axelrod, D.I. 1958. Evolution of the Madro-Tertiary geoflora. Bot. Rev. 24(7):434-509.

Barnosky, C.W. 1983. Late-Quaternary vegetational and climatic history of southwestern Washington. unpubl. Ph.D. thesis Univ. Washington.

Barrett, S.W. and S.F. Arno. 1982. Indian fires as an ecological influence in the northern Rockies. J. For. 80(10):647-651.

Boyer, J.S. 1967. Leaf water potentials measured with a pressure chamber. Plant Physiol. 42:133-137.

Buntley, G.J. and F.C. Westin. 1965. A comparative study of developmental color in a chestnut-chernozem-brunizem soil chronosequence. Soil Sci. Amer. Proc., 579-582.

Cooper, J.G. and G. Suckley. 1859. The Natural History of the Washington Territory. Bailliere Bros. New York.

Crandell, D.R. 1965. The glacial history of western Washington. In Wright, H.E. and D.G. Frey (eds.), The Quaternary of the United States. Princeton University Press, Princeton, N.J. pp. 341-353.

Davis, M.B. 1973. Pollen evidence of changing land use around the shores of Lake Washington. Northwest Sci. 47(3):133-148.

Deegan, H.W. 1971. History of Mason County, Washington. Rev. ed. Shelton, WA.

Dyrness, C.T., J.F. Franklin and W.H. Moir. 1974. A preliminary classification of forest communities in the central portion of the western Cascades in Oregon. U.S. IBP, Confierous Forest Biome Bull. 4, Univ. of Washington.

Eliot, W.A. 1938. Forest Trees of the Pacific Coast G.P. Putnam's Sons, New York.

Elmendorf, W.W. 1960. The structure of Twana culture. Monographic Supp. #2 28(3), Washington State University.

Faegri, K. and J. Iverson 1975. Textbook of Pollen Analysis. Hafner Press, New York.

Fonda, R.W. and J.A. Bernadi. 1976. Vegetation of Sucia Island in Puget Sound, Washington. Bull. of Torrey Bot. Club 103:99-109

Fowells, H.A. 1965. Sylvics of forest trees of the United States. USDA Handbook 271.

Franklin J.F. and C.T.Dyrness. 1973. Natural vegetation of Oregon and Washington. PNW For. and Range Exp. Sta. USDA Gen. Tech. Rep. PNW-8.

Gauch, H.G. 1982. Multivariate Analysis in Community Ecology. Cambridge Univ. Press, New York.

Gibson, H.H. 1913. American Forest Trees. Hardwood Record, Chicago, 235-237.

Ginter-Whitehouse, D.L., T.M. Hinckley, S.G. Pallardy. 1983. Spatial and temporal aspects of water relations of three tree species with different vascular anatomy. For. Sci. 29(2):317-329.

Governor's Ad Hoc Executive Water Emergency Committee Staff. 1977. History of droughts in Washington state. 39pp.

Griffin, J.R. Oak woodlands. 1977. In Barbour,M. and J. Major (eds.), Terriestrial Vegetation of California. Wiley and Sons, New York, 383-410.

-------- 1980. Sprouting in fire-damaged valley oaks, Chews Ridge, California. In Proc. of the Symp. on the Ecology, Management and Utilization of California Oaks. USDA PSW For. and Range Exp. Station. Gen. Tech. Rep. PSW-44, 216-219.

Gunther, E. 1973. Ethnobotany of Western Washington. Univ. of Wash. Press, Seattle. 64 pp.

Habeck, J.R. 1961. The original vegetation of the mid-Willamette Valley, Oregon. Northwest Sci. 35:65-77.

Haeberlin, H. and E. Gunther. 1930. The Indians of Puget Sound. Univ. of Wash. publ. in Anthropology. 4(1), 1-84.

Hall, F.C., D.W. Hedrick and R.F. Keninston. 1959. Grazing and Douglas-fir establishment in the Oregon white oak type. J. For. 57:98-103.

