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Foothill Oak Woodlands of the Interior Valleys of Southwestern Oregon

Abstract

We describe the vegetation of the Oregon white oak woodlands found on foothills in the interior valleys of southwestern Oregon. Reconnaissance plots were used to sample the vegetation. Cluster and gradient analyses were used to identify community types, examine relationships between community types, and relate community composition to the environment. Five community types were recognized from a data set of 53 plots. Four of these community types were ordered along a precipitation gradient, while the fifth occurred on ridge lines and rock outcrops. Floristic composition and structure of these woodlands have been disturbed by fire suppression, livestock grazing, introduction of alien species, and firewood harvest. Without changes in land management, the oak woodlands characteristic of southern Oregon will diminish.

Introduction

Low elevations within southwestern Oregon are bounded by oak woodlands, which are transitional to savannas and grasslands. These woodlands are the lower elevation limit for forest vegetation in the region (Waring 1969, Franklin and Dyrness 1973). *Quercus garryana* (Oregon white oak), with a natural range from Vancouver Island to southern California (Griffin and Critchfield 1972), dominates the foothill and valley bottom woodlands. These oak woodlands reflect a climatic transition between mesic lowlands of the Willamette Valley and northwestern Oregon (where *Q. garryana* reaches optimal development), and xeric lowlands within the interior valleys of northern California. This unique environment supports the convergence of taxa common to both California and Pacific Northwest floristic provinces (Stebbins and Major 1965, Raven 1977).

Many bottomland stands were cleared for agriculture. Stands on less fertile upland sites have often been utilized for livestock grazing, and more recently for fuel wood. We assume overstory canopy structure and composition of these sampled stands are near pristine but little is known about original understory species composition. Disturbance from livestock grazing, fire suppression, and wood harvesting have initiated the establishment of non-native herbaceous species that competitively displace many of the native taxa.

The objectives of this study were to: 1) document the major plant community types that occupy these foothill woodlands, determining their composition and structure; and 2) interpret the environmental factors influencing their distribution.

Study Area

The interior region of southwestern Oregon is comprised of the Umpqua and Rogue River watersheds (Figure 1). The area is a complex mixture of valleys, foothills, and mountains. Major mountain ranges border the region on the east, south, and west. The northern edge of the Umpqua River watershed forms the northern boundary. Elevations typically range from 150 to more than 1300 m within the region.

The near-Mediterranean climate is characterized by winter rains and dry, hot summers (Figure 2). Precipitation maps published for the area (Froehlich *et al.* 1982, McNabb *et al.* 1982) show a complex pattern of rainshadow effects, but an overall trend of decreasing precipitation from north to south and from west to east. Roseburg (Figure 2) receives an annual mean of 800 mm of precipitation, while Medford receives on average only 400 mm. The dry season typically lasts five months (May-September). Occasional frosts can occur throughout much of the year, although mean minimum temperature drops below freezing only at the Medford station.

The region overlaps portions of both the Klamath Mountain Province and the Western

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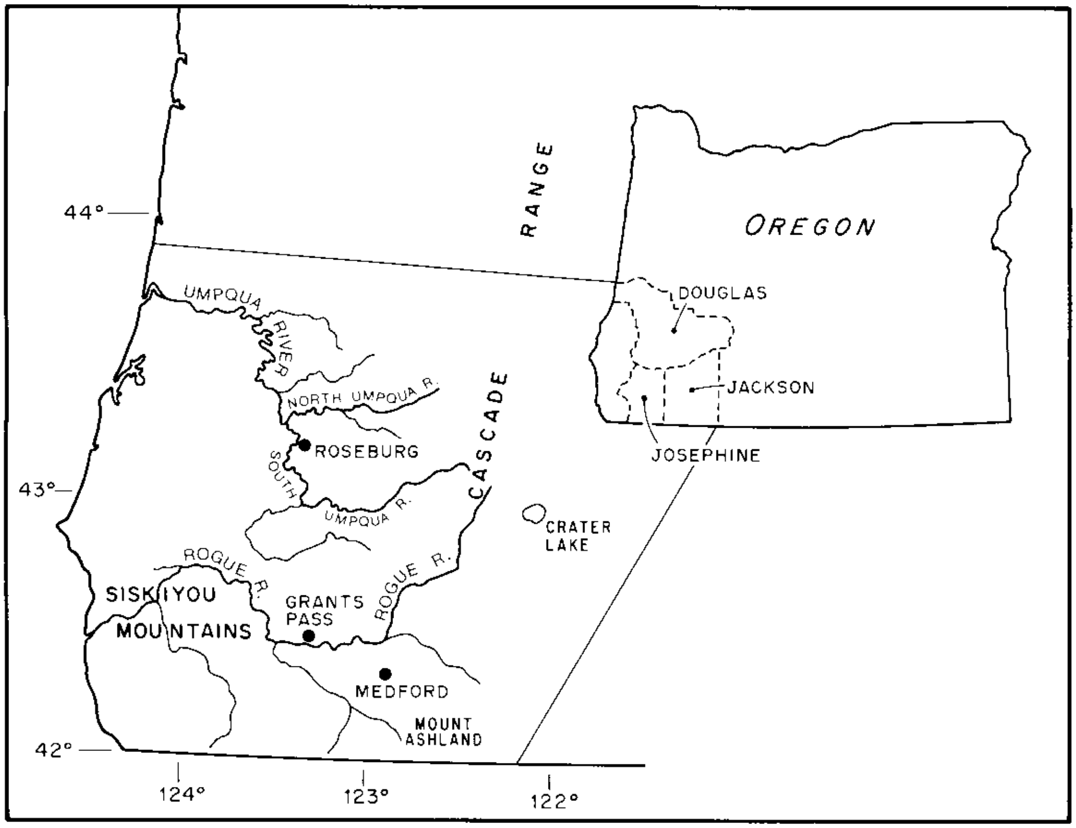

