5 Vegetation

Thomas Atzet
David L. Wheeler
Brad Smith
Jerry Franklin
Gregg Riegel
Dale Thornburgh

INTRODUCTION

Concepts

Vegetation is an expression of its past and present operational environment. Light, heat, water, and nutrients compose the primary environment. They form interactive gradients across the landscape, producing similar combinations of species where environments are equivalent (Mason and Langenheim 1957, Daubenmire 1959, Spomer 1973). Because it is difficult and expensive to measure these primary factors on all sites, and because plants indicate their operational environment, plant associations are used as indicators. Plant associations—combinations of plants that are repeated across equivalent environments—are the basic unit of environmental classification used in this chapter.

Vegetation is classified into plant associations based on multivariate analysis of plot data from southwestern Oregon and northwestern California. The climax concept (Daubenmire 1966, Daubenmire 1968) is used to group associations into series based on the dominant climax species. Series are further grouped into associations based on vegetation, environment, and likely response to management. Descriptions of associations refer to stable, undisturbed stands unless otherwise stated.

A detailed discussion of each association in the area (there are over 200) is beyond the scope of this chapter. A brief overview of the major series is presented; the reader may refer to literature cited for comprehensive coverage. Details on keying sites to plant associations are given in Atzet and McCrimmon (1990). Species are referred to by their common names; a table of common names and equivalent Latin binomials is given at the end of this book. The convention for naming the various associations is that names of species within associations are separated by dashes when the species belong to the same layer and by slashes when the species are from different layers. White fir/dwarf Oregongrape and white fir-sugar pine are examples.

VEGETATIONAL SETTING

The forests of southwestern Oregon and northern California, known for their diversity, provide habitat for over 20 commercial conifers and several commercial hardwoods. Some endemic conifers, such as Brewer spruce and Baker's cypress, are sparsely scattered throughout the area; other endemics, such as Port-Orford-cedar and Sadler oak, are more common. There are over 100 endemic plants in the area, some of them rare (Webb 1987, Smith and Sawyer 1988; J.O. Sawyer and D.A. Thornburgh, unpublished report on file at USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California; 1969).

The southern Oregon-northern California area is the southern limit of Pacific silver fir, Alaska-cedar, and noble fir, and it is the northern limit for coast redwood, Jeffrey pine, tanoak, and Shasta red fir. The area is referred to as centrally significant to floral development in the Pacific Northwest (Whittaker 1960). Species from the Sierras, the California and Oregon coast ranges, and the Cascades continue to intergrade. The grand fir/white fir complex (Zobel 1973, 1974, and

1975), and the noble fir/California red fir/Shasta red fir swarm (Franklin et al. 1978) are examples. The area will continue to serve as a source and a sink for genetic diversity as the climate varies. Thus, the vegetative diversity, a response to the geologic and climatic diversity, provides the creative land manager a unique array of species and operational environments, resulting in unparalleled silvicultural challenges and opportunities.

HISTORICAL OVERVIEW

Gradual climatic changes have always caused shifts in the ranges of species. Plants continuously disperse seed beyond their existing range, and the best-adapted individuals survive to reproduce as long as conditions are favorable.

Alternating cold and hot climates during the Tertiary Period (the first of the Cenozoic Era, beginning about 60 million years ago) brought species into the area from the north, approximately Alaska and Canada, and the south, the Sierra Madres of northern Mexico (Axelrod 1976). Northern elements include, but are not limited to, ancestors of mountain hemlock, noble fir, subalpine fir, Pacific silver fir, and Alaska-cedar. Their descendants presently inhabit cooler niches in the area. Subalpine fir occupies upper elevational slopes near timberline. Mountain hemlock, noble fir and Alaska-cedar are found at high elevations or on cold northern aspects. Generally these species reflect the environmental adaptations of their ancestry.

Today's coastal element—Port-Orford-cedar, Sitka spruce, western redcedar, redwood, Douglas-fir, dogwood, tanoak, alder, and maple—developed in the area. Ancestors of these last four appeared later during the Tertiary Period (Detling 1961 and 1968), and enriched the diversity. Because all the coastal species except Douglas-fir still require relatively moist summers, they tend to inhabit cooler areas where evapotranspirational demand is low. The present range of the coastal species is far greater than that of the other elements.

The Mexican element, known as the Madro-Tertiary geoflora (Axelrod 1976), invaded as the climate dried, expanding northward. Pines, oaks, and madrone are genera still common today. They inhabit drier lowlands and upper slopes where soil water availability is low and evapotranspirational demand is high.

Fossil remains of eastern hardwoods (beech, basswood, and elm, for example) have been found in Oregon, an indication of wet, humid summers of the Tertiary Period (Axelrod 1976). Remaining hardwood species are now found near streams and in areas where summer humidity is high.

More recently, the Ice Age and the Xerothermic Period further affected local flora. Ice covered much of the Cascades as far south as Crater Lake, but the Klamath Province was generally spared except for scattered alpine glaciation on northern aspects (Hansen 1955). As would be expected during cold conditions, the northern flora was again pushed south. Mountain hemlock, Pacific silver fir, Alaska-cedar, and noble fir became more common in the area. As the climate warmed, these species became restricted to cold habitats, such as glacial cirques and other high-elevation areas.

The Xerothermic Period—4,000 years of elevated temperatures and dry climate ending about 4,000 years ago (Detling 1961)—pushed north such chaparral species as the oaks, manzanitas, and ceanothus. Adapted to the hot, dry conditions of the period, these genera became a common component of the flora as far north as southern Washington. Today they are restricted to islands of shallow soils and hot, dry microclimates. They were and still are efficient in the hot, dry, exposed soils left by fire and other disturbances. This highly competitive group loses its advantage to temperate conifers under conditions of low light, high moisture, and moderate temperatures.

The area of northwestern California and southwestern Oregon hosts a diversity of species from ancient northern and southern environments that mixed with locally evolved flora. Each species tends to reflect its origin. Species of northern descent occur in the colder environments of the upper elevations, and species of southern descent occur in hot, dry environments such as shallow slopes and recently disturbed sites. Endemic species that evolved in the area require warmth and moisture, and thus they inhabit sites close to the ocean or inland sites that trap moisture and remain humid late into the day during the growing season. Although this overview is simplified, it illustrates how a knowledge of floristic

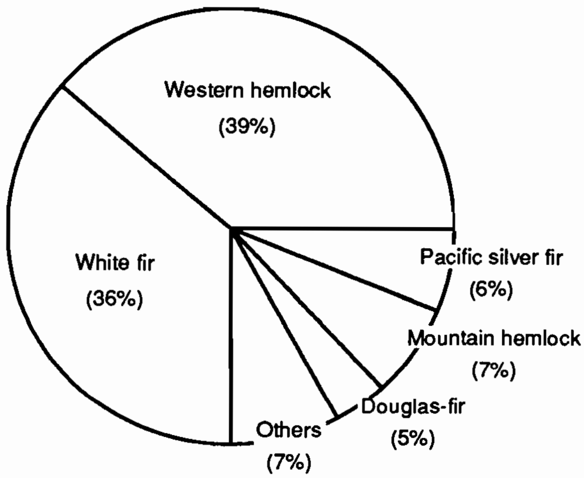

Figure 5-1. Relative proportion by area of the series in the Cascade Province.

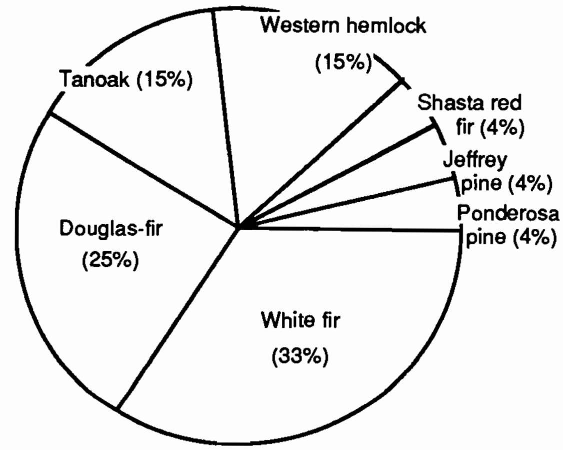

Figure 5-2. Relative proportion by area of the series in the Klamath Province.

history can increase understanding of environmental requirements, genetic plasticity, and management potential.

VEGETATION

The Cascade and Klamath Geological Provinces differ in their breadth of diversity. The Klamath Province, known for its geologic and floristic diversity, is a combination of marine and continental climates superimposed on elevational gradients which are crisscrossed by a variety of drainage patterns (Whittaker 1960 and 1961, Atzet 1979). The Cascade Province is less diverse geologically and climatically, and it generally drains from east to west. Elevation influences the distribution of series, plant associations, and species more than any other single factor.

The forests of southwestern Oregon and northwestern California are composed of at least 16 series. The most common are the white fir, western hemlock, Douglas-fir, tanoak, and mountain hemlock series (T. Atzet, D.L. Wheeler, J. Franklin, and B. Smith; FIR Report 4(4):6-8, 1983). These major series are discussed here along with the white oak series, which provides contrast with major upland forests. Minor series include the ponderosa pine, Shasta red fir, Port-Orford-cedar, western redcedar, western white pine, Jeffrey pine (B. Smith, T. Atzet, D. Wheeler, and J. Franklin; FIR Report 5(4):6-7, 1984), Pacific silver fir, Sitka spruce, lodgepole pine, and subalpine fir series. Most of these climax species are less prevalent and less important for timber management than species in the major series (Franklin and Dyrness 1973, Atzet and Wheeler 1984).