Hansen, H.P. 1938. Postglacial forest succession and climate in the Puget Sound Region. Ecol. 19:528-543.

----------1947. Climate versus fire and soil as factors in post glacial forest succession in the Puget lowlands of Washington. Am. Jour. Sci. 245(5): 265-286.

Harden, J. 1982. A quantitative index of soil development from field descriptions: esamples from a chronosequence in central California. Geoderma 28(1):1-28.

Hedrick, D.W. and R.F. Keniston. 1966. Grazing and Douglas-fir growth in the Oregon white oak type. J. For. 64:735-738.

Henry, J.D. and J.M.A. Swan. 1974. Reconstructing forest history from live and dead plant material -an approach to the study of forest succession in southwest New Hampshire. Ecol. 55:772-783.

Heusser, C. 1969. Modern pollen spectra from the Olympic Peninsula, Washington. Bull. of the Torrey Bot. Club 96(4):407-417.

----------1978a. Modern pollen rain in the Puget Lowland of Washington. Bull. of the Torrey Bot. Club 105(4):296-305.

----------1978b. Modern pollen rain of Washington. Can. Jour. of Bot. 56:1510-1517.

----------1978c. Modern pollen spectra from western Oregon. Bull. of the Torrey Bot. Club 105(1):14-17.

----------1983. Vegetational History of the Northwestern United States including Alaska <u>in</u> Late-Quaternary Environments of the United States, H.E. Wright, ed. vol 1. The Late-Pleistocene, University of Minnesota Press, Minneapolis

Hill, M.O. 1979a. DECORANA - a FORTRAN program for Detrended Correspondence Analysis and Reciprocal Averaging. Cornell Univ., Ithica, New York.

----------1979b. TWINSPAN - a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell Univ., Ithica, New York.

Hinckley, T.M. and D.R.M. Scott. 1971. Estimates of water loss and its relation to environmental parameters in Douglas-fir saplings. Ecol. 52:520-524.

Irgens-Moller, H. 1955. Forest-tree genetics research: <u>Quercus</u> L. Econ. Bot. 9(1):53-71.

Johnson, H.M. 1933. Oregon white oak: properties and uses. The Timberman 34(11):14-16.

Kleinbaum, D.G. and L. Kupper. 1978. <u>Applied Regression Analysis and other Multivariate Methods</u>. Duxbury Press, Boston. 556 pp.

Krajina, V.J. 1970. Ecology of forest tres in British Columbia. Ecology of western North America 2. Dept. of Botany, Vancouver. 1-146

Lang, F.A. 1961. A study of vegetation change in the gravelly prairies of Pierce and Thurston Counties, western Washington. unpubl. M.S. thesis, Univ. of Wash. 109 pp.

Lewis, H.T. 1973. Patterns of Indian burning in California: ecology and ethnobotany. in Ballena Press Anthrop. Papers #1

Longhurst, W.M. 1956. Stump sprouting of oaks in response to seasonal cutting. J. Range Mngmt. 9:194-196.

McCulloch, W.F. 1940. Oregon oak - tree of conflict. Amer. For. 46(6):264-266.

McDonald, P.M. 1969. Silvicalh characteristics of California black oak (Quercus kelloggii Newb.). USDA For. Serv. Res. Pap. PSW-53

McDonald, P.M., D. Minore and T. Atzet. 1983. Southwestern Oregon - northern Calfornian hardwoods. in Silvicultural systems for the major forest types of the United States. USDA For. Serv. Agric. Handbook #455 p. 29-32.

Minore, D. 1979. Comparative autecological characteristics of northwestern tree species - a literature review. PNW For. and Range Experiment Station Gen. Tech. Rep. PNW-87

Morris, W.G. 1934. Forest fires in Oregon and Washington. The Oregon Hist. Quarterly 35(4):113-339.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York 547 pp.

Newman, D.E. 1983. A 13,500 year pollen record from Mercer Slough, King County, Washington. unpubl M.S. thesis, Univ. of Wash.