Figure 1. Generalized map of southwestern Oregon, detailing the study area.

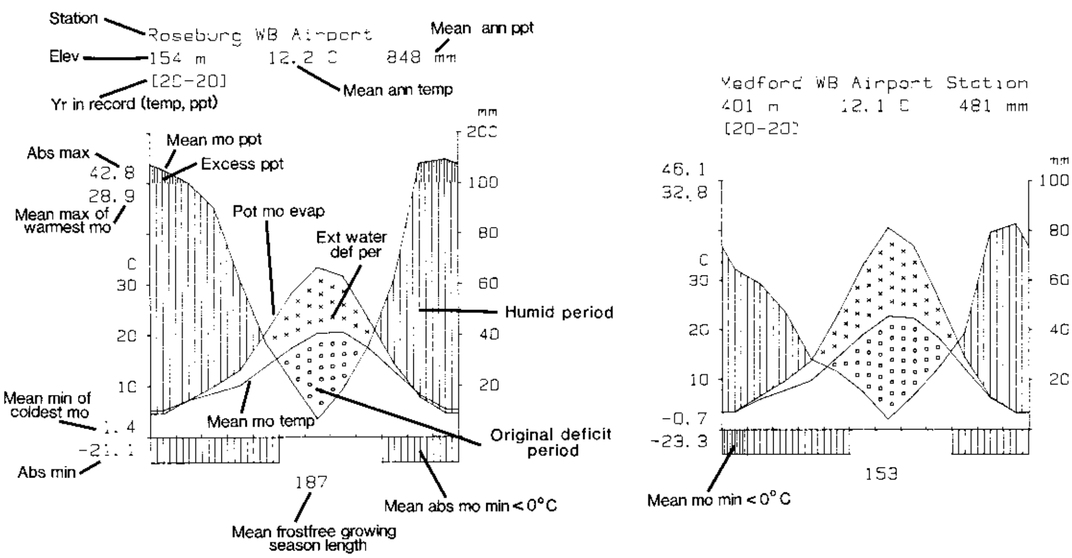

Figure 2. Climate diagrams for Roseburg and Medford, Oregon, patterned after Walter (1985). To better represent the dry season these diagrams were modified to include a potential evapotranspiration curve (Schreiber 1977). Precipitation and temperature data are averages from 1967 to 1987. Extremes are extracted from the whole weather record of more than 100 years for each station. Weather data supplied by K. Redmond, former State Climatologist, Oregon State University.

Cascades Province (Franklin and Dyrness 1973), and is geologically diverse. Important parent materials include tuffs and andesites in the Western Cascades Province and metamorphosed sediments and volcanics, ultramafics, and granitics in the Klamath Mountain Province (Wells and Peck 1961).

Soils are very diverse, with more than 50 series identified (Stearns-Smith and Hann 1986). Soils in the Western Cascade Province are classified as Xerumbrepts or Haplumbrepts, while those in the Klamath Mountain Province fall into a diverse range of suborders related to parent material (Franklin and Dyrness 1973).

