Quercus garryana Dougl. ex Hook. Oregon White Oak

Fagaceae Beech family

William I. Stein

Oregon white oak ***(Quercus garryana)***, a broadleaved deciduous hardwood common inland along the Pacific Coast, has the longest north-south distribution among western oaks-from Vancouver Island, British Columbia, to southern California. It is the only native oak in British Columbia and Washington and the principal one in Oregon. Though commonly known as Garry oak in British Columbia, elsewhere it is usually called white oak, post oak, Oregon oak, Brewer oak, or shin oak. Its scientific name was chosen by David Douglas to honor Nicholas Garry, secretary and later deputy governor of the Hudson Bay Company.

Habitat

Native Range

The range of Oregon white oak (fig. 1) spans more than 15" of latitude from just below the 50th parallel on Vancouver Island in Canada south nearly to latitude 34" N. in Los Angeles County, CA. South of Courtenay, BC, Oregon white oak is common in the eastern and southernmost parts of Vancouver Island and on adjacent smaller islands from near sea level up to 200 m (660 ft) or more (47). It is not found on the British Columbia mainland except for two disjunct stands in the Fraser River Valley *(28)*. In Washington, it is abundant on islands in Puget Sound and distributed east and west of the Sound and then south and east to the Columbia River at elevations up to 1160 m (3,800 ft) (68). Oregon white oak is widespread at lower elevations in most of the Willamette, Umpqua, and Rogue River Valleys of western Oregon *(67,68)*. It is also common in the Klamath Mountains and on inland slopes of the northern Coast Ranges in California to San Francisco Bay but infrequent from there southward to Santa Clara County (29).

In small tree and shrub sizes, Oregon white oak extends inland to just east of the Cascade Range, mainly in the Columbia River and Pit River drainages *(29,50,67,68,71)*. It has a scattered distribution the entire length of the western Sierra Nevada south to the Tehachapi Mountains in Kern and northern Los Angeles Counties where it forms extensive brush fields at elevations up to 2290 m ***(7,500*** ft) *(29,76)*.

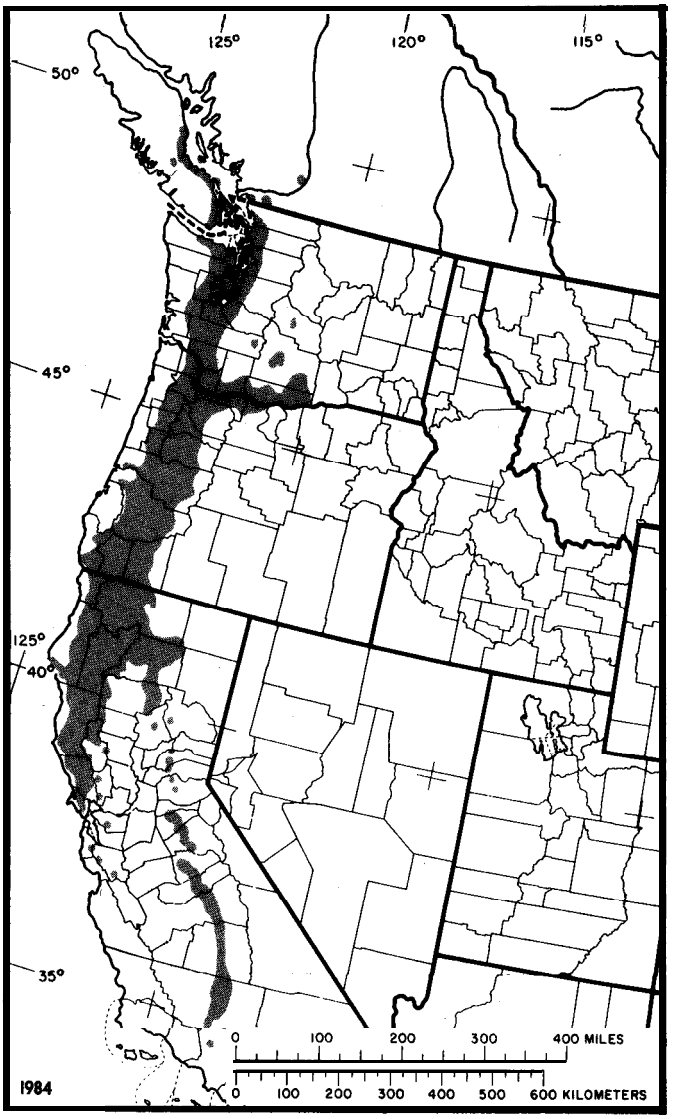

Figure 1--The native *range of Oregon white oak.*

Climate

Oregon white oak grows in diverse climates, ranging from the cool, humid conditions near the coast to the hot, dry environments in inland valleys and foothill woodlands. Records from 48 climatic observation stations within or bordering its range indicate that Oregon white oak has endured temperature ex-

The author is Plant Ecologist, Pacific Northwest Research Station, Portland. OR.

tremes of -34" to 47" C (-30" to 116" F) *(45,47,53,77)*. Average annual temperatures range from 8" to 18° C (46° to 64" F); average temperatures in January, from -11" to 10" C (13" to 50° F); and in July, from *16"* to 29" C (60° to 84" F).

Average annual precipitation ranges from 170 mm (6.7 in) at Ellensburg, WA, east of the Cascades to 2630 mm (103.5 in) at Cougar, WA, west of the Cascades. Precipitation at the southern end of the range of Oregon white oak (Tehachapi) averages 270 mm (10.6 in), similar to that at northerly locations east of the Cascades-Ellensburg, Yakima, and Goldendale in Washington and The Dalles and Dufur in Oregon. Average annual snowfall ranges from little, if any, at several locations to 417 cm (164 in) at Mineral in Tehama County, CA. Average precipitation in the growing season (April through September) ranges from 30 mm (1.2 in) at Tehachapi, CA, and Ellensburg, WA, to 630 mm (24.8 in) at Cougar, WA. Length of average frost-free season (above 0" C; 32" F) ranges from 63 days at Burney in Shasta County, CA, to 282 days at Victoria, BC.