Norton, H.H. 1979. The association between anthropogenic prairies and important food plants in western Washington. Northwest Anthropological Res. Notes 13(2):175-200.

Olsen, S. and M. Randlett. 1978. An illustrated history of Mason County. Mason County Senior Center, Shelton, Wash.

Ovington, J.D. 1954. II. The forest floor. J. Ecol. 42:71-80.

Phillips, E.L. 1968. Washington climate for these counties: King, Kitsap, Mason, Pierce. Cooperative Extension Service, Wash. State Univ., Pullman. 65 pp.

Phleger, F.B. 1951. Ecology of Foraminifera, Northwest Gulf of Mexico: Part I. Foraminefera distribution. Geological Society of Amer. Memoirs 46:1-88.

Plumb, T.R. and P. McDonald. 1981. Oak management in California. Gen. Tech. Rep. PSW-54, 12 pp.

Plumb, T.R. 1980. Response of oaks to fire. in Proc. of the Symp. on the Ecology , Management and Utilization of California oaks. USDA Gen. Tech. Rep. PSW-44, 202-215.

Ramborger, T.D. 1980. The influence of two tree sjpecies on the prairie soils of Pierce County, Washington. umpubl. M.S. thesis, Univ. of Wash

Ritchie, G.A. and T.M. Hinckley 1975. Yhr pressure chamber as an instrument for ecological research in Advances in Ecol. Res. 9:165-254.

Rossi, R.S. 1980. History of cultural influences on the distribution and reproduction of oaks in California. in Proc. of the Symp. on the Ecology, Management, and Utilization of California oaks. Gen. Tech. Rep. PSW-44, 7-18

Roy, D.F. 1955. Hardwood sprout measurements in northwestern California. USDA Cal. For. and Range Exp. Station, For. Res. Notes #95

Rozhnova, T.A and T.V. Kasatkina. 1970. Soils forming under oak forests in the northwest. Soviet Soil Sci. 2(5):527-536.

Russo, F.G. 1969. A comparison of soil properties under forest and grass cover in Thruston County, western Washington. unpubl. M.S. thesis, Univ. of Wash.

Sander, I.V., P.S. Johnson and R. F. Watt. 1976. A guide for evaluating the adequacy of oak advance reproduction. USDA For. Serv. Gen. Tech. Rep. NC-23

Scheffer, T.H. 1959. Field studies of the Garry oak in Washington. Univ. of Wash. Arboretum Bull. 22: 88-89.

--------- 1960. Fruiting of the Garry oak. Univ. of Wash. Arboretum Bull. 23:138-139.

Schleynis, R.I. 1965. Differences in soil formation beneath spruce and oak forests in the northwestern USSR. Soviet Soil Sci. 8(3):226-234.

Scott,D.R.M. 1962. The Pacific Northwest Region. In Barrett,J.W. (ed.), Regional Silviculture of the United States. Ronald Press, New York, 503-570.

Silen, R.R. 1958. Silvical characteristics of Oregon white oak. PNW For. and Range Exper. Station Silvical Series # 10

Sprague, F.L. and H.P. Hansen. 1946. Forest succession in the McDonald Forest, Willamette Valley, Oregon. Northwest Sci. 20(4):89-98.

Sugihara, N.G., M.M. Hektner, L.R. Reed and J.M. Lenihan. 1983. Oregon white oak woodlands of Redwood National Park: descriptions and management considerations. in Proc 1st Biennial Conf. of Research in California's National Parks, 177-182.

Taylor, R.J. and T. Boss. 1975. Biosystematics of Quercus garryana in relation to its distribution in the state of Washington. Northwest Sci. 49(1):49-57.

Thilenius, J.F. 1964. Synecology of the white - oak (Quercus garryana Dougl.) woodlands of the Willamette Valley, Oregon. unpubl. Ph.D. thesis , Oregon State Univ.

--------- 1968. The Quercus garryana forests of the Willamete Valley, Oregon. Ecol. 49:1124-1133.