Evergreen forests dominate the regional vegetation (Franklin and Dyrness 1973). At lower elevations both evergreen broadleaf species and conifers occur, while at upper montane and subalpine elevations conifers are the sole tree species. Important lower elevation taxa include conifers such as: *Pseudotsuga menziesii* (Douglas-fir), *Abies concolor* (white fir), *Pinus ponderosa* (ponderosa pine), and *Calocedrus decurrens* (incense-cedar) and broadleaf species such as: *Quercus garryana*, *Q. kelloggii* (California black oak), *Arbutus menziesii* (madrone), and *Lithocarpus densiflorus* (tanoak).

Quercus garryana is an important woodland and forest species at lower elevations along valley margins and in the foothills. It may be a codominant with *Q. kelloggii*, for example, or be the exclusive species in woodlands (defined as a community type with trees generally growing in open spacing with a well-developed understory). As a forest tree, it occurs in association with a variety of broadleaf and coniferous taxa.

Methods

Sampling Methods

The fragmented, highly disturbed oak woodland landscape in southwestern Oregon possesses special problems for the development of a vegetation classification. We began by identifying potential sample sites using aerial photographs. Each site was visited and sampled if judged to be suitable. Sample criteria included (1) no visible signs of current or recent livestock grazing; (2) no visible signs of recent fire; (3) presence of a mature overstory with trees at least 100 years old and canopy cover greater than 20 percent (i.e., a woodland or forest); and (4) dominance or codominance of *Q. garryana* in the overstory and seedling and sapling size classes.

Data at each plot were collected using an efficient reconnaissance-oriented method (Franklin *et al.* 1970) similar in many respects to the relevé (Braun-Blanquet 1963). Each plot was representative of the stand with no obvious vegetation discontinuities. A plot consisted of a 500 m^2 circle, within which a complete tally of all vascular plants was made. Projected, relative crown cover was ocularly estimated for each species. In addition, cover for each tree species was estimated in each of five size classes ($<$1.4 m tall; 0 $<$ dbh $<$ 1 dm; 1-3 dm dbh; 3-10 dm dbh; and $>$10 dm dbh). Tree and snag basal area was estimated by prism. General stand composition and structure was described by estimating cover in each of six lifeform strata [moss and lichen, herbaceous, low shrub ($<$0.5 m), tall shrub ($>$0.5 m), reproduction (trees $<$3 m), and trees greater than 3 m]; counting species in all strata except mosses and lichens; estimating relative cover of litter; and measuring the height of a stand dominant. Nomenclature follows Munz (1973) and Hitchcock and Cronquist (1973).

Physical parameters recorded: elevation, aspect, slope, topography (including slope position and horizontal and vertical configuration); and ground cover for loose rock, bedrock, and bare mineral soil surface. Annual and dry season (May-September) precipitation values were interpolated from isohyetal lines for each plot on precipitation maps produced by Froehlich *et al.* (1982) and McNabb *et al.* (1982). A 40 cm soil pit was excavated at each plot to examine the litter layer and upper soil horizons. Litter and soil depth were recorded along with proportions of gravel and stones in the upper 40 cm. Soil pH was assessed using indicator dyes.

Analytical Methods

The principal goal of this study was to identify plant community types by examining vegetation data for cluster pattern. A community type is an abstract unit of vegetation that is defined by physiognomic, floristic and dominance characteristics. All stands assigned to a community type share a similar physiognomy, flora, and relative dominance of component species. The flora, composed of native and non-native taxa, reflect current environmental conditions and may not persist over extended time.

The traditional phytosociological method of identifying community types in a data set is the ordered table (Westhoff and van der Maarel 1978). Several computer programs now exist that automate both the ordering of phytosociological tables and the identification of types within the ordered table. A computer program called TWINSPAN (Two Way INdicator SPecies ANalysis; Hill 1979a) was used initially to cluster the data and identify tentative community types. Indicator species analysis is a type of cluster analysis. TWINSPAN was used because of its speed, efficiency, and ability to handle large data sets. The initial types were subsequently refined using gradient analysis and manual table-sorting techniques. Eight initial types were interpreted from the TWINSPAN results. Examination of the floristic data in ordered tables (program ASSTAB, written by B. Smith), the environment data (elevation, aspect, annual, precipitation, etc.) and the display of data in ordination space resulted in the collapse of the eight initial types into five. These types were judged as being relatively distinct. This process of refining the initial types using manual techniques incorporates judgment of the ecological indicator value of the species involved. This kind of judgment cannot be incorporated into the automated tools that only use the species abundance data. As such, this process becomes more art than science.