Soils and Topography

Oregon white oak can grow on a wide variety of sites, but on good sites it is often crowded out by species that grow faster and taller. Hence, Oregon white oak is most common on sites that are too exposed or droughty for other tree species during at least part of the year, including inland valleys and foothills, south slopes, unglaciated and glaciated rocky ridges, and a narrow transition zone east of the Cascades between conifer forest and treeless, dissected plateau. Although usually considered a xeric species, Oregon white oak also commonly occurs in very moist locations-on flood plains, on heavy clay soils, and on river terraces. These locations appear to have two common characteristics-standing water or a shallow water table during a lengthy wet season and gravelly or heavy clay surface soils that probably are droughty during the extended dry season. The distribution of Oregon white oak gives evidence that it can withstand both lengthy flooding and drought.

Oregon white oak grows on soils of at least four orders: Alfisols, Inceptisols, Mollisols, and Ultisols. Specific soil series include Hugo and McMahon in coastal northern California and Goulding near Santa Rosa *(75,78)*. In Oregon's Willamette Valley, Oregon white oak is found on soils derived from alluvial deposits (poorly drained gray brown Amity and Dayton series), sedimentary rocks (deep, well-drained brown Steiwer, Carlton, Peavine, Bellpine, Melbourne, and Willakenzie series), and basic igneous rocks (brown or reddish, moderately deep, well-drained Nekia, Dixonville, and Olympic series) *(22,38,67,73)*. A subsurface clay layer that restricts water penetration is characteristic of soils in most of these series. White oak stands near Dufur in eastern Oregon grow in soils derived from basalt and andesite (32); in southern Oregon, they grow in soils derived from andesite, granite, and serpentine (79). On the southeastern tip of Vancouver Island, BC, seven soils supporting a vegetational sequence of grass, Oregon white oak, and Douglas-fir were gravelly loams or gravelly sandy loams that developed on young, nonhomogeneous parent materials *(11)*.

Soils under Oregon white oak stands are generally acidic, ranging in pH from 4.8 to 5.9 *(11,75,78)*. Bulk densities ranging from 0.61 to 1.45 have been measured *(73,78)*. Many white oak stands grow on gentle topography; only one-fourth of those examined in the Willamette Valley were on slopes greater than 30 percent (73).

Associated Forest Cover

Oregon white oak is found in pure, closed-canopy stands; in mixture with conifers or broad-leaved trees; and as scattered single trees or groves on farmlands, woodlands, and prairies (fig. 2). It grows to large sizes but is also found extensively as scrub

Figure *2-Pure oak woodland on a ranch in the Willamette* Valley, *OR. Hairy mistletoe plants* (Phoradendron villosum) *are prominent in the* leafless *treetops.*

forest. The best stands are in western Oregon and Washington-in the Cowlitz, Lewis, and Willamette River drainages-but stands or trees with substantial volume are found from British Columbia to central California. Dense dwarf or shrub stands of

Oregon white oak, earlier identified as ***Quercus garryana*** var. *breweri*, and other stands previously identified as ***Q. garryana*** var. ***semota,*** form dense thickets over large areas in California *(29,35,57,76,81)*. Similar dwarf or shrub forms grow to a more limited extent on severe sites in the rest of its range *(57,79)*.

Oregon white oak is recognized as a distinct forest cover type (Society of American Foresters Type 233) and is listed as an associated species in at least eight other forest cover types *(20)*: Pacific Douglas-Fir (Type 229), Port Orford-Cedar (Type 231), Redwood (Type 232), Douglas-Fir-Tanoak-Pacific Madrone (Type 234), Pacific Ponderosa Pine (Type 245), California Black Oak (Type 246), Knobcone Pine (Type 248), and Blue Oak-Digger Pine (Type 250). Its prominence and occurrence in these types, as well as in several others for which it is not specifically listed, vary widely.

Plant communities have been identified in parts of the Oregon white oak type. A Garry oak community of two types (oak parkland and scrub oak-rock outcrop), a Garry oak-arbutus, and an arbutus-Garry oak community have been defined in the Victoria, BC, metropolitan area (42). Four communities, ranked in order from wettest to driest, have been identified in white oak forests of the Willamette Valley: Oregon white oak/California hazel/western swordfern, Oregon white oak/sweet cherry/common snowberry, Oregon white oak/Saskatoon serviceberry/common snowberry, and Oregon white oak/Pacific poison-oak (73). These communities are floristically similar, being differentiated primarily by the relative coverage and frequency of a few shrub species. Five Oregon white oak communities identified in the North Umpqua Valley of Oregon were similar to the xeric Oregon white oak/Pacific poison-oak association of the Willamette Valley; a sixth was a riparian association dominated by Oregon white oak and Oregon ash (*Fraxinus latifolia)* (62). In California, four communities dominated by Oregon white oak were found in the Bald Hills woodlands of Redwood National Park (70) and three communities dominated by Oregon white oak or related hybrids were identified in a limited area on Bennett Mountain (75). The shin oak brush association, largely composed of Oregon white oak, is a distinctive plant community in Kern and Los Angeles Counties (76).

The composition of Oregon white oak communities varies greatly because of differences in soil, topography, and climate, and in fire and grazing histories. Because of proximity to farmlands, many communities include introduced forbs and grasses. Pacific poison-oak *(Rhus* ***diversiloba)*** and common snowberry ***(Symphoricarpos*** *albus)* are probably the most widespread and characteristic shrub associates. Species often found with Oregon white oak are listed in table 1. The listing is not exhaustive; it just indicates the great variety of common associates. Species associated with Oregon white oak in chaparral communities and on serpentine soils are listed in other ***sources*** *(15,16,79)*.

Life History

Reproduction and Early Growth

Flowering and Fruiting-Oregon white oak flowers somewhat later in the spring than many of its associates. Flowering has been noted in March, April, May, and June *(72,74)*, but the seasonal span is probably greater over the wide range of latitudes and elevations where this species occurs. Flowers appear concurrently with new leaves and extension of twig growth.

The species is monoecious, bearing slim, staminate flowers (catkins) that emerge from buds on existing twigs and also appear on the basal end of developing twigs (64). Some catkins associated with new twig growth just originate from the same bud; others are located as much as 5 mm (0.2 in) from the base on new growth. Catkins are pale yellow tinged with green. Fully extended catkins vary greatly in length-in one collection, from 3 to 10 cm (1.2 to 3.9 in). Catkins of the same twig and cluster are in various stages of development-some are fading before others reach full size. The faded dry catkin is light brown and fragile.