Ugolini, F.C. and A.K. Schlichte. 1973. The effect of Holocene environmental changes on selected western Washington soils. Soil Sci. 116(1), 218-227

United States Soil Survey Staff. 1951. Soil survey manual U.S. Dept. of Agric. #18. 503 pp.

United States Weather Bureau. 1969. Climatological summary, Washington State.

Van Wagner,C.E. 1978. Age-class distribution and the forest fire cycle. Can. J. For. Res. 8:220-227.

Volland, L.A. and J.D. Dell. 1981. Fire effects on Pacific Northwest forest and range vegetation. USDA For. Serv. PNW R6 RM 067.

Waring, R.H. and J. Major. 1964. Some vegetation of the California coastal redwood region in relation to gradients of moisture, nutrients, light and temperature. Ecol. Mon. 34(2):167-215.

Whittaker,R.H. 1967. Gradient analysis of vegetation. Biol. Rev. 42:207-264.

Wilkes, C. 1844. Narrative of the United States expedition during the years 1838, 1839, 1840, 1841, 1842. Vol 5, Lea and Blanchard, Philadelphia, Penn. 558 pp.

Wright, H.A. 1972. Shrub responses to fire. in The wildland shrubs: their biology and utilization. USDS For. Serv. Gen. Tech. Rep. INT-1.

Wright, H.A. and A.W. Bailey. 1982. Fire Ecology. J. Wiley and Sons, New York.

Zobel, D.B., A. McKee and G. Hawk. 1976. Relationships of environment to composition, structure and diversity of forest communities of the central western Cascades of Oregon. Ecol. Mon. 46:135-156.

APPENDIX

Vegetation of Oak Patch Preserve

Tree stratum

Pinus contorta var. contorta Dougl.
Pinus monticola Dougl.
Pseudotsuga menziesii (Mirbel) Franco.
Quercus garryana Dougl.
Phamnus purshiana DC.
Salix lasiandra Benth.
Thuja plicata Donn.
Tsuga heterophylla (Raf.) Sarg.

Shrub and subshrub stratum

Amelanchier alnifolia Nutt.
Arctostaphylos uva-ursi (L.) Spreng.
Berberis aquifolium Pursh
Berberis nervosa Pursh
Corylus cornuta var. californica Marsh.
Cornus stolonifera Michx.
Gaultheria shallon Pursh
Holodiscus discolor (Pursh) Maxim.
Physocarpus capitatus (Pursh) Kuntze
Polystichum munitum (Kaulf.) Presl
Pyrus fusca Raf.
Rosa gymnocarpa Nutt.
Rosa nutkana Presl
Rosa pisocarpa Gray
Spiraea douglasii Hook.
Symphoricarpos albus (L.) Blake
Vaccinium ovatum Pursh
Vaccinium parvifolium Smith

Herb, Grass and Graminoid stratum

Achillia millefolium ssp. lanulosa L.
Brodiaea coronaria (Salisb.) Engl.
Carex pensylvanica var. vespertina Lam.
Carex spp.
Chrysanthemum leucanthemum L.
Danthonia intermedia Vasey
Delphinium sp.
Elymus glaucus Buckl.
Fragaria vesca var. crinita L.
Fritillaria lanceolata Pursh

Herb, Grass and Graminoid stratum (cont.)

Hieracium albiflorum Hook.
Holcus lanatus L.
Hypericum perforatum L.
Lathyrus nevadensis var. pilosellus Wats.
Linnaea borealis var. longistylis L.
Lonicera ciliosa (Pursh) DC.
Plantago lanceolata L.
Plectritus congesta (Lindl.) DC.
Poa pratensis L.
Potentilla glandulosa var. glandulosa Lindl.
Prunella vulgaris L.
Psoralea physodes Dougl.
Pteridium aquilinum (L.) Kuhn
Rubus ursinus Cham & Schlecht.
Senecio jacobaea L.
Taraxacum sp.
Trientalis latifolia Hook.
Vicia americana Muhl.
Viola adunca Sm.