Detrended correspondence analysis (DCA), as implemented in the computer program DECORANA (Hill 1979b), was used in community type designation to determine factors influencing community distribution. Ordinations of the individual plot data were used to help refine the classification. Each plot was coded according to the community type to which it was allocated, thereby allowing visual inspection of community type distribution in ordination space. Once community type membership was finalized, ordination of composite data (the average abundance of all species that occur in the individual plot data assigned to a specific community type) examined relationships between types in an attempt to understand the underlying factors controlling the distribution of types. Each type in the final classification was represented by one composite plot. Ordination scores from the composite ordinations were rank correlated, using Kendall's *tau* (Grieg-Smith 1983), with physical variables precipitation (annual and dry season) and elevation to identify potential underlying determinants of vegetation pattern.

Diversity, ubiquity, and similarity patterns were analyzed with AID-N (Overton *et al.* 1987). Richness and dominance were the two components of diversity examined. Richness and dominance were calculated for each plot and then averaged for each community type. Richness, N_1, was simply expressed as number of species (Hill 1973). N_2 was the dominance index used (Hill 1973), and is the reciprocal of Simpson's *lambda* (Hill 1973). Ubiquity refers to a set of measures that index the distribution of individual species across a data set. Two measures of ubiquity were used. The first (U_0) was constancy and the second (U_2) is calculated as:

$$U_{2(i)} = \frac{\left(\sum_j^n p_{ij}\right)^2}{\sum_j^n p_{ij}^2}$$

where n is sample size and P_{ij} is relativized datum for attribute $_i$ on sample-unit $_j$ (Overton *et al.* 1987). This equation is of the same form as N_2 except that the summation occurs across all occurrences of one species, while for N_2 the summation is across all species in one sample unit. U_2 is normally expressed, like constancy, as a percentage of sample size:

$$U_{2(i)} = U_{2(i)} \times \frac{100}{n}$$

where n is sample size.

Results

Fifty-three plots containing a total of 88 species were sampled. The species have the following life-form spectrum: 7 trees, 8 shrubs, and 73 herbs and grasses. The 5 most ubiquitous species (in descending order) are *Q. garryana*, *Cynosurus echinatus* (hedgehog dogtail), *Rhus diversiloba* (poison-oak), *Poa trivialis* (roughstalk bluegrass), and *Bromus carinatus* (California brome) (Table 1).

Elevations range from 160 to 1000 m, with an overall mean of 610 m. Predicted mean annual precipitation ranges from 500 to 1750 mm with a corresponding dry-season rainfall of 100 to 220 mm. Slope inclinations are generally below 30% and have southerly exposures.

Classification

Five community types are recognized using TWINSPAN (Table 1): *Quercus garryana/Bromus*

TABLE 1. Constancy[1] (Con) and characteristic cover[2] (Cov) for selected species[3] by community type. Species ordered alphabetically within growthform strata.

	Quercus garryana									
					Pseudotsuga menziesii					
	Bromus carinatus		*Cynosurus echinatus*		*Festuca ovina*		*Elymus glaucus*		*Cercocarpus montanus*	
Number of plots	17		13		10		10		3	
	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Tree Layer										
Arbutus menziesii	24	14	15	2	50	1	50	7	67	18
Cercocarpus montanus	24	1	–	–	30	T	10	1	100	17
Pinus ponderosa	35	10	31	3	60	5	10	T	67	10
Pseudotsuga menziesii	18	8	15	1	80	7	90	5	33	T
Quercus garryana	100	32	100	38	100	34	100	33	100	52
Quercus kelloggii	18	5	15	8	20	3	30	23	–	–
Tall Shrub Layer										
Ceanothus cuneatus	71	2	46	6	30	5	10	T	100	12
Rhus diversiloba	82	8	85	4	100	4	90	12	–	–
Symphoricarpos albus	24	2	38	T	60	T	20	T	33	T
Low Shrub Layer										
Lonicera hispidula	35	T	8	T	50	1	20	T	33	T
Herb Layer										
Anthriscus scandicina	94	2	85	9	60	3	80	4	33	T
Bromus carinatus	100	12	15	1	30	2	10	T	–	–
Bromus mollis	29	3	54	6	30	10	20	6	–	–
Cynosurus echinatus	82	6	85	20	80	4	90	8	67	T
Dactylis glomerata	–	–	15	8	–	–	70	13	–	–
Daucus pusillus	–	–	–	–	–	–	–	–	67	6
Elymus glaucus	18	1	62	T	60	2	90	7	67	T
Festuca myuros	–	–	8	20	–	–	–	–	–	–
Festuca pratensis	12	T	38	8	10	T	10	5	–	–
Festuca occidentalis	6	1	–	–	20	20	50	12	33	T
Festuca ovina	53	9	8	5	70	10	–	–	–	–
Marah oreganus	6	T	8	T	10	T	–	–	67	12
Poa trivialis	65	7	54	7	60	6	30	7	33	T
Pteridium aquilinum	–	–	–	–	–	–	10	T	33	35
Sanicula graveolins	82	T	23	T	60	T	90	T	–	–