The closed pistillate flowers are small, deep red, and covered with whitish hairs (64). They appear in axils of developing leaves, either single and sessile or as many as five or six on a short stalk up to 2 cm (0.8 in) long. Two flowers are often located at the base of the stalk and several along and at its tip. Basal flowers may be open while others on the stalk are still tiny and tightly closed. Flower openings are narrow; the interior elements are greenish to yellowish. Flowers were found on new growth that had extended only 1 cm (0.4 in) or up to 12 cm (4.7 in); most flowers were on new growth 4 to 7 cm (1.6 to 2.8 in) long. Flowering appears at its fullest when the first leaves are about half size; when leaves approach full size, catkins are withered. On a single tree, flowering seems to be a short event, perhaps a week long, as leaves develop quickly once growth starts.

Individual trees are known to flower abundantly, but observations are needed on the regularity of flowering and on the variability within and between stands and locations.

Table l-Trees, shrubs, and herbs associated with Oregon white oak in different parts of its range[1]

Trees	Shrubs	Herbs
Abies grandis	*Amorpha californica*	*Agropyron spicatum*
Acer circinatum	Arctostaphylos columbiana	Agrostis spp.
Acer glabrum	*Arctostaphylos manzanita*	*Allium* spp.
Acer macrophyllum	*Arctostaphylos media*	*Athysanus pusillus*
Aesculus californica	*Arctostaphylos uva-ursi*	*Avena barbata*
Alnus rubra	*Berberis aquifolium*	*Balsamorhiza deltoides*
Amelanchier alnifolia	*Berberis nervosa*	*Brodiaea* spp.
Arbutus menziesii	*Ceanothus cuneatus*	*Bromus* spp.
Betula occidentalis	*Ceanothus integerrimus*	*Camassia* spp.
Castanopsis chrysophylla	*Ceanothus velutinus*	*Carduus pycnocephalus*
Cercocarpus betuloides	*Cornus stolonifera*	*Carex* spp.
Cornus nuttallii	*Crataegus oxyacantha*	*Chlorogalum pomeridianum*
Corylus cornuta	*Cytisus scoparius*	*Collinsia* spp.
Crataegus douglasii	*Gaultheria shallon*	*Crocidium multicaule*
Fraxinus la tifolia	*Hedera helix*	*Cynosurus echinatus*
Heteromeles arbutifolia	*Holodiscus discolor*	*Dactylis glomerata*
Juniperus scopulorum	*Osmaronia cerasiformis*	*Danthonia californica*
Libocedrus decurrens	*Philadelphus lewisii*	*Delphinium menziesii*
Lithocarpus *densiflorus*	Physocarpus capitatus	*Dentaria* californica
Pinus contorta	*Purshia tridentata*	*Dodecatheon hendersonii*
Pinus mon ticola	*Rhus diversiloba*	*Dryopteris argu ta*
Pinus ponderosa	*Ribes sanguineum*	*Elymus glaucus*
Pinus sabiniana	*Rosa eglanteria*	*Eriogonum nudum*
Populus tremuloides	*Rosa gymnocarpa*	*Eriophyllum lanatum*
Populus trichocarpa	*Rosa nutkana*	*Erythronium oregonum*
Prunus avium	*Rubus laciniatus*	*Festuca* spp.
Prunus emarginata	*Rubus parviflorus*	*Fritillaria lanceola ta*
Prunus virginiana	*Rubus procerus*	*Galium* spp.
Pseudotsuga menziesii	*Rubus ursinus*	*Holcus lanatus*
Pyrus communis	*Spiraea be tulifolia*	*Hypericum perforatum*
Pyrus fusca	*Spiraea douglasii*	*Lathyrus* spp.
Pyrus malus	*Symphoricarpos albus*	*Lomatium utriculatum*
Quercus agrifolia	*Symphoricarpos mollis*	*Lonicera ciliosa*
Quercus chrysolepis	*Symphoricarpos rivularis*	*Lotus micranthus*
Quercus douglasii	*Vaccinium ovatum*	*Lupinus* spp.
Quercus *kelloggii*	Vaccinium *parvifolium*	Melica geyeri
Rhamnus purshiana	*Viburnum ellipticum*	*Mimulus* spp.
Salix spp.		*Montia* spp.
Sambucus cerulea		*Nemophila heterophylla*
Taxus brevifolia		*Osmorhiza* spp.
Thuja plicata		*Phacelia linearis*
Tsuga heterophylla		*Platyspermum scapigera*
Umbellularia californica		*Plectritis* spp.
		Poa pratensis
		Polystichum munitum
		Pteridium aquilinum
		Ranunculus spp.
		Sanicula crassicaulis
		Sedum spathulifolium
		Sherardia arvensis
		Silene californica
		Sisyrinchium douglasii
		Stipa spp.
		Thysanocarpus curvipes
		Trifolium tridentatum
		Vicia americana
		Viola ocella ta
		Zigadenus venenosus

[1] *Sources:* 4,10,11,13,20,22,24,28,31,32,35,42,47,54,62,63,67,69,70,71,72,73,75,78

Seed Production and Dissemination-Seed crops may be heavy but are considered irregular. The large acorns, typically about 3 cm (1.2 in) long and half as wide, mature in one season and ripen from late August to November. The age when a tree first bears fruit, the age of maximum production, and the average quantity produced have not been determined. In one collecting effort, about 18 kg (40 lb) of acorns per hour could be hand-picked from the ground under woodland trees between Redding and Weaverville, CA. The yield was estimated to be 5 to 9 kg (10 to 20 lb) each for trees 3 to 9 m (10 to 30 ft) tall and 15 to 30 cm (6 to 12 in) in diameter; production for this fair crop was about 560 kg/ha (500 lb/acre) *(81).* Northeast of Mount Shasta, a fair crop the same year yielded about 23 kg (50 lb) of acorns from a single tree 8 m (25 ft) in height and crown spread. In the Willamette Valley, acorns were dispersed from September to November, and three crops ranged from failure to 1737 kg/ha (1,550 lb/acre) ovendry-weight basis *(12).* Large crops of acorns are also produced by shrubby forms of Oregon white oak, but density of the stands can make collection difficult.