The western hemlock series and the white fir series dominate the Cascade Province, covering 39 percent and 36 percent of the area, respectively (Figure 5-1). The western hemlock series occurs mainly north of the Rogue-Umpqua divide. The white fir series is dominant south of the divide and occurs on dry sites north of the divide. The mountain hemlock, Pacific silver fir, and Douglas-fir series occupy approximately 7, 6, and 5 percent of the area, respectively. Mountain hemlock associations are commonly found in the High Cascades on soils derived from Mazama ash. The Douglas-fir series occurs sporadically on shallow soils throughout the area. The lodgepole pine series occurs in pumice frost pockets. The Shasta red fir series tends to occur on warmer, south-facing basaltic soils (T. Atzet, D. Wheeler, G. Riegel, B. Smith, and J. Franklin; FIR Report 6(1):4-7, and 6(3):6-7, 1984). The western redcedar series is mostly confined to riparian sites. The Oregon white oak series occurs on hot, shallow soils at low elevations.

The white fir series occupies about 33 percent of the Klamath Province (Figure 5-2), followed by the Douglas-fir series (25 percent) and the tanoak series (15 percent), which occur at successively lower elevations. The tanoak series occurs on warm, wet coastal sites and inland areas with deep soils and low evapotranspirational demand. Four other series, the western hemlock, Shasta red fir, Jeffrey pine, and ponderosa pine/oak series, collectively occupy approximately 27 percent of the area (Waring 1969, Sawyer and Thornburgh 1977). The remainder is occupied by other minor series such as Port-Orford-cedar, mountain hemlock, and western white pine, and by riparian and nonforested meadows and grasslands.

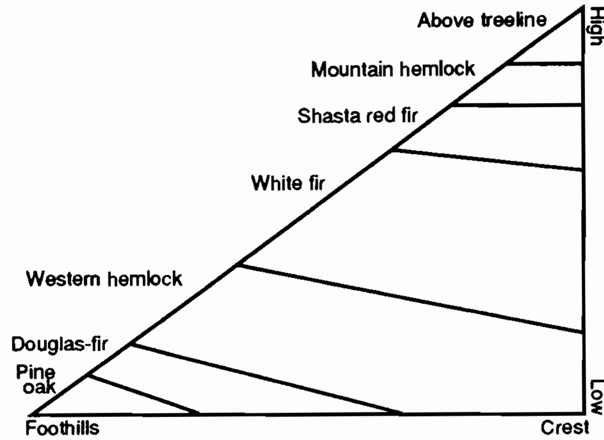

Figure 5-3. Diagrammatic east-to-west cross-section of the southern Oregon Cascades near Prospect, showing the relative positions of major series.

CHARACTERISTICS OF THE MAJOR SERIES

Elevational distribution of the major series ranges from near sea level on the coast (the western hemlock series) to over 7,000 ft in the Cascades (the mountain hemlock series) (Figures 5-3 and 5-4).

Low temperatures commonly limit survival and growth above 5,000 ft. The mountain hemlock series and three other minor series, including the western white pine, Shasta red fir, and Pacific silver fir series, occur in this limited environment. The lodgepole pine series, interestingly, occurs at an average elevation of below 5,000 ft, yet it is associated with one of the coldest and most difficult-to-regenerate environments (Figure 5-3). The series often occurs in cold-air pockets or valleys below major peaks, such as the pumice flats west of Crater Lake National Park and the concavities of the Dead Indian Plateau.

The western hemlock series is productive in moist, temperate environments. It occurs near the coast at elevations averaging about 2,000 ft in the Siskiyou Province and 3,300 ft in the Cascades (Figure 5-5).

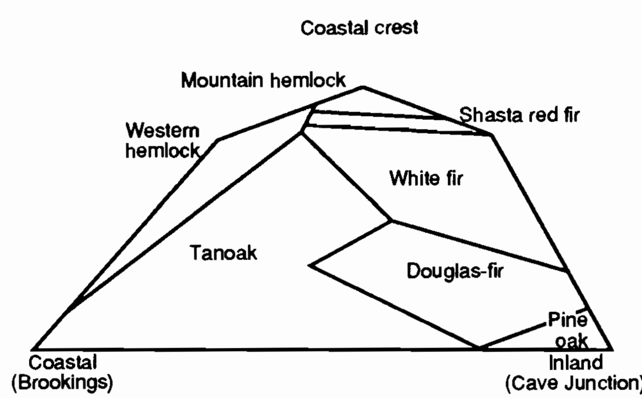

Figure 5-4. Diagrammatic east-to-west cross-section of the Klamath Province near the Oregon-California border, showing the relative positions of the series.

The ponderosa pine and Oregon white oak series occur at low elevations where diurnal temperature variation is extreme and evapotranspirational demand is high. Both occur mostly on shallow soils; however, the oak series can be found in deeper valley soils. Isolated stands of ponderosa pine

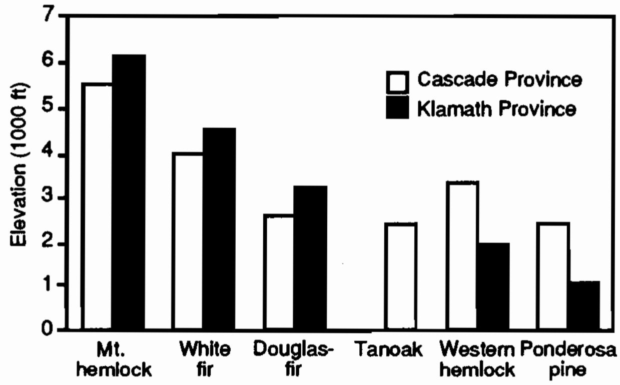

Figure 5-5. Average elevation of the series of the Klamath and Cascade Provinces.

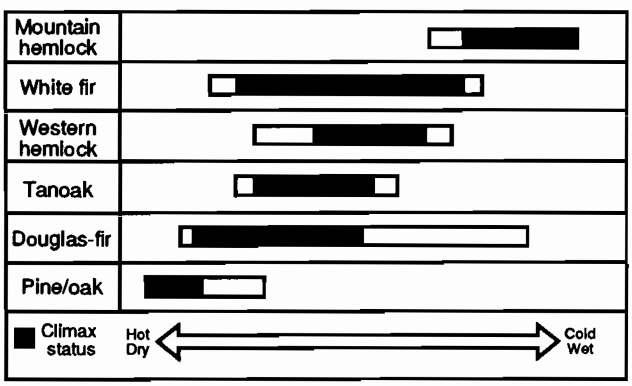

Figure 5-6. Occurrence of the major tree species along an environmental gradient where they are expected to have climax status.

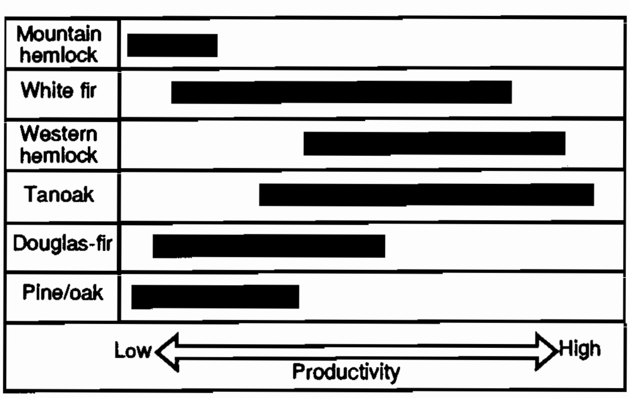

Figure 5-7. Relative range of site productivity for sites occupied by the major series.

can occasionally be found at middle elevations on heavy clay soils. Although these soils are saturated in the spring, they are droughty during the growing season, and ponderosa pine appears to be the only regenerating species. Although ponderosa pine grows well on hot, dry sites with shallow, droughty soils, it is the climax species on only a few sites in either province (Figures 5-6 and 5-7).

Fire has been a significant, if not the dominant, factor in maintaining compositional and structural diversity in the area. Forests of all series have burned, although fire return intervals differ. Intervals between fires vary from approximately 20 to 200 years (Atzet and Wheeler 1982, Walstad et al. 1990).

Problems with competing vegetation are too pervasive to be well defined at the series level. Although the tanoak series stands out as a problem series, the presence of specific competitors within each series calls for a specific approach to vegetation management (Tappeiner and McDonald 1984, Tappeiner et al. 1984). For example, snowbrush ceanothus is common in the white fir, western hemlock, tanoak, and Douglas-fir series; however, it affects crop tree growth more in some plant associations than in others within each series. These differences will be covered in the series descriptions.

The Mountain Hemlock Series

Mountain hemlock, in both the high Cascade and the Klamath Geological Provinces, generally occurs on cool, north-facing cirque topography at elevations lower than 5,000 ft, or in continuous stands on all types of topography above 5,000 ft. Although individual trees have been found as low as 2,000 ft in the Klamath Province, mountain hemlock is not an important stand component below 4,000 ft. In the high Cascade Province, most stands are associated with relatively young, sterile ash and pumice soils. In the Klamath Province, mountain hemlock is not associated with any particular geology or soil.

Mountain hemlock is efficient in the cold, moist climates of the high Cascades, but less so westward as the growing-season temperature increases with decreasing elevation. To the east, the rain shadow of the Cascades favors species that perform well in cold, dry environments.

Table 5-1. Mountain hemlock associations by group characteristic. "Mountain Hemlock" precedes all names.