[1]Occurrences expressed as percent of sample size. A dash indicates an absent species.
[2]Cover averaged over number of occurrences. 'T' represents trace values of less than 0.5%. A dash indicates an absent species.
[3]Either constancy greater than 45% and characteristic cover greater than 5% or an occurrence with cover greater than 15%.

carinatus, *Quercus garryana-Pseudotsuga menziesii/Elymus glaucus* (blue wildrye), *Quercus garryana/Cynosurus echinatus*, *Quercus garryana-Pseudotsuga menziesii/Festuca ovina* (sheep fescue), and *Quercus garryana-Cercocarpus montanus* (=*C. betuloides*) (birchleaf mountain mahogany). Floristic differences between community types are subtle, due to the widespread prevalence and dominance of naturalized taxa. *Quercus garryana* dominates or codominates with *Pseudotsuga* the overstory and reproductive layers (seedlings and saplings) of these stands. The understory is generally dominated by grasses and forbs with a minor shrub component. Each community type is briefly described below in reference to the information contained in Tables 1, 2, and 3.

The *Quercus garryana/Bromus carinatus* (QUGA/BRCA) community type occurs on flat to convex, mid- and upper-slope positions below 1000 m elevation. This is the driest community type, with an average annual precipitation of less than 640 mm. *Quercus garryana* dominates the

TABLE 2. Estimates of mean and standard deviation ( ) for selected physical, environmental, and soil variables by community type.

	Quercus garryana									
					Pseudotsuga menziesii					
	Bromus carinatus		*Cynosurus echinatus*		*Festuca ovina*		*Elymus glaucus*		*Cercocarpus montanus*	
Number of plots	17		13		10		10		3	
Site variables										
Elevation (m)	667	(159)	596	(176)	607	(313)	484	(150)	702	(215)
Slope (%)	17	(10)	16	(20)	13	(6)	26	(14)	43	(26)
Aspect (deg)[1]	31	(0.27)	162	(0.64)	267	(0.20)	229	(0.50)	146	(0.87)
Annual precip. (mm)[2]	640	(40)	780	(380)	850	(220)	1160	(240)	890	(220)
Dry season precip. (mm)[2]	100	(10)	130	(40)	130	(20)	140	(20)	40	(-)
Soil surface and profile variables										
Rock cover (%)	5	(12)	6	(10)	3	(9)	0.1	(0.3)	0.7	(0.5)
Bare soil cover (%)	0.5	(1)	3	(6)	2	(5)	3	(6)	0	(0)
Litter cover (%)	26	(39)	50	(42)	45	(41)	26	(41)	38	(53)
Litter depth (cm)	1.6	(0.8)	1.2	(0.4)	1.4	(0.7)	1.3	(0.5)	4	(1)
Acidity (pH)[3]	6.5	(0.4)	6.4	(0.4)	6.4	(0.6)	6.1	(0.5)	6.1	(0.5)
Coarse fragments (%)[4]	26	(31)	8	(13)	6	(6)	5	(6)	47	(8)
Depth (cm)[5]	5 to > 40		2 to > 40		13 to > 40		20 to 40		>40	

[1]The estimates for aspect are mean and 'r' which is a measure of concentration about the mean aspect (Batschlet 1981) and has a range of 0 to 1. An 'r' value of 1.0 indicates all measures are identical.

[2]Precipitation values for each plot were interpolated from isohyetalines using annual (Froehlich *et al.* 1982) and dry season, May-September (McNabb *et al.* 1982) precipitation maps.

[3]pH of the first 20 cm of the top mineral horizon.

[4]Percent of first 40 cm of the uphill soil pit surface occupied by coarse fragments (gravel and larger).

[5]Depth expressed only as a range.

overstory. Other overstory species all have less than 35% constancy. The understory is characterized by a sparse shrub layer set in a grass-dominated herbaceous layer. Five of the 11 most common species in the herbaceous layer are grasses. Important herbaceous taxa include *Bromus, Anthriscus scandicina* (bur beakchervil), *Cynosurus, Sanicula graveolens* (sanicle), and *Brodiaea pulchella* (purplehead brodiaea). Common shrubs include *Rhus* and *Ceanothus cuneatus* (wedgeleaf ceanothus).