The heavy seeds disseminate by gravity only short distances from the tree crowns, except on steep slopes. Local transport is attributed primarily to the food-gathering activities of animals. In the past, Indians-and also pigeons-may have been responsible for long-distance colonization of Oregon white oak *(28,71).*

Seedling Development-Acorns of Oregon white oak must be kept moist until they germinate. In nature, moisture is maintained by a layer of leaves or through shallow insertion into soil from impact, rodent activity, animal trampling, or other soil disturbances. A moisture content of 30 percent or more must be maintained in cool regulated storage to maintain seed viability. Storage conditions have not been determined specifically for Oregon white oak; several methods recommended for keeping seeds moist should be suitable *(46,65).*

The acorns are large and heavy, averaging about 5 g each (85/lb). Viability has been better than 75 percent in the few samples tested *(46),* but the usual quality of the seeds is unknown. The seeds are not dormant; they will germinate soon after dispersal if subjected to warm, moist conditions. They will also germinate prematurely in low-temperature stratification. Normally, seeds retain viability only until the next growing season; chances of extending the viability period have not been determined.

Seedlings of Oregon white oak generally appear in the spring. Germination is hypogeal, and the rapid development of a deep taproot is believed responsible for their ability to establish in grass. Shoot development is relatively slow but can be greatly accelerated with long photoperiods (43). Seedlings are not produced now for forest plantings, but raising them in containers is readily possible. Direct seeding of acorns should also prove successful if seeds and young seedlings are protected from rodents and other predators. In at least some circumstances, natural reproduction from seed seems to occur readily *(13,28,35).*

Vegetative Reproduction-Oregon white oak sprouts abundantly from dormant buds on cut stumps, root collars, and along exposed trunks. Sprouts provide the most certain way to obtain natural regeneration. In 3 years, stump sprouts in 49 clumps in northwestern California averaged 10 per clump; height of the tallest sprout averaged 2.8 m (9.2 ft) and crown diameter per clump 2.5 m (8.2 ft) (52). Larger stumps produced more sprouts, larger clumps, and faster growing shoots. The spread of Oregon white oak by root sprouts has been noted in widely separated instances *(28,68,69,70,71,74).* In general, the rooting or layering of oak cuttings is difficult, and there is no reason to believe that Oregon white oak would be easier to reproduce by these methods than other oaks.

Sapling and Pole Stages to Maturity

Growth and Yield-Under favorable conditions, mature Oregon white oak trees are 15 to 27 m (50 to 90 ft) tall and 60 to 100 cm (24 to 40 in) in d.b.h. *(34,48,72,73).* A maximum height of 36.6 m (120 ft), crown spread of 38.4 m (126 ft), and diameter of 246 cm (97 in) at d.b.h. are on record *(2,35).* Typically, open-grown trees have short boles bearing very large, crooked branches that form dense, rounded crowns (fig. 3). Such trees occupy much space but do not produce much volume for commercial use, except for fuel. In contrast, forest-grown trees 70 to 90 years old have slim, straight boles, fine side branches, and narrow crowns *(60).* Trees measured in northwestern California had average form classes of 63 and 68 (34). Branchwood of trees over 60 cm (24 in) in d.b.h. averaged 24 percent of total cubic volume. Trees of better form are probably developing now because young stands are more even aged and better stocked than those in the past, but such stands are limited in extent and widely scattered.

Resource inventories of various intensities indicate that the Oregon white oak type occurs on at least 361 400 ha (893,000 acres) in California, Oregon, and Washington and, as a species, comprises 26.2

million m^3 (926 million ft^3) or more of growing stock *(7,8,9,10,21,25,26,27)*. As a component of woodland and other vegetation types, Oregon white oak is found on an additional 299 100 ha (739,000 acres) in California and in sizeable, undefined areas in Oregon and Washington. In California, the mean stand growing-stock volume in the type was 76.9 m^3/ha (1,099 ft^3/acre), and the maximum found was 314.7 m^3/ha (4,498 ft^3/acre).

Oregon white oak generally grows slowly in both height and diameter, but there are exceptions. Limited data from widely separated locations indicate that six to eight rings per centimeter (16 to 20/in) is a common rate for slower growing Oregon white oaks *(28,68,72,75)*. For example, trees in a full stand 47 to 70 years old on deep Willakenzie soil at Corvallis, OR, averaged 14 m (46 ft) in height, 15 cm (6.0 in) in d.b.h., and eight rings per centimeter (20/in) in radial growth (38). Oregon white oak has the capability, however, of growing faster than five rings per centimeter (13/in) *(31,48,72,80)*. In the Cowlitz River Valley, the fastest rate shown on large stumps was 1.9/cm (4.9/in); in the Willamette Valley, the rate averaged 4.6/cm (11.8/in) for four forest-grown trees 95 to 135 years old that averaged 24 m (80 ft) tall and 48 cm (19 in) in d.b.h.

Basal area of Oregon white oak stands has ranged from 8.0 to 60.8 m^2/ha (35 to 265 ft^2/acre), with up to 19.3 m^2/ha (84 ft^2/acre) additional basal area of other species present. In these and other stands averaging 10 cm (4 in) or more in d.b.h., number of oak stems ranged from 10 to 2,800/ha (4 to 1,133/acre) *(1,4,31, 62,69,70,72,75)*. Volumes for stands on different sites and of different ages are not known. One 80-year-old stand that averaged 160 trees 9 cm (3.6 in) and larger in d.b.h. would yield about 94.5 m^3/ha (15 cords/acre) *(60)*.

Rooting Habit-Oregon white oak has a deep taproot and a well-developed lateral system; it is very windfirm even in wet areas. Fast taproot extension and sparse development of laterals are shown by seedlings in the first few weeks of growth. Despite formation of a deep taproot, a high percentage of oak roots are found in upper soil layers. Only 11 percent of the total number of oak roots were found below 76 cm (30 in) in deep Willakenzie soil (38). In contrast, 28 percent of the total Douglas-fir roots in the same soil were found below 76 cm (30 in).

Reaction to Competition-Oregon white oak has been classed as intermediate in tolerance, intolerant, and very intolerant of shade (47). Perhaps such a range of tolerance best describes its status in different situations. Clearly, it is not tolerant of overtopping by Douglas-fir and associated conifers. Dead oaks often found beneath Douglas-fir canopies bear witness that they could not endure the shade *(40,72)*. In some locations and situations, Oregon white oak perpetuates itself, indicating that it can reproduce adequately in its own shade. Branch development on open-grown trees may be very dense. Sparse development of side branches in closed stands provides evidence, however, that it should be classed as intolerant of shade.