Mountain hemlock association name	*Dominant group characteristic*
/pinemat manzanita /grouse huckleberry /dwarf bramble	Cold
/Pacific rhododendron -white fir-Shasta red fir /thin-leaved huckleberry	Cool
/parry rush /skunkleaf polemonium /red mountain-heath /whitevein pyrola /huckleberry-oak	Moderate

Mountain hemlock is a late-successional or climax species. It is shade tolerant, reproduces well on organic substrates (Minore 1979), and, like many late-successional species, tends to cycle nutrients internally. Little nutrient capital is lost by needle drop, an advantage on sites where external cycling is limited by cold temperatures.

Association descriptions

Shasta red fir, lodgepole pine, and western white pine are major associates; subalpine fir and Engelmann spruce are minor associates. Subalpine fir occurs on wet sites and Engelmann spruce on sites with high water tables. Brewer spruce is frequently a minor component in the Klamath Province. Scattered throughout the range of this series, but less commonly associated, are Douglas-fir, white fir, sugar pine, incense-cedar, western hemlock, and—rarely toward the eastern edge of the range—ponderosa pine. The most common associated shrubs are grouse and thin-leaved huckleberry. Common prince's-pine, dwarf bramble, and pinemat manzanita occur occasionally; squawcarpet is rare.

Regenerating large clearcuts (20 acres or more) in the mountain hemlock series has been difficult. Many failures result from planting inappropriate species, but extreme cold also kills a high percentage of natural seedlings. Slopes of less than 15 percent are the most susceptible to frost because they tend to collect rather than drain cold air. Mountain hemlock is a prolific seeder; natural regeneration is often observed near the edges of clearcuts, depending on their orientation to snow accumulation, sun, and wind. Biomass production is limited by cold soil and air temperatures. Productivity varies greatly by association; the warmest and most productive sites can be recognized by the abundance of herbaceous growth.

Mountain hemlock associations are listed in Table 5-1. In the Cascades the series can be divided into two groups. The first group, found on cold sites, includes the mountain hemlock/pinemat manzanita, mountain hemlock/grouse huckleberry, and mountain hemlock/dwarf bramble associations. The second group, found on cool sites, includes the mountain hemlock/Pacific rhododendron, mountain hemlock-white fir-Shasta red fir, and mountain hemlock/thin-leaved huckleberry associations. Table 5-2 displays the major differences.

In the Klamath Province, five associations have been identified: the mountain hemlock/parry rush, mountain hemlock/skunkleaf polemonium, mountain hemlock/red mountain-heath, mountain hemlock/whitevein pyrola, and mountain hemlock/huckleberry oak associations (Sawyer and Thornburgh 1977; J.O. Sawyer and D.A. Thornburgh, unpublished reports on file at USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California; 1970, 1971, and 1974) (Table 5-1). Mountain hemlock is the dominant species in both the overstory and reproductive layers. All stands are low in productivity and difficult to regenerate.

Management considerations

Management opportunities for this series are limited by deep, persistent snow pack, a short, cool growing season, and poorly developed soils. Although productivity is low and reforestation difficult, management for water, wildlife, biological diversity, and recreation require maintaining appropriate stocking levels in a mosaic across the landscape. Here are some silvicultural issues to consider when managing mountain hemlock stands for timber production:

Table 5-2. Differences between the cold and cool groups of the mountain hemlock series of the Cascade Mountains.

Cold associations	*Cool associations*
Pumice and ash parent rock	Andesite and basalt parent rock
Occurs in the high Cascades	Occurs in the western Cascades
Highest-elevation forests	Lower elevation forests
Mostly on flat slopes	Mostly on steeper slopes
Fire regime is intense and infrequent	Fire regime varies, frequency moderate
Low species diversity	Moderate to low species diversity
Not much structural variety	Multistoried stand structure
Low visual variety, great background	Foreground variety low to moderate
Dispersed recreational opportunities	Access steep and difficult
Low productivity	Low to moderate productivity
Reforestation problems	Vegetation management problems
Fragile system	Resilient system

Advance regeneration, particularly mountain hemlock, Shasta red fir, red fir, and sometimes Engelmann spruce, often provides a prompt, reliable new stand if the trees are undamaged (Figure 5-8). Natural seeding of lodgepole pine, Shasta red fir, red fir, mountain hemlock, and, at lower elevations, white fir is common on newly disturbed, frost-protected sites where seed sources are present (T. Atzet and J. Means, unpublished report on file at USDA Forest Service, Siskiyou National Forest, Grants Pass, Oregon).

Natural regeneration after harvest becomes established sooner in small openings than in large ones, and establishment is often most rapid on the shaded south edges of clearcuts. Regeneration will probably be hastened by keeping clearcuts small to maximize these edge effects, but it may still be unsatisfactory in 5 years. Limited experience indicates the shelterwood system can provide adequate regeneration in 5 to 10 years.

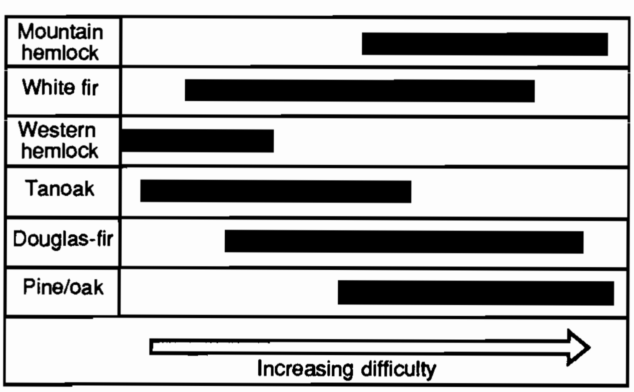

Figure 5-8. Relative difficulty of establishing conifer regeneration for the major series.

Planting has been relatively ineffective on these cold, snowy sites. Timing is critical. Trees must be planted immediately before fall snowfall or immediately after spring snowmelt. Even so, survival of artificial regeneration, particularly Douglas-fir, has been unacceptably low. Western white pine is not a good candidate for reforestation because it is susceptible to white pine blister rust. This disease is carried by gooseberries and currants (*Ribes* spp.), which are common in many associations.

Stands growing on granitic and pyroclastic soils present regeneration problems because of their poor heat retention and low water-holding capacities. Soils derived from granitics are exceptionally prone to surface erosion and small slides. Care should be taken to keep the litter layer intact. Organic matter moderates extremes in soil moisture and temperature, increases fertility, and reduces surface erosion.

The White Fir Series

White fir occurs throughout the Sierra Nevada of California and the intermountain and southern Rocky Mountain regions. The northwestern extent of the species is in the Klamath Mountains of southwestern Oregon and the central and southern portions of the Oregon Cascades. Grand fir, a closely related species, also occurs in southwestern Oregon. Where the ranges of these two species overlap, they interbreed (Zobel 1973), and the hybrids are also called white fir. In northern California and southern Oregon, the range of grand fir is limited to the immediate coastal and riparian zones. North of the McKenzie River, it expands eastward into the Cascades and the Rockies.

The white fir series is the most widespread and diverse and one of the most productive. It offers a variety of management options in timber production, wildlife, forage, and recreation. All of the major tree species in the area are found in the series, from Alaska-cedar, mountain hemlock, and red fir, characteristic of cooler sites, to ponderosa pine and Oregon white oak, characteristic of warmer, drier sites (D.L. Wheeler, T. Atzet, B. Smith, and J. Franklin; FIR Reports 8(2):4-6 and 8(3):6-9, 1986) (Table 5-3). Over 60 shrubs and 200 herbs are common associates. Baldhip rose, dwarf Oregongrape, creeping snowberry, and common prince's-pine are the most common. Forty-four plant associations have been identified in southwestern Oregon and northern California (Sawyer and Thornburgh 1977, Atzet and Wheeler 1984, Atzet and McCrimmon 1990). Several of the more common associations and their characteristics are described in this chapter.

The environment of the white fir series varies from cool and moist to warm and dry. There are few sites where frost or extreme heat occur; environments are generally mild. Elevations range from 2,000 to over 6,000 ft. In the Klamath Mountains, the series occurs below the Shasta red fir series and above the Douglas-fir series (Figure 5-4). Along the coast, it occurs above the western hemlock and tanoak series.

Association descriptions

Cold—Except for the white fir-Alaska-cedar association, the cold associations are found mainly in cold environments or frost pockets. This association is scattered in the Klamath Province and is an important refuge for a number of relict Ice Age species.

The white fir-mountain hemlock association found throughout the Cascades is the coldest of

Table 5-3. White fir associations by group characteristic. "White fir" precedes all names.

White fir association name	*Dominant group characteristic*
-lodgepole pine -mountain hemlock -Alaska-cedar	Cold
-Shasta red fir/currant -Shasta red fir/western prince's-pine -Shasta red fir/dwarf Oregongrape -Shasta red fir/baldhip rose -Shasta red fir/creeping snowberry	Cool, moist
-Sadler oak/western prince's-pine -Sadler oak/dwarf Oregongrape/ Oregon boxwood -Sadler oak/dwarf Oregongrape -Sadler oak/golden chinkapin	Shallow, rocky soils
-silver fir /thin-leaved huckleberry/vanillaleaf /dwarf bramble/vanillaleaf -Rocky mountain maple /herb -Rocky Mountain maple/dwarf Oregongrape -western hemlock/vine maple	Cool
-Brewer spruce/thin-leaved huckleberry -Brewer spruce/slender salal -Brewer spruce/western prince's pine	Shallow, cold soils
/dwarf Oregongrape/salal /dwarf Oregongrape/windflower /western prince's-pine/twinflower /western prince's-pine/pyrola /trillium /American vetch /western serviceberry/windflower -vine maple/vanillaleaf	Mesic
-Port-Orford-cedar -Port-Orford-cedar/depauperate -Pacific yew -tanoak -dwarf Oregongrape /hazel-western serviceberry	Humid
-Incense-cedar/dwarf Oregongrape -Douglas-fir/dwarf Oregongrape -Douglas-fir/creambush oceanspray -Douglas-fir/depauperate -Douglas-fir -Douglas-fir/Piper's Oregongrape	Hot
/creeping snowberry /poison-oak -ponderosa pine	Hot, dry

the white fir associations. Cold soil and air temperatures limit regeneration and growth particularly of white fir and Douglas-fir. Problems are compounded on pumice soils, particularly where gophers feed on the rich herb layer. On most sites, naturally seeded western white pine, Shasta red fir, red fir, and mountain hemlock are better adapted.