The *Quercus garryana/Cynosurus echinatus* (QUGA/CYEC) community type occurs at low elevations ($\bar{x}$ = 596 m) on a variety of topographic positions with 780 mm of annual precipitation. *Quercus garryana* dominates the overstory with few other tree species present. *Cynosurus* is the dominant understory species in this type. Two other annuals, *Anthriscus* and *Bromus mollis* (soft brome), are relatively important.

The *Quercus garryana-Pseudotsuga menziesii/ Festuca ovina* (QUGA-PSME/FEOV) community type occurs primarily on valley bottom or toe-slope positions below 1000 m elevation. Annual precipitation (850 mm) is the average for the woodlands we examined. *Quercus garryana* and *Pseudotsuga* codominate the overstory and reproductive layers. The sparse understory is characterized by low cover of *Rhus*, and either *F. ovina*, or *F. occidentalis* (western fescue). Other common taxa include *Cynosurus, Symphoricarpos albus* (white snowberry), and *Osmorhiza chilensis* (sweet cicely).

The *Quercus garryana-Pseudotsuga menziesii/ Elymus glaucus* (QUGA-PSME/ELGL) community type is the most mesic of the types examined, with the highest annual and dry season precipitation (1160 and 140 mm, respectively). This type occurs at the lowest elevations (484 m) of the five community types. The overstory is characterized by an open canopy of *Q. garryana* with occasional *Q. kelloggii. Pseudotsuga* is rarely present in the overstory but small numbers are present consistently in the reproductive layers. The understory contains a patchy and variable cover of *Rhus* and

TABLE 3. Mean and standard deviation ( ) of structural components by community type.

	Quercus garryana									
					Pseudotsuga menziesii					
	Bromus carinatus		*Cynosurus echinatus*		*Festuca ovina*		*Elymus glaucus*		*Cercocarpus montanus*	
Number of plots	17		13		10		10		3	
Physical structure										
Basal area (m^2 ha^{-1})	18	(9)	28	(13)	23	(10)	27	(12)	38	(28)
Height (m)[1]	11	(5)	11	(3)	20	(11)	20	(9)	–	–
Cover by layer										
Tree overstory	37	(18)	40	(17)	41	(14)	44	(9)	68	(20)
Tree reproduction	4	(6)	1	(1)	1	(1)	2	(3)	7	(11)
Tall shrub	6	(8)	5	(7)	5	(5)	11	(14)	0	(0)
Low shrub	6	(11)	3	(10)	2	(4)	0.4	(1)	18	(13)
Herbaceous	41	(18)	43	(15)	32	(16)	45	(14)	48	(36)
Moss and lichen	3	(7)	1	(1)	0.4	(.6)	4	(9)	0.1	(.1)
Average richness by layer[2]										
Tree (total)	2.1	(1.3)	1.9	(1.0)	3.7	(1.6)	3.4	(0.7)	4.3	(1.5)
Tall shrub	1.4	(1.2)	2.3	(1.2)	2.5	(1.1)	1.8	(1.2)	0.0	(0.0)
Low shrub	1.6	(1.5)	0.4	(0.7)	1.3	(1.5)	1.0	(0.8)	1.7	(1.2)
Herbaceous	21.2	(8.5)	12.8	(4.1)	16.6	(6.9)	19.5	(7.6)	17.3	(8.3)
Total	26.5	(8.7)	17.5	(5.5)	24.1	(9.6)	25.7	(8.0)	23.3	(8.0)
Average N_2 diversity by layer[2]										
Tree (total)	1.4	(0.7)	1.1	(0.5)	1.5	(0.6)	1.6	(0.4)	2.0	(0.6)
Tall shrub	1.1	(0.9)	1.3	(0.5)	1.5	(0.6)	1.1	(0.9)	0.0	(0.0)
Low shrub	1.0	(1.0)	0.3	(0.5)	0.9	(0.9)	0.8	(0.6)	1.0	(0.0)
Herbaceous	3.5	(1.6)	3.1	(1.0)	3.7	(2.5)	4.5	(1.3)	2.2	(1.0)
Total	4.4	(1.7)	3.7	(1.7)	4.0	(1.8)	4.9	(1.0)	3.9	(0.4)

[1]Average number of species per 500 m^2 plot. The tree layer includes species in both overstory and reproduction.
[2]Average N_2 diversity per 500 m^2 plot. The tree layer includes species in both overstory and reproduction.

a dense matrix of grasses and forbs. Common herbs and grasses include *Elymus*, *Cynosurus*, *Dactylis glomerata* (orchardgrass), and *Anthriscus*.