Oregon white oak functions as both a seral and a climax species. It is long lived, reproduces from both seeds and sprouts, forms nearly pure stands, and can endure great adversities. In fact, it rates as a climax species because it has greater ability than other species to establish itself and persist where yearly or seasonal precipitation is sparse, where soils are shallow or droughty, or where fire is a repeated natural occurrence.

Figure 3—*Mature open-grown Oregon white oak on a cultivated knoll near Amity, OR; its establishment predates settlement of the Willamette Valley.*

Geologic and floristic evidence indicates that Oregon white oak associations have evolved through successive eras as components of relatively arid pine-oak forests, have repeatedly advanced northward from a locus in the southwestern United States and

Figure 4—*In the absence of fire, many Oregon white oak stands are invaded and eventually overtopped by Douglas-firs.*

northwestern Mexico, and have repeatedly retreated as North American climates warmed and cooled *(16)*. The most recent northward advance ended about 6,000 years ago; the more arid vegetation types, including oak woodlands, are now being replaced by conifer forest favored by the climatic trend toward cooler and moister conditions.

The seral role of Oregon white oak is illustrated by major changes occurring in the Willamette Valley. Open oak woodlands, savannas dotted with oaks, and grasslands were prominent and widespread before the territory was settled; fires-natural as well as those set by Indians-maintained these open conditions *(30,31,36,44,61)*. Postsettlement exclusion of fire permitted development of closed-canopy white oak stands that are typically of two ages-large spreading trees, now 270 to 330 years old, are scattered among smaller trees of narrow form, 60 to 150 years old (73). Where not restricted by agricultural practices, young oaks continue to encroach into grassland. But, in turn, many oak stands are being invaded and superseded by bigleaf maples or conifers, mainly Douglas-fir (fig. 4). A similar sequence of events is occurring in the northern oak woodland, a distinctive Oregon white oak type in California *(5,51,69)*. Unless steps are taken to reverse present trends, the Oregon white oak type will continue to become a less prominent part of the western flora. A reduction in species diversity will also occur, for open-canopy communities have a more varied composition than closed conifer communities *(13)*.

Damaging Agents-Because of their attractiveness as food, seed crops of Oregon white oak are often decimated quickly *(12)*. Larvae of the filbertworm *(Melissopus latiferreanus)* and the filbert weevil *(Curculio occidentalis)* damage crops even before acorns ripen *(23)*. Maturing or ripe acorns are consumed by woodpeckers, pigeons, doves, jays, wood ducks, mice, chipmunks, squirrels, pocket gophers, woodrats, deer, bear, and other wildlife, as well as by domestic animals.

Wind, wet snow, and freezing rain damage Oregon white oak less than associated hardwoods, but in tests it showed only moderate resistance to cold. Dormant buds collected northwest of Corvallis, OR, withstood -15" C (5" F) and twigs -20" C (-4" F) without injury *(55)*.

Large Oregon white oaks are obviously fire resistant; they have withstood annual or periodic fires for years. But small oaks may be killed or badly damaged by fire, as evidenced by the increased density and spread of oak stands since the advent of fire control.

More than 110 pathogens have been found on the leaves, twigs, trunk, or roots of Oregon white oak (59). Most are of minor consequence; many are saprophytes. Leaf-spot, mildew, and anthracnose fungi sometimes attack the foliage, but control methods have been suggested for only one-an anthracnose disease *(Gnomonia quercina)*. In 1968, this fungus caused moderate to severe dying of leaves and possibly death of oak trees in southern Pierce County, WA ***(14)***. Premature browning of foliage is occasionally widespread in the Willamette Valley, but the causes and effects have received only incidental attention. The hairy mistletoe is common on Oregon white oak in Oregon and California, forming conspicuous, rounded growths in the upper crown (fig. 2). Its effect on growth and vigor of this host is undetermined. The white pocket root and butt rot *(Polyporus dryophilus)* and the shoestring root rot *(Armillaria mellea)* are probably the most damaging rots found in Oregon white oak. Its heartwood is generally very durable; stumps and even relatively small stems may remain intact for years.

Although Oregon white oak is host to hundreds of insect species *(19)*, damage is usually not severe, and loss of trees to insect attack is uncommon. The western oak looper *(Lambdina fiscellaria somniaria)* is probably the most damaging insect on white oak from Oregon north to British Columbia. In some years, oaks over large areas in the Willamette Valley are defoliated *(23)*. The damage is temporary since the trees leaf out the next year and outbreaks are not sustained. The western tent caterpillar *(Malacosoma californicum)* and the Pacific tent

caterpillar *(M. constrictum)* are widely distributed defoliators with a preference for oaks. Several species of aphid, particularly *Tuberculatus columbiae*, feed on the underside of oak leaves; the snowy tree cricket *(Oecanthus fultoni)* lives in open-grown oaks and associated species; and several leafrollers *(Abebaea cervella* and *Pandemis cerasana)* are found on Oregon white oak. Oregon white oak is the principal host for *P. cerasana,* an introduced leafroller causing sporadic defoliation that is now maintaining a relatively high population and slowly extending its range around Victoria, BC (17). Many gall wasps are found on oaks; those prominent on Oregon white oak include *Andricus californicus,* which forms large, persistent, applelike galls on twigs; *Bassettia ligni,* which causes seedlike galls under the bark of branches that often girdle and kill the branch; *Besbicus mirabilis,* which forms mottled, spherical galls on the underside of leaves; and *Neuroterus saltatorius,* which forms mustard-seed-like galls on lower leaf surfaces that drop in the fall and jump around like Mexican jumping beans caused by activity of the enclosed larvae *(18,23).*

Only incidental damage by animals has been noted on vegetative parts of Oregon white oak. Douglas squirrels and western gray squirrels sometimes debark small branches infested by gall wasp larvae (64). Damage is scattered and may involve as much as one-fourth of a tree's crown. Gophers and other burrowing animals, which are abundant on forest borders, damage some roots. Livestock inflict some trampling and feeding damage on young oaks.

Special Uses

The wood of Oregon white oak is dense, with specific gravity ranging from 0.52 to 0.88 when ovendry *(66),* has moderate strength in static bending tests, but does not absorb shocks well (47). It rates high in compression and shear strength and is outstanding among 20 northwestern woods in tension and side hardness tests (47). The heartwood is at least as durable as that of white oak *(Quercus alba)* (58). Pallets made from Oregon white oak compare favorably in strength with those made from other species (66) and are higher in withdrawal resistance for nails or staples (41).