Cool, moist—Shasta red fir occupies the cold, moist end of the white fir series. It is a co-climax species with white fir. Soils, derived from basalts, are relatively deep and have few rocks. True firs are productive, but low ambient temperatures, indicated by the presence of mountain hemlock, mean that Douglas-fir growth will be marginal. Incense-cedar performs well on sites with basic soils and soils where root rots are a problem.

The white fir-Shasta red fir/currant association is found primarily east of Cave Junction in the Illinois Valley, where late-season frost often damages planted stock, particularly on south aspects. On south-facing granitic soils, the planting window is short. These soils, with low specific heat and conductivity, are slow to warm but quick to dry. Biomass production is moderate. Several currant and gooseberry species are common; the risk of blister rust is high. Shrub and herb competition may be significant, especially where snowbrush ceanothus is present. Alaska oniongrass and Idaho fescue, which are native grasses, are well suited for erosion control.

Shallow, rocky soils—Sadler oak, the major associate in this group, is a branchy, woody shrub very similar to Pacific rhododendron in appearance. Endemic to the Klamath Province, it is mostly restricted to sites with shallow soils and much surface rock. It indicates cool sites and can be a tough competitor. The four Sadler oak associations are slightly more productive than the Shasta red fir associations.

The white fir-Sadler oak/western prince's-pine association, the most productive of the four, is found throughout the western Klamath Province and portions of the coastal rain shadow. Soils, derived from granitics or metamorphosed parent materials, are relatively deep. The most productive sites are on metasedimentary soils of the Applegate Formation. Surface rock content may be high (above 10 percent), but rocks usually form a shallow alluvial layer. Thin-leaved huckleberry and Rocky Mountain maple indicate cool soil temperatures, which may limit Douglas-fir survival and growth.

Cool—This group is composed of associations found on cool sites with cold soils. Snow tends to accumulate and remain well into spring. The white fir-western hemlock/vine maple association, however, is the warmest of the group. Temperatures are relatively even, but spring frost can still cause reforestation failures. Vegetation management is necessary on some sites. Snowbrush ceanothus, vine maple, and Pacific rhododendron are intense competitors. Temperature rather than moisture is likely to be the most limiting environmental factor.

The white fir/thin-leaved huckleberry/vanillaleaf association is most common in the Cascade Province. Thin-leaved huckleberry indicates cool temperatures, and vanillaleaf is a weak indicator of adequate moisture. The association is generally cool but productive. There are no outstanding regeneration problems on most sites.

Shallow, cold soils—The Brewer spruce associations reflect a unique combination of parent material, elevation, and local climate. Brewer spruce competes well on shallow, infertile, cool soils and in areas of low evapotranspirational demand. Such sites are often found on north-facing, steep, concave slopes that were glacially carved but not quite into typical cirques. Brewer spruce is a relict from a cooler, moister climate that once prevailed in the Klamath Province (Waring et al. 1975). It is common in the eastern part of the Province near Mount Shasta. Stands are more open than surrounding forests and differ in species composition. These three associations provide excellent wildlife habitat because of their structural diversity and abundant edge, and they also show diversity of plant species.

The white fir-Brewer spruce/thin-leaved huckleberry association is the coolest and least productive of the Brewer spruce associations. Brewer spruce, white fir, and Shasta red fir will outproduce Douglas-fir, and Sadler oak will compete with conifer regeneration. Sites with thin-leaved huckleberry are cool and moist. Sites with creambush oceanspray tend to have shallow and infertile soils. Both rock and the Sadler oak are barriers to planting. Site preparation improves survival of crop trees.

Mesic—This group represents the environmental middle of the white fir series. Associations are similar to one another and do not present serious management problems. Soils are generally deep and the climate is moderate. Temperature limitations on survival and growth are uncommon. Moisture stress limits growth late in the growing season. Sites of these associations have a history of successful regeneration. Douglas-fir now dominates most sites, but the cover of white fir is increasing in unharvested and fire-protected stands. A variety of species can be used for regeneration. The most serious problem for the group is managing competing vegetation.

The white fir/American vetch association, described by Sawyer and Thornburgh (1977), is a common type in the Klamath Province. Douglas-fir and white fir dominate the tree layer, and golden chinkapin and canyon live oak are common understory species. This association is one of the driest in the group. Reforestation difficulty usually increases with increasing cover of canyon live oak.

Humid—This group is characterized by associations that occur near the coast, in fog-prone areas, in or near riparian zones, or in protected concavities with low evapotranspirational demand. The greater the distance from the coast, the more likely it is that Port-Orford-cedar and Pacific yew will be confined to riparian zones. Similarly, tanoak, dwarf Oregongrape, and California hazel are more widespread toward the coast; they tend to occur inland only on the most humid sites or on soils with high water-holding capacity. Generally, competing vegetation is the most serious problem, although rocky soils in the Port-Orford-cedar association, particularly near riparian zones, can inhibit survival of planted stock (Zobel and Hawk 1980, Zobel et al. 1985). Generally, this group of associations includes some of the most productive sites in the area.

The white fir-tanoak association occurs primarily in the coastal rain shadow, less often in the western Klamaths. It is found mostly on west-facing slopes. Tanoak as the major co-dominant indicates a relatively productive site, although it is a significant competitor with regeneration. Tanoak, Port-Orford-cedar, sugar pine, dwarf Oregongrape, sword fern, and western twinflower indicate moist, productive sites. Creeping snowberry indicates the drier extreme. Moisture may be available either from the soil or indirectly from reduced evapotranspirational demand created by frequent foggy days during the growing season. Canyon live oak indicates shallow, coarse soils. Overall site productivity is depends on the depth of surface rock. Douglas-fir growth is excellent; sugar pine and incense-cedar are also appropriate for regeneration. Port-Orford-cedar performs well where red huckleberry is found.

Hot—Soils of the hot group have enough water-storage capacity to delay moisture stress until late spring or early summer. Drought may limit the survival of white fir under full sunlight, but the rest of the associated conifers will perform well. Competing vegetation is a problem on a few sites, however, and its effects can significantly reduce both survival and growth.

The white fir-Douglas-fir/Piper's Oregongrape association is found more often in the Cascades than in the Klamaths. Shrub and herb cover is sparse. Soil depth is shallower than average for the series, and surface layers are often rocky, creating regeneration difficulties. Piper's Oregongrape, more common in the Klamaths, indicates shallow, coarse-textured soils with high coarse-fragment content. Douglas-fir, ponderosa pine, and sugar pine are appropriate for regeneration. Establishment of white fir will be slowest on the most disturbed sites and fastest under a heavy shelterwood.

Hot, dry—This group is the hottest and driest of the white fir series. Creambush oceanspray is one of the most reliable hot-site indicators found in the group. Typical sites face south, and moisture evaporates rapidly in the intense sunlight. Moisture is the most limiting factor. Blueblossom ceanothus and various species of manzanita are common competitors.

Management considerations

Providing general directions for management in the white fir series is difficult because its environments range so widely. Site-specific analysis is essential. The series hosts a diversity of potential crop species. Keeping a mix in proportion to that of the previous stand helps maintain biological diversity and site resilience.

Douglas-fir, ponderosa pine, and incense-cedar are appropriate for regenerating the driest sites. Microsite planting—varying spacing in moist or shaded areas—may increase survival. Other silvicultural options that reduce the radiation load may be necessary to achieve full stocking.

Hardwoods, although not usually considered crop trees, provide habitat for animals, which are part of the biological web that keeps ecosystems healthy. They should be a part of a balanced prescription for ecosystem management.

The greater the degree of disturbance, the greater the need for the pioneer species such as Douglas-fir, incense-cedar, sugar pine, ponderosa pine, and Shasta red fir (S.D. Hobbs; FIR Report 6(1):3-4, 1984). These species tend to survive better under the extreme diurnal fluctuations in temperature often associated with even-aged management.

Because moisture is often the most limiting environmental factor, maintaining soil organics and structure—the key to water-holding capacity—and reducing evaporation will result in the highest survival rates. Non-essential plants will compete for water and thus lower survival and growth.