The *Quercus garryana-Cercocarpus montanus* (QUGA-CEMO) community type is a rare type that appears to be restricted to ridges and rock outcrops at higher elevations ($\bar{x}$ = 702 m) and is restricted to soils on sites with nearly double the coarse fragment content of the other plant community types we describe. Dry season precipitation (40 mm) is the lowest of all community types, although annual precipitation (890 mm) values are average for the five community types. *Quercus garryana* and *Cercocarpus* are the most abundant components of the dense overstory. The understory is typically sparse and patchy. Shrubs are uncommon, except for small amounts of *Rhus*. Typical herbs include *Marah oreganus* (Oregon bigroot), *Daucus pusillus* (rattlesnake weed), *Eriophyllum lanatum* (wooly eriophyllum), and *Galium aparine* (catchweed bedstraw).

Relationships

The eigenvalues of the four axes of the composite ordination, as calculated by DECORANA were (in order) 0.417, 0.158, 0.004, and 0.000 (Figure 3). The relative magnitudes of the axes lead us to interpret only the first two and ignore axes 3 and 4. The first axis separates the QUGA-CEMO community type from the other four types and reflects the floristic differences between this community type and the others. The second axis of the ordination appears to order the community types from relatively moist (low scores) to relatively dry (high scores). The QUGA/BRCA community type,

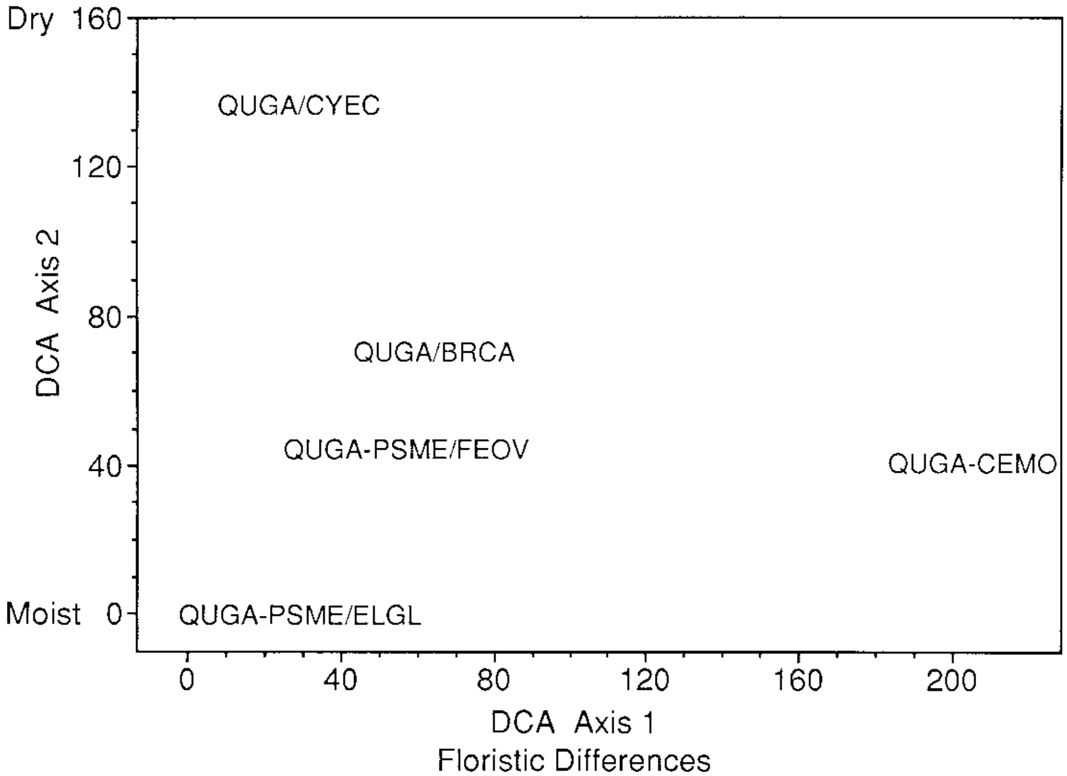

Figure 3. Detrended correspondence analysis (DCA) ordination of composite sample-units. Acronyms for the community types are: QUGA/CYEC, *Quercus garryana/Cynosurus echinatus;* QUGA/BRCA, *Quercus garryana/Bromus carinatus;* QUGA-PSME/FEOV, *Quercus garryana-Pseudotsuga menziesii/Festuca ovina;* QUGA-PSME/ELGL, *Quercus garryana-Pseudotsuga menziesii/Elymus glaucus;* and QUGA-CEMO, *Quercus garryana/Cercocarpus montanus.*

however, does occur in sites with lower precipitation than the QUGA/CYEC type (Figure 3). Results of the rank correlation (Kendall's *tau*) between axis 2 scores and average annual precipitation (γ = 0.8) reinforces this interpretation. To further pursue the role of relative moisture in defining vegetation patterns within these woodlands we rank correlated ordination scores from a data set of original plot data (minus the QUCA-CEMO community type plots) with annual and dry season precipitation values. Correlations with the first axis scores from this ordination were $\gamma = 0.73$ and $\gamma = 0.63$, respectively.