Specialty items, fenceposts, and fuel are now the primary uses of Oregon white oak. The wood is considered one of the best fuels for home heating and commands top prices. It has been used for flooring, interior finish, furniture, cooperage staves, cabinet stock, insulator pins, woodenware, novelties, baskets, handle stock, felling wedges, agricultural implements, vehicles, and ship construction *(60).* Consumption of Oregon white oak totaled 12 454 m^3 (2,185,000 fbm) exclusive of fuel in 1910 but has since declined (60).

Although Oregon white oak is not grown commercially for landscape purposes, scattered native trees, groves, and open stands are highly valued scenic assets in wildland, farm, park, and urban areas *(35,42,49,56).* Mistletoe is a scenic growth on Oregon white oaks that is collected and sold as a decorative and festive minor product.

Until recent times, meal or mush made from acorns of many oaks (including Oregon white oak) was a common Indian food *(35,71,81).* When crops were heavy, white oak acorns were also gathered and stored by local ranchers for feed, mainly for hogs. Livestock forage for acorns and prefer those of white oaks to black oaks (81). The leaves have a protein content of 5 to 14 percent *(35,56),* and Oregon white oak is rated as good to fair browse for deer but poor for domestic livestock.

Oregon white oak woodlands and forests provide favorable habitat for wildlife (6) and also produce substantial amounts of forage for sheep and cattle (33). Infrequently, cattle are poisoned by foraging on oak; one instance involving Oregon white oak has been documented (37).

Oak-dominated forests in the western part of the Willamette Valley in Oregon have a higher diversity of birds in all seasons than adjacent conifer forests (3). Oregon white oak and ponderosa pine-Oregon white oak associations are preferred brood habitats for Merriam's wild turkey in south-central Washington (39).

Greenhouse experiments have shown that Oregon white oak is a good host for the gourmet truffle, *Tuber melanosporum* (43). The feasibility of managing Oregon white oak stands for truffle production, as many oak stands are managed in Europe, is being investigated.

Genetics

Though Oregon white oak populations in Washington are disjunct and scattered, the chemical and morphological characteristics of their foliage are similar *(71).* Genetic differences appear so minor that seed distribution from a common source by Indians has been postulated. Ecotypic variation was observed in top and root growth of young seedlings from seed collections made from Corvallis, OR, southward (43). First-year seedlings from northern sources were taller and heavier.

Quercus garryana hybridizes naturally with four other oaks. *Quercus x subconvexa* Tucker *(Q. durata x garryana),* a small tree found in Santa Clara and Marin Counties, CA, is noteworthy because of its

morphologically dissimilar parents-Q. *garryana* is a deciduous tree, *Q. duratu* an evergreen shrub, and the hybrid is tardily deciduous *(74). Quercus x howellii* Tucker *(Q. dumosu x garryana)* is also a small tree found in Marin County and a hybrid between a deciduous tree and an evergreen or tardily deciduous shrub or tree. *Quercus x eplingii C.* H. Muller *(Q. douglasii x garryana)*, a tree with deciduous leaves, is found in Lake and Sonoma Counties, CA *(75)*. Hybrids between Q. *gurryuna* and *Q. lobata* are also found in Sonoma County (4).

Literature Cited

1. Allwine, G., B. Lamb, and H. Westberg. 1985. Application of atmospheric tracer techniques for determining biogenic hydrocarbon fluxes from an oak forest. p. 361-382. *In* Hutchison, B. A., and B. B. Hicks, eds. The Forest-Atmosphere Interaction: Proceedings of the Forest Environmental Measurements Conference, Oak Ridge, Tennessee, October 13-28, 1983. D. Reidel Publishing Company.
2. American Forestry Association. 1945. Report on American big trees. American Forests 51(1):30–36.
3. Anderson, Stanley H. 1972. Seasonal variations in forest birds of western Oregon. Northwest Science 46(3):194–206.
4. Barnhardt, Stephen J. 1981. Personal correspondence. Santa Rosa Junior College, Santa Rosa, CA.
5. Barnhardt, Stephen J., Joe R. McBride, Carla Cicero, Paul da Silva, and Peter Warner. 1987. Vegetation dynamics of the northern oak woodland. p. 53-58. Plumb, Timothy R., and Norman H. Pillsbury, tech. coords. *In* Proceedings of the Symposium on Multiple-Use Management of California's Hardwood Resources, November 12-14, 1986, San Luis Obispo, California. USDA Forest Service, General Technical Report PSW-100. Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.
6. Barrett, Reginald H. 1980. Mammals of California oak habitats-Management implications. p. 275-291. Plumb, Timothy R., tech. coord. *In* Proceedings of the Symposium on the Ecology, Management, and Utilization of California oaks, June 26-28, 1979, Claremont, California. USDA Forest Service, General Technical Report PSW-44. Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.
7. Bassett, Patricia M., and Daniel D. Oswald. 1981. Timber resource statistics for southwest Washington. USDA Forest Service, Resource Bulletin PNW-91. Pacific Northwest Forest and Range Experiment Station, Portland, OR. 24 p.
8. Bassett, Patricia M., and Daniel D. Oswald. 1981. Timber resource statistics for the Olympic Peninsula, Washington. USDA Forest Service, Resource Bulletin PNW-93, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 31 p.
9. Bassett, Patricia M., and Daniel D. Oswald. 1983. Timber resource statistics for eastern Washington. USDA Forest Service, Resource Bulletin PNW-104. Pacific Northwest Forest and Range Experiment Station, Portland, OR. 32 p.
10. Bolsinger, Charles L. 1988. The hardwoods of California's timberlands, woodlands, and savannas. USDA Forest Service, Resource Bulletin PNW-148. Pacific Northwest Research Station, Portland, OR. 148 p.
11. Broersma, Klaas (Clarence). 1973. Dark soils of the Victoria area, British Columbia. Thesis (M.S.), University of British Columbia, Vancouver. 110 p.
12. Coblentz, Bruce E. 1980. Production of Oregon white oak acorns in the Willamette Valley, Oregon. Wildlife Society Bulletin 8(4):348–350.
13. Cole, David. 1977. Ecosystem dynamics in the coniferous forest of the Willamette Valley, Oregon, U.S.A. Journal of Biogeography 4(2):181–192.
14. Davidson, Roy M., Jr. 1976. Anthracnose of native oaks. Washington State University Cooperative Extension Service, E.M. 3027 (rev). Pullman. 2 p.
15. Detling, LeRoy E. 1961. The chaparral formation of southwestern Oregon, with considerations of its postglacial history. Ecology 42(2):348–357.
16. Detling, LeRoy E. 1968. Historical background of the flora of the Pacific Northwest. University of Oregon Museum of Natural History, Bulletin 13. Eugene. 57 p.
17. Evans, David. 1970. Life history and immature stages of *Pandemis cerasana* (Lepidoptera: Tortricidae). The Canadian Entomologist 102(12):1597–1603.
18. Evans, David. 1972. Alternate generations of gall cynipids (Hymenoptera: Cynipidae) on Garry oak. The Canadian Entomologist 104(11):1805–1818.
19. Evans, David. 1985. Annotated checklist of insects associated with Garry oak in British Columbia. Canadian Forestry Service, Information Report BC-X-262. Pacific Forest Research Centre, Victoria, BC. 36 p.
20. Eyre, F. H., ed. 1980. Forest cover types of the United States and Canada. Society of American Foresters, Washington, DC. 148 p.
21. Farrenkopf, Thomas 0. 1982. Forest statistics for eastern Oregon, 1977. USDA Forest Service, Resource Bulletin PNW-94. Pacific Northwest Forest and Range Experiment Station, Portland, OR. 28 p.
22. Franklin, J. F. 1972. Maple Knoll, Pigeon Butte, and Willamette Floodplain Research Natural Areas. *In* Federal Research Natural Areas in Oregon and Washington: a guidebook for scientists and educators. p. MA-l to MA-5, p. PI-l to PI-5, and p. WP-1 to WP-5. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.
23. Furniss, R. L., and V. M. Carolin. 1977. Western forest insects. U.S. Department of Agriculture, Miscellaneous Publication 1339. Washington, DC. 654 p.
24. Ganders, Fred R. 1977. Spring wild flowers of the Gulf Islands. Davidsonia 8(2):17–23.
25. Gedney, Donald R., Patricia M. Bassett, and Mary A. Mei. 1986. Timber resource statistics for non-federal forest land in northwest Oregon. USDA Forest Service, Resource Bulletin PNW-140. Pacific Northwest Research Station, Portland, OR. *26* p.
26. Gedney, Donald R., Patricia M. Bassett, and Mary A. Mei. 1986b. Timber resource statistics for non-federal forest land in southwest Oregon. USDA Forest Service, Resource Bulletin PNW-138. Pacific Northwest Research Station, Portland, OR. 26 p.