The Tanoak Series

Tanoak has both pioneer and climax characteristics. It grows faster than most conifers in full sunlight and survives indefinitely in dense shade. Having the advantages of both sexual and vegetative reproductive systems (Harrington 1989), it produces consistent acorn crops and resprouts aggressively. It is one of the few hardwoods with persistent foliage and can photosynthesize during warm spells in winter. It is sensitive to low-intensity fire, but it maintains a basal burl that vigorously resprouts (Tappeiner and McDonald 1984). However, because it requires consistently high levels of moisture and moderate, even temperatures for survival and growth, its range is limited. It occurs on the Oregon coast from Reedsport, near the Umpqua River, south almost to Marin County, California, and sporadically on inland sites that seldom freeze and have abundant soil water. The northern extreme of its range is south of Bandon, where the risk of frost during the growing season is more common than it is at more southerly locations; Brookings and Gold Beach average seven days of frost with minimum temperatures of 18°F, Port Orford averages 11 days with a minimum of 14°F, and Bandon averages 22 days with a minimum of 14°F. Tanoak's range is somewhat coincidental with that of coastal redwood (Zinke 1977), and consequently it is likely to have similar environmental requirements. Moreover, it is considered to be a climax species in many sites dominated by coastal redwood.

Tanoak occurs at an average elevation of about 2,400 ft; however, individuals occur at elevations as high as 5,000 ft. Cover is negatively correlated with elevation, but not strongly ($r=-0.37$). Tanoak is found on all combinations of slope and aspect in this area, but inland populations prefer northerly aspects.

Tanoak occurs on all types of parent rock and soil, but least often on ultrabasics (serpentine and peridotite). Abundance decreases inland as water becomes scarcer; this trend is even more pronounced on granitic soils. Soil depths average 39 inches, slightly deeper than the average depth for the Klamath Province.

Tanoak is seldom the overstory dominant. Even at its maximum development it does not attain the height of associated conifers. Without repeated disturbance, however, it would dominate both the canopy and the understory. Fire has been the most important agent keeping it in a subordinate position. Repeated, mild underburns have killed sensitive adults and set back sprouts while sparing thicker-barked species such as Douglas-fir, sugar pine, and other conifers. Intense fire tends to favor tanoak because it readily sprouts with a fully functional root system. Light disturbance, such as uneven-aged conifer harvest, also tends to stimulate tanoak growth.

The tanoak series (T. Atzet, D. Wheeler, B. Smith, G. Riegel, and J. Franklin; FIR Report 6(4):7-10, 1985) occurs on the most productive sites in southwestern Oregon and northern California. Twenty-eight associations have been identified, not including the coastal area of California, which has not been classified. These associations (Table 5-4) are floristically similar to those of the western hemlock series, which is intermixed with the tanoak series north of the Rogue River. At the coast, the tanoak series occurs east of the narrow Sitka spruce series. Inland, it occupies an elevational band above the Douglas-fir series and below the white fir series (Figure 5-4). The elevational range is from sea level to 4,500 ft, averaging 2,400 ft. The average aspect is north.

Douglas-fir is the most common overstory dominant, averaging about 60 percent cover. Sugar pine, which occurs in about 40 percent of the stands, averages about 10 percent cover in those stands. The presence of sugar pine increases inland, east of the coastal crest. Understory regeneration is dominated by tanoak, averaging about 50 percent cover. Douglas-fir, Pacific madrone, sugar pine, golden chinkapin, white fir, and canyon live oak all commonly occur; they are listed in order of decreasing cover. Dwarf Oregongrape is the most common shrub, occurring on 60 percent of the sites and with an average cover of 10 percent. Salal averages the highest cover (<40 percent) but is present on only 40 percent of the sites. Evergreen huckleberry and Pacific rhododendron each averages 36 percent cover. Other common shrubs, such as baldhip rose, creeping snowberry, poison-oak, and hairy honeysuckle, are found on about 25 percent of the sites but make up less than 10 percent of the cover.

In dense coastal stands, herbaceous development is inhibited by low light levels and build-up of tanoak litter. Inland stands are more often disturbed and usually lack such dense woody cover; consequently, they support higher herbaceous cover. Sword fern, bracken, beargrass, vanillaleaf, and western twinflower are the most common herbs. None averages more than 10 percent cover except western twinflower, at 11 percent cover.

The 28 associations in the tanoak series can be divided into three groups: coastal, transitional, and inland. Rare associations and associations with similar characteristics are listed in the table but are not described in the text.

Table 5-4. Tanoak associations by group. "Tanoak" precedes all names.

Tanoak association name	*Dominant group characteristic*
-California laurel/evergreen huckleberry	Coastal
/evergreen huckleberry	
/evergreen huckleberry-salal	
-California laurel/Pacific rhododendron	
/Pacific rhododendron-evergreen huckleberry	
/Pacific rhododendron	
-California laurel/whipple-vine	
/Pacific rhododendron-salal	
-western redcedar/evergreen huckleberry	
-coast redwood	
-western hemlock	
/salal	Transitional
-Port-Orford-cedar	
/California coffeeberry	
/beargrass	
/salal-Pacific rhododendron	Inland, moist
/salal-dwarf Oregongrape	
-vine maple	
-white fir-vine maple	
-white fir-dwarf Oregongrape	
-white fir-California hazel	
-Sadler oak/salal	
/dwarf Oregongrape	
/dwarf Oregongrape-poison-oak	Inland, dry
-canyon live oak/dwarf Oregon grape	
-canyon live oak	
-canyon live oak/poison-oak	
/poison-oak-hairy honeysuckle	

Association descriptions

Coastal—Coastal associations have a high cover of salal, Pacific rhododendron, evergreen huckleberry, and sword fern. The average elevation of the group is about 2,000 ft. Soil depth averages 42 inches. These associations are productive, with few regeneration problems. Many have high potential for natural regeneration. Competitive cover may be high, but because resources are abundant, the effects of competition may not be as detrimental to survival and growth as on inland sites, where water and other resources are scarce.

The presence of California laurel, vine maple, and Pacific yew characterize the three tanoak-California laurel associations, which commonly occur in bottomland positions and along stream channels. These associations have the lowest average elevation of the series. They often occur near the coast, where moist air and fog are common and the evapotranspirational demand is low. These associations are some of the most important because of their proximity to riparian and aquatic systems. The integrity of these systems depends directly on careful upslope management.

Transitional—The tanoak/salal association represents the transition between the coastal and inland groups. Evergreen huckleberry, a major coastal species, is absent, and dwarf Oregongrape and Piper's Oregongrape, commonly found inland, are present. Some other transitional species include Smith fairy-bell, western yellow wood-sorrel, and deer-fern. Creeping snowberry, baldhip rose, and western prince's-pine also characterize this association. Few management problems have been identified except on the occasional area with surface rock or skeletal soils.

The tanoak-Port-Orford-cedar association varies in its composition and generally borders stream channels. It supports both coastal species such as evergreen huckleberry and Pacific rhododendron, and inland species associated with wet sites. Port-Orford-cedar averages about 40 percent cover and is a minor climax species. The spread of Phytophthora root rot is currently a concern. Management practices are being altered in an attempt to check the spread of infection (Zobel et al. 1985; also see the Port-Orford-cedar Management Guide developed by the Siskiyou National Forest and the Interregional Committee). Because the spread of Phytophthora is enhanced by streams, the safest sites for Port-Orford-cedar are in the driest associations that support it.

Inland, moist—Inland associations can be broken into two groups. The moist associations are the most productive, the highest in elevation (3,708 ft), and have the deepest soils (34 inches). The dry associations occur at lower elevations (2,500 ft), and have shallower soils (30 inches). The dry group is less productive and may have reforestation problems.

The tanoak/salal-dwarf Oregongrape association generally occurs east of the coastal crest. It is occasionally found coastward but only on the driest sites. Sugar pine, golden chinkapin, incense-cedar, and an occasional ponderosa pine can be found. Most species dependent on the coastal climate are absent. Dwarf Oregongrape, an indicator of deep soils, is found here. Major differences between the tanoak/salal-Pacific rhododendron association and the tanoak/salal-dwarf Oregongrape association are soil depth and operability. Soil depth averages 36 inches on the first and 41 inches on the second. Both sites are productive with few silvicultural problems.

The tanoak-dwarf Oregongrape is a common, indistinct association. In vegetation it is similar to the tanoak-white fir/dwarf Oregongrape association. The soils are deep (40 inches) and the climate is significantly warmer than other tanoak associations. Reforestation could be difficult on the hottest, driest sites. Moreover, the potential for competition from snowbrush ceanothus is high if that shrub is present in adjacent harvested areas or road cut and fill slopes, usually an indication that viable seed is present in the soil. In regenerating such areas, disturbance must be held to a minimum, planting delays avoided, and large stock used. Any vegetation management technique, whether pulling or cutting of weeds or applying herbicides, should be implemented early.

Inland, dry—These associations are found on a combination of relatively shallow soils, with surface rock of up to 20 percent and a high coarse-fragment content in the surface soil horizons. Dry-site indicators such as poison-oak, hairy honeysuckle, and canyon live oak are common and sometimes abundant. Competition for moisture, the most limiting factor, will be severe in most years, and sprouting of hardwoods, if left uncontrolled, will impede newly planted conifers.

The tanoak/dwarf Oregongrape-poison-oak association is the most productive of the dry tanoak group because it has the best soil surface features of the group. Litter averages 88 percent, moss cover averages 20 percent, and bare ground and rock make up 4 and 2 percent, respectively. Pacific madrone and sugar pine are abundant. Poison-oak occurs on all sites, but it is sparse. Poison-oak is an indicator of hot, dry soil surface conditions. Therefore, the choice of species and seedling placement is critical to survival.

Management considerations

Prompt establishment of crop trees is the key to regeneration success. Using advance regeneration, which provides adapted, established seedlings, is one of the most rapid regeneration methods in even-aged systems. The new crop should be healthy, undamaged, diverse, and not suppressed. Pre-harvest underburning could be used to stimulate Douglas-fir or other early-seral species commonly used to regenerate timber production sites. Using either advance regeneration or natural regeneration fits well with a "New Perspectives" approach to forestry. If artificial regeneration methods are used, species selection should be based on the composition of the stand or surrounding stands, and placement in the harvested area should be based on the microenvironment.

The tanoak series has a high capacity for producing biomass (Figure 5-7), which is why managing competing vegetation is often necessary. The potential for competition is directly related to the cover of noncrop species on the site before harvest. Therefore, if a site with high noncrop cover is to be harvested, the manager should make it a priority to minimize cover, even before harvest. It is not uncommon for natural underburns to have kept understory shrubs at low cover. Pre-harvest underburning may eliminate the need for vegetation control after harvest. A unit's shape and size, the pre-harvest treatment, cutting prescription, and logging methods used, site preparation, species selection and placement, and timely planting all can reduce or eliminate the need for noncrop vegetation control.

Another common problem on productive sites is managing stand density. The higher the site quality, the higher the mortality of crop trees in overstocked stands. Therefore, significant volume loss occurs if thinning is delayed or ignored.

Tanoak stands provide thermal cover, hiding cover, and a consistent source of mast. Several species use the acorns. All seral stages of tanoak stands are important wildlife habitat. Because they are so widely distributed, tanoak associations are important for watershed protection. The series occurs throughout the coastal strip and the western Siskiyous. Cover in undisturbed stands is high and revegetation is prompt. The greatest potential for erosion is from improper road construction.

The Western Hemlock Series

Western hemlock grows along the Pacific Coast from the Kenai Peninsula in Alaska south into northern California. It also grows in the Cascades of Washington and Oregon and occurs as a major forest component of the Inland Empire region of northern Idaho and Montana and southeastern British Columbia. Coastal populations of western hemlock show a marked constriction of range south of Port Orford. South of this boundary, the species is largely restricted to the western slopes of the coastal mountains, except for a few isolated patches. North of the boundary, western hemlock occurs eastward well into the coastal mountains. The dividing line coincides with major changes in bedrock geology and climate in southwestern Oregon and northwestern California. Cascade populations occur as far south as Butte Falls, where they occupy some of the most productive sites in southwestern Oregon.

Western hemlock populations in the northern Klamath Mountains occur on sites ranging from 100 to 4,100 ft in elevation, but they are largely confined to northerly aspects and coastally influenced, windward slopes. Western hemlock occurs on all major bedrock types but least often on ultrabasics and granitics. Soils average 43 inches, about 6 inches deeper than the average for the region.

Western hemlock is the climax dominate throughout much of its range. It requires relatively high moisture levels and cool but not frosty temperatures. Inland populations occur on deep, moist soils at higher-than-average elevations.

The series distribution generally follows the species distribution. The series is restricted to the windward slopes and protected sites of the coastal Klamath Mountains south of the Rogue River, and to moist, moderate environments in the southwestern Oregon Cascades (B. Smith, T. Atzet, D. Wheeler, and J. Franklin; FIR Report 7(3):8-10, 1985).

Seral Douglas-fir occurs on over 90 percent of the plots and typically dominates the stand. Western hemlock is usually found as a minor overstory component, but it is the major reproducing species. High proportions of tanoak (66 percent) and Port-Orford-cedar (35 percent) in the coastal Klamath Province indicate that this series is similar to and overlaps with portions of the tanoak and Port-Orford-cedar series. In the Cascade Province, white fir is western hemlock's major competitor for climax status.

Understory species in the Klamath and Cascade Provinces are generally similar. Dwarf Oregongrape, sword fern, salal, and Pacific rhododendron are common. Important species unique to the Klamath Province include tanoak,

Table 5-5. Western hemlock associations by group. "Western hemlock" precedes all names.

Western hemlock association name	*Dominant group characteristic*
-western white pine/thin-leaved huckleberry	Cool
/thin-leaved huckleberry/Oregon oxalis	
-Pacific silver fir	
-Douglas maple/starry false Solomon's-seal	
-western redcedar-western hemlock/ Pacific rhododendron	Moist
-western redcedar-western hemlock/ whipple-vine	
-western redcedar	
-California laurel/sword fern	
-vine maple-red alder	
-Port-Orford-cedar/Pacific rhododendron	
-western redcedar/Oregon oxalis	
-western redcedar-Pacific dogwood	
-western redcedar/snow bramble	
-western redcedar/dwarf Oregongrape	
-western redcedar/Pacific rhododendron	
-western redcedar-Douglas-fir	
/sword fern	
-Pacific yew/Pacific rhododendron	Moderate
/dwarf Oregongrape/Oregon oxalis	
/dwarf Oregongrape/vanillaleaf	
/dwarf Oregongrape/western twinflower	
/Pacific rhododendron/western twinflower	
-California laurel/Pacific rhododendron	
-Port-Orford-cedar/Sierra laurel	
-white fir	Dry
-Sadler oak	
/salal/Oregon oxalis	
/salal/twinflower	
/salal/white-flowered hawkweed	
/salal	
-incense-cedar/Pacific rhododendron/ queen's cup	
-incense-cedar/salal	
-golden chinkapin/Pacific rhododendron	

Sadler oak, and California laurel. These distinguish the western hemlock series in southwestern Oregon from otherwise similar western hemlock forests to the north.

Thirty-one associations are defined for the western hemlock series (Table 5-5). They represent four groups with similar environments: cool, moist, moderate, and dry (group names indicate only the relative environments within the series). Two western redcedar associations are included because of their similarity to the series.

Association descriptions

Cool—The western hemlock-western white pine /thin-leaved huckleberry association (typical of the cool group) is usually dominated by Douglas-fir in the overstory, with western hemlock, western white pine, white fir, and Pacific yew as consistent associates. The association is more abundant in the Cascade Province, where the environment is cool but not cold, and relatively moist. Pacific yew and Pacific dogwood are strong indicators of moist sites. Elevation averages about 4,000 ft, but stands often occur in protected concavities at lower elevations. Soils are generally deep and fertile. Thick stands of thin-leaved huckleberry can hamper regeneration efforts.

Moist—Atmospheric moisture and low evaporative demand typify this group. Fog and clouds are common during the growing season. Inland sites are typically in drainages or valley bottoms where humidity remains high throughout the day. Soils are deep and usually replenished with rain several times during the summer.

The western hemlock-California laurel/sword fern association usually occurs near the coast below 1,600 ft on soils derived from marine sediments, gneiss, or volcanic rock. This association indicates moist habitats. Abundant California laurel and tanoak form a subcanopy under western hemlock and Douglas-fir. Western redcedar is common and does well in this type. The understory consists of a patchy shrub layer of either evergreen huckleberry or vine maple and a nearly complete cover of sword fern.

Moderate—The moderate group is a nondescript group typical of the average western hemlock association. These stands occur at middle elevations, between 2,600 to 3,400 ft, on cool, moist soils. They are found mainly to the east of

Table 5-6. Douglas-fir associations by group. "Douglas-fir" precedes all names.

Douglas-fir association name	*Dominant group characteristic*
-white fir-Jeffrey pine	Cool
-white fir	
-white fir-ponderosa pine	
-white fir/creambush oceanspray	
-white fir/dwarf Oregongrape	
/Pacific rhododendron	Moist
-tanoak-sugar pine	
-tanoak/poison-oak	
-tanoak	
-tanoak-canyon live oak	
-Sadler oak	Mesic
/creeping Oregongrape	
/dwarf Oregongrape	
/dwarf Oregongrape/sword fern	
/salal/sword fern	
/poison-oak-Piper's Oregongrape	Hot, dry
/poison-oak	
/poison-oak/Pacific hound's-tongue	
/poison-oak/bracken	
-ponderosa pine	
/depauperate	
-Jeffrey pine	
/buckbrush	
-Oregon white oak/poison-oak	

the coastal crest and north of the mouth of the Rogue River, and often occur between the drier midslope associations and the riparian zones of small streams. Soils are generally derived from marine sediments. Large, old Douglas-fir dominates mature stands; western hemlock and western redcedar occur abundantly as co-dominants. Small numbers of western yew and tanoak are found on most plots. The understory is the richest among all associations in the series, with no one species exhibiting strong dominance or high cover. Dwarf Oregongrape, twinflower, red huckleberry, and vanillaleaf are characteristic components. Vine maple and Pacific rhododendron may need to be controlled in order to establish regeneration promptly.

Dry—Relatively dry habitats in the series are characterized by the western hemlock/salal association. These stands occur between 1,300 and 3,600 ft on most aspects. Soils are the shallowest of the coastal western hemlock associations. Douglas-fir and western hemlock again dominate the overstory. Tanoak is usually present in small amounts. The understory is characterized by abundant salal and, often, Pacific rhododendron.

Management considerations

The western hemlock series is highly productive. Deep, moist soils ensure good growth and high stocking, and the mild climate allows a diverse selection of valuable species for regeneration. Douglas-fir and western hemlock grow extremely well in all associations. Western redcedar, Port-Orford-cedar, redwood, and white fir do well on associations where they commonly occur. Sugar pine, incense-cedar, and ponderosa pine are excellent performers on drier, warmer, or more basic soils.

Competing vegetation can be a problem. Pacific rhododendron, salal, Sadler oak, evergreen huckleberry, and tanoak are the strongest competitors; they sometimes interfere with planting even after being burned. See also the management discussion on the tanoak series, above.

The Douglas-Fir Series

Douglas-fir, the most common dominant and most versatile conifer in the Pacific Northwest, occurs prominently in all series. It occurs along the immediate coast, in the high Cascades above 6,000 ft, and on most sites in between. It competes well on most aspects, slopes, and parent rock types.