27. Gedney, Donald R., Patricia M. Bassett, and Mary A. Mei. 1987. Timber resource statistics for non-federal forest land in west-central Oregon. USDA Forest Service, Resource Bulletin PNW-143. Pacific Northwest Research Station, Portland, OR. 26 p.
28. Glendenning, R. 1944. The Garry oak in British Columbia-an interesting example of discontinuous distribution. The Canadian Field-Naturalist 58(2):61–65.
29. Griffin, James R., and William B. Critchtield. 1972. The distribution of forest trees in California. USDA Forest Service Research Paper PSW-82 (reprinted with supplement, 1976). Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. 118 p.
30. Habeck, James R. 1961. The original vegetation of the mid-Willamette Valley, Oregon. Northwest Science 35(2):65–77.
31. Habeck, James R. 1962. Forest succession in Monmouth township, Polk County, Oregon since 1850. Montana Academy of Sciences Proceedings 21:7–17.
32. Hall, F. C. 1972. Mill Creek Research Natural Area. *In* Federal Research Natural Areas in Oregon and Washington: a guidebook for scientists and educators. p. ML-1 to ML–4. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.
33. Hall, F. C., D. W. Hedrick, and R. F. Keniston. 1959. Grazing and Douglas-fir establishment in the Oregon white oak type. Journal of Forestry 57(2):98–103.
34. Hornibrook, E. M., R. W. Larson, J. J. Van Akkeren, and A. A. Hasel. 1950. Board-foot and cubic-foot volume tables for some California hardwoods. USDA Forest Service, Forest Research Notes 67. California Forest and Range Experiment Station, Berkeley. 31 p.
35. Jepson, Willis Linn. 1910. The silva of California. Memoirs of the University of California. vol. 2. The University Press, Berkeley. 480 p.
36. Johannessen, Carl L., William A. Davenport, Artimus Millet, and Steven McWilliams. 1971. The vegetation of the Willamette Valley. Association of American Geographers, Annals 61(2):286–302.
37. Kasari, Thomas R., Erwin G. Pearson, and Bruce D. Hultgren. 1986. Oak (Quercus *garryana)* poisoning of range cattle in southern Oregon. The Compendium on Continuing Education for the Practicing Veterinarian 8(9):F17–18, 20–22, 24, 29.
38. Krygier, James T. 1971. Project completion report on comparative water loss of Douglas-fir and Oregon white oak. Oregon State University Water Resources Research Institute and School of Forestry, Corvallis. 135 p.
39. Mackey, Dennis L. 1986. Brood habitat of Merriam's turkeys in south-central Washington. Northwest Science 60(2):108–112.
40. McCulloch, W. F. 1940. Oregon oak-tree of conflict. American Forests 46(6):264–266, 286, 288.
41. McLain, Thomas E., and E. George Stern. 1978. Withdrawal resistance of pallet nails and staples in five western woods. Virginia Polytechnic Institute and State University Wood Research and Wood Construction Laboratory, Report 155. Blacksburg. 11 p.
42. McMinn, R. G., S. Eis, H. E. Hirvonen, and others. 1976. Native vegetation in British Columbia's capital region. Canadian Forestry Service, Report BC-X-140. Victoria, BC. 18 p.
43. Michaels, Thomas J. 1981. Personal communication. Oregon State University, Corvallis.
44. Morris, William G. 1934. Forest fires in western Oregon and western Washington. Oregon Historical Quarterly 35(4):313–339.
45. National Oceanic and Atmospheric Administration. 1979. Climatological data, 1979 annual summary, 83(13) California, 85(13) Oregon, 83(13) Washington. National Climatic Center, Asheville, NC.
46. Olson, David F., Jr. 1974. Quercus L. Oak. *In* Seeds of woody plants in the United States. p. 692-703. C. S. Schopmeyer, tech. coord. U.S. Department of Agriculture, Agriculture Handbook 450. Washington, DC.
47. Packee, Edmond Charles. 1976. An ecological approach toward yield optimization through species allocation. Thesis (Ph.D.), University of Minnesota. St. Paul. 740 p.
48. Patillo, Greg. 1981. Personal correspondence. Silvaseed Co., Roy, WA.
49. Peattie, Donald Culross. 1953. A natural history of western trees. Houghton Mifflin, Boston, MA. 751 p.
50. Peck, Morton Eaton. 1941. A manual of the higher plants of Oregon. Binfords and Mort, Portland, OR. 866 p.
51. Reed, Lois J., and Neil G. Sugihara. 1987. Northern oak woodlands-ecosystem in jeopardy or is it already too late? p. 59-63. *In* Plumb, Timothy R., and Norman H. Pillsbury, tech. coords. Proceedings of the Symposium on Multiple-Use Management of California's Hardwood Resources, November 12-14, 1986, San Luis Obispo, California. USDA Forest Service, General Technical Report PSW-100. Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. 462 p.
52. Roy, D. F. 1955. Hardwood sprout measurements in northwestern California. USDA Forest Service, Forest Research Notes 95. California Forest and Range Experiment Station, Berkeley. 6 p.
53. Ruffner, James A. 1978. Climates of the States. vols. 1 and 2, sections for California, Oregon, and Washington. Gale Research Company, Detroit, MI.
54. Saenz, Loretta, and J. 0. Sawyer, Jr. 1986. Grasslands as compared to adjacent *Quercus garryana* woodland understories exposed to different grazing regimes. Madroño 33(1):40–46.
55. Sakai, A., and C. J. Weiser. 1973. Freezing resistance of trees in North America with reference to tree regions. Ecology 54(1):118–126.
56. Sampson, Arthur W., and Beryl S. Jespersen. 1963. California range brushlands and browse plants. University of California Extension Service, Manual 33. Berkeley. 162 p.
57. Sargent, Charles Sprague. 1895. The silva of North America. vol. 8. Houghton Mifflin, Boston, MA. 190 p.
58. Scheffer, Theodore C., George H. Englerth, and Catherine G. Duncan. 1949. Decay resistance of seven native oaks. Journal of Agricultural Research 78(5/6):129–152.
59. Shaw, Charles Gardener. 1973. Host fungus index for the Pacific Northwest-l. Hosts. Washington Agricultural Experiment Station, Bulletin 765. Pullman. 121 p.
60. Silen, Roy R. 1958. Silvical characteristics of Oregon white oak. USDA Forest Service, Silvical Series 10. Pacific Northwest Forest and Range Experiment Station, Portland, OR. 13 p.