In the Cascades, Douglas-fir is considered seral except on shallow, rocky, and droughty soils, where it achieves climax status. Droughty sites are more common in southwestern Oregon and northern California, where the series occurs in an elevational band below the white fir series (Figures 5-3 and 5-4). The Cascade associations are scattered in the warmer, drier environments; the Klamath associations occur in zones. Douglas-fir is the climax species on approximately 15 percent of the sites in the Klamaths, where it now dominates the overstory. Its present dominance in other series is primarily a result of harvest and frequent fires. It most efficiently produces biomass at temperatures between 75 and 85°F (Cleary and Waring 1969) but survives, with negligible growth, in less than 2 percent of full sunlight (Atzet and Waring 1970). It is intolerant of low temperatures after buds burst in spring.

The series ranges in elevation from 300 to 6,000 ft. It occurs on all aspects and on slopes from 0 to 120 percent. Soil depths average about 35 inches, or approximately 4 inches less than the average for the region. The series is common on inland sites east of the coastal crest and west of the Cascades. Coastal and Cascade environments tend to favor tanoak, western hemlock, and white fir as the dominant climax species.

Douglas-fir dominates the overstory, with Pacific madrone, golden chinkapin, canyon live oak, tanoak, and white fir present in the understory or in subordinate positions. In most cases Pacific madrone has been overtopped, but golden chinkapin, tanoak, and white fir regenerate and survive in limited amounts in the shade of the overstory canopy. Dwarf Oregongrape, creambush oceanspray, poison-oak, baldhip rose, and creeping snowberry are common. The series can be divided into four groups (Table 5-6) based on their relative environment: cool, moist, mesic, and hot and dry.

Association descriptions

Cool—The Douglas-fir-white fir/dwarf Oregongrape association is the most common association of the cool group. It is in the eastern Klamath Province, away from the coastal influence. At mid-elevation sites (about 4,000 ft) with soil depths of about 40 inches, it is the most productive association of the series. Dwarf Oregongrape, golden chinkapin, and western prince's-pine are common. Golden chinkapin indicates the shallowest soils; cover decreases with increasing soil depth. Drought tolerance in regeneration species is not critical in any association in this series.

Moist—The moist associations are found only in the Klamath Province. They are dominated by tanoak, which generally occurs where soil moisture is plentiful or evaporative demand is low. Temperatures are moderate during the growing season. Vegetation management is the most critical silvicultural concern because tanoak quickly draws down soil moisture supplies.

The Douglas-fir/Pacific rhododendron association occurs in moist environments near the coast or in pathways of marine influence inland. Golden chinkapin, salal, and dwarf Oregongrape are common. Total shrub cover often exceeds 100 percent. Sadler oak occurs on the coolest sites, and beargrass is often found on cold, dry sites, which are difficult to regenerate. Tanoak averages about 10 percent cover in old, closed stands; however, cover increases after harvest and burning.

Mesic—The mesic group is a mix of associations with little in common with the other groups in the series. The Douglas-fir/Sadler oak association, for example, occurs in cool environments but has shallow, rocky, and often basic soils. The Douglas-fir/creeping Oregongrape association is relatively hot and dry, but much less so than associations in the hot, dry group. The Douglas-fir/dwarf Oregongrape association epitomizes the moderate element of the series.

The Douglas-fir/salal/sword fern association occurs mainly in the Cascade Province. Soil depth averages 44 inches but ranges from 24 to over 50 inches. The association occurs on upper slopes exposed to wind and desiccation. Moss cover averages less than 15 percent. Incense-cedar, sugar pine, and Pacific madrone are common in the tree layers, and creambush oceanspray is the second most dominant shrub. Existing vegetation (salal, creambush oceanspray, and madrone) can be competitive, and stored ceanothus seed can germinate and totally occupy the site within 5 years after harvest and burning.

Hot, dry—The hot, dry group includes some of the harshest commercial sites in the area. Associations here are marginally productive. The Douglas-fir-Jeffrey pine, Douglas-fir/buckbrush, and Douglas-fir-Oregon white oak/poison-oak associations are examples. The Douglas-fir/poison-oak association is typical for the Klamath Province, and the Douglas-fir/poison-oak/bracken association is representative of the Cascades.

The Douglas-fir/poison-oak association occurs on inland Klamath Province sites at a relatively low elevation (2,000 ft). However, sites can be found above 4,000 ft on shallow, south-facing slopes. Moisture limits production; stress can occur as early as the beginning of May. Fire frequency is high, and litter cover and soil organic levels are low.

Table 5-7. White oak associations. "White oak" precedes all names.

White oak association name	Dominant group characteristic
/California brome	Hot, dry
/hedgehog dogtail	
-Douglas-fir/sheep fescue	
-Douglas-fir/blue wildrye	
-mountain mahogany	
-woods strawberry	

Management considerations

Most sites are limited by lack of moisture early in the growing season. Soils are often rocky and skeletal, and reforestation is sometimes difficult (Atzet 1981). Increased survival is obtained by conserving soil moisture and channeling it to the crop trees and by reducing radiation loads.

Reducing the cover of competing vegetation has consistently resulted in increased diameter growth (Gratkowski 1961, Newton 1967, Hobbs 1984; O.T. Helgerson; FIR Report 6(3):5-6, 1984; S.D. Tesch; FIR Report 8(2):10-11, 1986). Matching species to site conditions will increase survival and growth. In order of decreasing tolerance of moisture stress, ponderosa pine, incense-cedar, Douglas-fir, sugar pine, and white fir are all appropriate as regeneration.

The Oregon White Oak Series

The classification of this series into associations is tentative because the valley aprons have been repeatedly disturbed by mining, grazing, logging, and fire. Sites with a stable enough stand structure and species composition to characterize the capability of the land are difficult to find (G. Riegel, B. Smith, J. Franklin, T. Atzet, and D. Wheeler; FIR Report 7(2)3-4, 1985). Moreover, because the series is not commonly used for timber production, it has received less study; and therefore, information about the ecology and management of these woodlands is limited. The series is presented here as the dry extreme of forested sites.

Oregon white oak occurs from the southeastern tip of Vancouver Island to the Transverse Ranges in southern California. It is most abundant in the interior valleys west of the Cascades and the Sierras. In Oregon, it is largely confined to valleys and foothills located between the crest of the Cascades on the east and the Coast Range on the west. It is usually found in open forests or woodlands.

The oak woodlands of southwestern Oregon are in a transitional phase between the climax oak woodlands found in California and the climax conifer woodlands generally found in the Willamette Valley, making successional interpretations difficult. We believe that Oregon white oak will dominate the overstory and understory reproduction of the associations described here for the next several centuries. The series does not include stands that typically support other hardwoods such as Pacific madrone or California black oak or abundant Douglas-fir or ponderosa pine regeneration (G.M. Riegel, B.G. Smith, and J.F. Franklin, personal communication).

Most oak-dominated stands occur in the inland valleys between the Cascades and the Klamath Mountains, well below 3,000 ft elevation on droughty sites, or scattered near or on the valley floor. Sites are more common in the southern and eastern portions of the area, where annual precipitation is less than 40 inches and dry-season rainfall is less than 6 inches. Soils typically have a lower rock content and slightly less acidity than soils in coniferous forests.

Oregon white oak dominates both the overstory and understory regeneration in these forest stands. A general north-to-south trend is apparent in both stand structure and composition. To the south, oak woodlands are open, almost savanna-like, with small amounts of ponderosa pine commonly present. In contrast, stands at the northern end of the region tend to be more closed and to include some Douglas-fir. Pacific madrone is occasionally abundant, especially on the moist sites that have been disturbed. California black oak and incense-cedar are the only other common overstory species.

Shrub cover is generally low in most associations. Poison-oak occurs in most associations, but it is usually not abundant. Grasses and herbs are common and abundant. Although native grasses are present, introduced species form a major component of the understory in many stands. Common grasses include hedgehog dogtail, blue wildrye, California brome, and various fescues.

Catchweed bedstraw and sanicula are common herbs.

Six associations are recognized in this series (Table 5-7). Four of them are easily ordered along a gradient of elevation and precipitation. At the dry extreme is the Oregon white oak/California brome association. Relatively moist sites are characterized by the Oregon white oak/blue wildrye association. Intermediate types are the Oregon white oak/hedgehog dogtail and Oregon white oak-Douglas-fir/sheep fescue associations. One association, the Oregon white oak-mountain mahogany association, occurs at somewhat higher elevations.

Association descriptions

The white oak/California brome association typically occurs on flat to convex mid- and upper-slope positions below 3,280 ft. It is the driest oak association. All stands are found on sites where the predicted average annual precipitation is 30 inches or less. Oregon white oak completely dominates the overstory, and ponderosa pine, California black oak, and mountain mahogany occur only occasionally. Douglas-fir is rare. The understory is largely composed of grasses and forbs and a sparse shrub cover. Common herbs include California brome, roughstalk bluegrass, hedgehog dogtail, and purple brodiaea.

Management considerations

Oak woodlands have historically supplied forage and firewood. An appropriate grazing system can improve productivity and palatability of forage. Grazing trials demonstrate that populations of weedy annuals can be reduced and vigor of desirable perennials increased by controlling the amount and duration of grazing. Short-duration grazing can control weedy annuals before spring flowering, when weeds are most palatable to livestock. Stands that have good populations of perennials can provide moderately palatable forage well into the spring. More research is needed on recruitment of perennial grasses.