61. Smith, John E. 1949. Natural vegetation in the Willamette Valley, Oregon. Science 109(2820):41–42.
62. Smith, Winston Paul. 1985. Plant associations within the interior valleys of the Umpqua River Basin, Oregon. Journal of Range Management 38(6):526–530.
63. Sprague, F. LeRoy, and Henry P. Hansen. 1946. Forest succession in the McDonald Forest, Willamette Valley, Oregon. Northwest Science 20(4):89–98.
64. Stein, William I. 1981. Personal observations. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, Corvallis, OR.
65. Stein, William I., Paul E. Slabaugh, and A. Perry Plummer. 1974. Chapter V. Harvesting, processing, and storage of fruits and seeds. *In* Seeds of woody plants in the United States. p. 98-125. C. S. Schopmeyer, tech. coord. U.S. Department of Agriculture, Agriculture Handbook 450. Washington, DC.
66. Stern, E. George. 1978. Performance of warehouse and exchange pallets made of six western woods. Virginia Polytechnic Institute and State University Wood Research and Wood Construction Laboratory, Report 156. Blacksburg. ***48*** p.
67. Stoutamire, Warren Petrie. 1951. The deciduous oak woodland association of the Pacific Northwest. Thesis (MS.), University of Oregon, Eugene. 25 p.
68. Sudworth, George B. 1908. Forest trees of the Pacific slope. U.S. Department of Agriculture, Washington, DC. 441 p.
69. Sugihara, Neil G., and Lois J. Reed. 1987. Prescribed fire for restoration and maintenance of Bald Hills oak woodlands. p. 446-451. *In* Plumb, Timothy R., and Norman H. Pillsbury, tech. coords. Proceedings of the Symposium on Multiple-Use Management of California's Hardwood Resources, November 12-14, 1986, San Luis Obispo, California. USDA Forest Service, General Technical Report PSW-100. Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. 462 p.
70. Sugihara, Neil G., Lois J. Reed, and James M. Lenihan. 1987. Vegetation of the Bald Hills oak woodlands, Redwood National Park, California. Madroño 34(3):193–208.
71. Taylor, Ronald J., and Theodore R. Boss. 1975. Biosystematics of ***Quercus garryana*** in relation to its distribution in the State of Washington. Northwest Science 49(2):49–57.
72. Thilenius, John Fredrick. 1964. Synecology of the white-oak (***Quercus garryana*** Douglas) woodlands of the Willamette Valley, Oregon. Thesis (Ph.D.), Oregon State University, Corvallis. 151 p.
73. Thilenius, John F. 1968. The ***Quercus garryana*** forests of the Willamette Valley, Oregon. Ecology 49(6):1124–1133.
74. Tucker, John M. 1953. Two new oak hybrids from California. Madroño 12(4):119–127.
75. Tunison, John Timothy. 1973. A synecological study of the oak-dominated communities of Bennett Mountain, Sonoma County, California. Thesis (M.A.), California State College—Sonoma, Rohnert Park. 143 p.
76. Twisselmann, Ernest C. 1967. A flora of Kern County, California. The Wasmann Journal of Biology 25(1 & 2):1–395.
77. U.S. Department of Commerce. 1964. Climatic summary of the United States-supplement for 1951 through 1960. Climatography of the United States. 86-4, California; 86-31, Oregon; 86-39, Washington. Washington, DC.
78. 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. Ecological Monographs 34(2):167–215.
79. Whittaker, R. H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30(3):279–338.
80. Witt, Joseph A. 1979. Ancient madrona and a stand of Garry oaks in Seattle. University of Washington Arboretum Bulletin 42(1):8–10.
81. Wolf, Carl B. 1945. California wild tree crops. Rancho Santa Ana Botanic Garden, Santa Ana Canon, Orange County, CA. ***66*** p.