The Oregon white oak series offers opportunities for fiber and firewood production, especially when these are linked to a goal of increased forage production. Oregon white oak, California black oak, and Pacific madrone all sprout when cut. This suggests that some form of coppice silvicultural systems may be appropriate for sustained production of chips and cordwood. However, we are unaware of any published research on either coppice management or growth and yield for these oak woodlands which would help in establishing acceptable annual harvest levels. Other management considerations exist; for example, wildlife production and water yield. A recent compendium of oak woodland management in California is a good source of ideas (Plumb 1980).

SUMMARY

Southwestern Oregon and northwestern California make up possibly the most ecologically diverse region in the United States (Whittaker 1961). Its floristic history, complex geology, combined marine and continental climate, and continuing influx of genetic materials from northern and eastern Oregon and California combine to provide a variety of habitats and a diversity of species.

The major series, in general order of decreasing elevation, are mountain hemlock, white fir, tanoak, western hemlock, Douglas-fir, and Oregon white oak. Over 170 preliminary forest associations have been described, and work is continuing.

High-elevation true fir and mountain hemlock associations and low-elevation Oregon white oak associations are the most difficult to revegetate after harvest or disturbance. High moisture stress limits growth, and low air and soil temperatures limit survival. Nutrients are limiting on ultrabasic, pumice, ash, and some granitic soils. Vegetation competition can limit crop tree survival, particularly in the tanoak series.

The Klamath Province is at once a sink and a source. It is a haven for ice-age relicts and chaparral species that expanded their range during the Xerothermic Period. The variety of genetic material is also a source, available regardless of the direction of climatic change. This variety of species from different sources and the large number of associated endemics should not be overlooked as a barometer for sensing climate change and forest health.

LITERATURE CITED

ATZET, T. 1979. Description and classification of the forests of the upper Illinois river drainage of southwest Oregon. Ph.D. thesis, Oregon State University, Corvallis. 211 p.

ATZET, T. 1981. Operational environment and factors limiting reforestation in the Siskiyou Mountains. P. 6-10 in S.D. Hobbs and O.T. Helgerson, eds. Reforestation of Skeletal Soils, Proceedings of a Workshop. Forest Research Laboratory, Oregon State University, Corvallis.

ATZET, T., and L.A. McCRIMMON. 1990. Preliminary plant associations of the southern Oregon Cascades. USDA Forest Service, Pacific Northwest Region, Siskiyou National Forest, Grants Pass, Oregon. 339 p.

ATZET, T., and R.H. WARING. 1970. Selective filtering of light by coniferous forests and minimum light energy requirements for regeneration. Canadian Journal of Botany 48(12):2163-2167.

ATZET, T., and D.L. WHEELER. 1982. Historical and ecological perspectives on fire activity in the Klamath Geological Province of the Rogue River and Siskiyou National Forests. USDA Forest Service, Pacific Northwest Region, Portland, Oregon. R6-Range-102. 16 p.

ATZET, T., and D.L. WHEELER. 1984. Preliminary plant associations of the Siskiyou Mountain Province. USDA Forest Service, Pacific Northwest Region, Siskiyou National Forest, Grants Pass, Oregon. 315 p.

AXELROD, D.I. 1976. History of the coniferous forests, California and Nevada. University of California. Publications in Botany 70:1-62.

CLEARY, B.D., and R.H. WARING. 1969. Temperature: collection of data and its analysis for the interpretation of plant growth and distribution. Canadian Journal of Botany 47:167-173.

DAUBENMIRE, R.F. 1959. Canopy coverage method of vegetation analysis. Northwest Science 33:43-64.

DAUBENMIRE, R.F. 1966. Vegetation: identification of typical communities. Science 151:291-298.

DAUBENMIRE, R.F. 1968. Plant Communities: A Textbook of Plant Synecology. Harper and Row, New York. 300 p.

DETLING, L.E. 1961. The chaparral formation of southwest Oregon, with considerations of its postglacial history. Ecology 42:348-357.

DETLING, L.E. 1968. Historical background of the flora of the Pacific Northwest. Museum of Natural History, University of Oregon, Eugene. Bulletin 13. 57 p.

FRANKLIN, J.F., and C.T. DYRNESS. 1973. Natural Vegetation of Oregon and Washington. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-8. 417 p.

FRANKLIN, J.F., F.C. SORENSEN, and R.K. CAMPBELL. 1978. Summarization of the ecology and genetics of the noble and California red fir complex. P. 133-139 in Proceedings, IUFRO Joint Meeting, Working Parties, Vancouver, B.C., Canada. Volume 1. British Columbia Ministry of Forestry, Information Service Branch, Victoria, B.C.

GRATKOWSKI, H. 1961. Use of herbicides on forest lands in southwest Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note 217. 18 p.

HANSEN, H.P. 1955. Postglacial forests in south central and central British Columbia. American Journal of Science 256:640-658.

HARRINGTON, T.B. 1989. Stand development and individual tree morphology and physiology of young Douglas-fir (*Pseudotsuga menziesii*) in association with tanoak (*Lithocarpus densiflorus*). Ph.D. dissertation, Oregon State University, Corvallis. 185 p.

HOBBS, S.D. 1984. The influence of species and stocktype selection on stand establishment: an ecophysiological perspective. P. 179-224 in M. L. Duryea and G. N. Brown, eds. Seedling Physiology and reforestation success. M. Nijhoff/Dr W. Junk Publishers. The Hague /Boston/Lancaster.

MASON, H.L., and J.H. LANGENHEIM. 1957. Language analysis and the concept of environment. Ecology 38:325-330.

MINORE, D. 1979. Comparative autecological characteristics of northwest tree species—a literature review. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-87. 70 p.

NEWTON, M. 1967. Response of vegetation communities to manipulation. P. 83-87 in Proceedings, Herbicides and Vegetation Management. School of Forestry, Oregon State University, Corvallis.

PLUMB, T.R., technical coordinator. 1980. Proceedings of the Symposium on the Ecology, Management, and Utilization of California Oaks. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. General Technical Report PSW-44. 368 p.

SAWYER, J.O., and D.A. THORNBURGH. 1977a. Montane and subalpine vegetation of the Klamath Mountains. P. 699-732 in M.G. Barbour and J. Major, eds. Terrestrial Vegetation of California. John Wiley and Sons, New York. p. 699-732.

SAWYER, J.O., and D.A. THORNBURGH. 1977b. Mixed evergreen forest. P. 359-381 in M.G. Barbour and J. Major, eds. Terrestrial Vegetation of California. John Wiley and Sons, New York.

SISKIYOU NATIONAL FOREST. 1984. Port-Orford-cedar Management Guide. USDA Forest Service, Siskiyou National Forest, Grants Pass, Oregon. 12 p.

SMITH, J.P., and J.O. SAWYER. 1988. Endemic vascular plants of northwestern California and southwestern Oregon. Madrōno 35(1):54-69.

SPOMER, G.C. 1973. The concepts of "interaction" and "operational environment" in environmental analysis. Ecology 54(1):200-204.

TAPPEINER, J.C., II, T.B. HARRINGTON, and J.D. WALSTAD. 1984. Predicting recovery of tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*) after cutting or burning. Weed Science 32:413-417.

TAPPEINER, J.C., II, and P.M. McDONALD. 1984. Development of tanoak understories in conifer stands. Canadian Journal of Forest Research 14:271-277.

WALSTAD, J.D., S.R. RADOSEVICH, and D.V. SANDBERG, editors. 1990. Natural and Prescribed Fire in Pacific Northwest Forests. Oregon State University Press, Corvallis. 317 p.

WARING, R.H. 1969. Forest plants of the eastern Siskiyous: their environmental and vegetational distribution. Northwest Science 43:1-17.

WARING, R.H., W.H. EMMINGHAM, and S.W. RUNNING. 1975. Environmental limits of an endemic spruce, *Picea breweriana*. Canadian Journal of Botany 53:1599-1613.

WEBB, L.O. 1987. A guide to sensitive plants of the Siskiyou National Forest. USDA Forest Service, Siskiyou National Forest, Grants Pass, Oregon. 255 p.

WHITTAKER, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30:279-338.

WHITTAKER, R.H. 1961. Vegetation history of the Pacific Coast states and the "central" significance of the Klamath Region. Madrōno 16:5-23.

ZINKE, P.J. 1977. The redwood forest and associated north coast forests. P. 359-381 in M.G. Barbour and J. Major, eds. Terrestrial Vegetation of California. John Wiley and Sons, New York.

ZOBEL, D.B. 1973. Local variation in intergrading *Abies grandis-Abies concolor* populations in the central Oregon Cascades: I. Needle morphology and periderm color. Botanical Gazette 134:205-220.

ZOBEL, D.B. 1974. Local variation in intergrading *Abies grandis-Abies concolor* populations in the central Oregon Cascades: II. Stomatal reaction to moisture stress. Botanical Gazette 135:200-210.

ZOBEL, D.B. 1975. Local variation in intergrading *Abies grandis-Abies concolor* populations in the central Oregon Cascades: III. Timing of growth and stomatal characteristics in relation to environment. Botanical Gazette 136:63-71.

ZOBEL, D.B., and G.M. HAWK. 1980. The environment of *Chamaecyparis lawsoniana*. American Midland Naturalist 103(2):280-297.

ZOBEL, D.B., L.F. ROTH, and G.M. HAWK. 1985. Ecology, pathology, and management of Port-Orford-cedar (*Chamaecyparis lawsoniana*). USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-184. 161 p.