The similarity matrix (Table 4), also based on composite plot data, illustrates the subtle differences between types, as few strong differences are visible. Only QUGA-CEMO has any dissimilarities with the other types.

TABLE 4. Percentage similarity[1] among composite sample-units for each community type.

	BRCA[2]	CYEC	FEOV	ELGL	CEMO
BRCA	100				
CYEC	59	100			
FEOV	63	49	100		
ELGL	44	41	42	100	
CEMO	48	31	42	28	100

[1]Similarity values were derived using AID-N analysis (Overton *et al.* 1987).

[2]BRCA – *Quercus garryana/Bromus carinatus* community type

CYEC – *Quercus garryana/Cynosurus echinatus* community type

FEOV – *Quercus garryana-Pseudotsuga menziesii/Festuca ovina* community type

ELGL – *Quercus garryana-Pseudotsuga menziesii/Elymus glaucus* community type

CEMO – *Quercus garryana-Cercocarpus montanus* community type

Structure

The four community types influenced by the precipitation gradient show some segregation in productivity. The drier QUGA/BRCA and QUGA/CYEC community types have maximum *Q. garryana* heights of 11 m compared to the mesic QUGA-PSME/FEOV and QUGA-PSME/ELGL types, where heights are closer to 20 m (Table 2). Cover by layer, richness, and diversity show little difference between types. The only marked exception is richness and diversity for the QUGA-CEMO type, which exhibit the lowest values of all types.

Discussion

Precipitation appears to be the key environmental factor governing distribution of *Q. garryana* woodland community types in southwestern Oregon. The significant rank correlations between ordination scores and precipitation values at both the individual plot scale and the community type scale strongly indicate that annual precipitation is a dominant factor in the distribution and composition of these woodlands.

The QUGA/ELGL community type receives the highest overall precipitation, has the highest diversity, and appears to have an understory with the smallest component of naturalized taxa. QUGA/CYEC, the second driest community type, has the largest number of introduced species. This type may represent several historic community types that have lost their distinctiveness due to past disturbances and the presence of highly competitive non-native annual grasses. *Cynosurus echinatus,* a non-native annual grass of low value that thrives in semi-moist soils under oaks, also indicates range deterioration and is common throughout these woodlands (Crampton 1974).

Quercus garryana is considered a climax species on xeric sites (Whittaker 1960, Atzet and Wheeler 1982). A long history of disturbance from livestock grazing, fire suppression, and fuel wood harvest has created an understory currently dominated by non-native annuals. With the dominance of early seral understory taxa, much of which is non-native, differentiating plant associations becomes difficult in an ecosystem that was dominated by late seral and climax perennials.

Relationship to Other Woodlands

Southwestern Oregon *Q. garryana* woodlands ecologically and floristically appear to be transitional from those of the Willamette Valley of northwestern Oregon and the Scott and Shasta valleys of northern California (Griffin 1977). The community types found in southwestern Oregon receiving less than 1000 mm annual precipitation are more like those occurring in northern California. The QUGA-PSME/ELGL type is more similar to Willamette Valley woodland types.

Thilenius (1968) described *Quercus/Rhus* on the most xeric sites in the Willamette Valley, from southern and western aspects of mid to upper slopes (0-20%). *Elymus* and *Cynosurus* were present in the understory. To the southwest, Sugihara *et al.* (1987) describe *Q. garryana* woodlands on Bald Hills in Redwood National Park, northwestern California. They also describe a xeric *Quercus/Cynosurus* community type which occurred on convex, southerly aspects and was the most heavily disturbed by grazing.

Woodlands that are most similar to those found in southwestern Oregon are from the interior valleys of the Umpqua River Basin. Atzet and McCrimmon (1990) describe a *Quercus garryana/ Fragaria vesca* var. *bracteata* plant association that occurs on valley floors along the North and South Umpqua Rivers or sites with shallow soils ($\bar{x}$ = 23 cm). Smith (1985) describes *Q. garryana* plant communities from a small area near the North Umpqua River. His apparent strategy was to sample all types regardless of age or disturbance. Several types resemble those found in southwestern Oregon including a *Quercus/Rhus/Taeniatherum asperum* (medusahead)/*Cynosusrus* type and a *Quercus/Rhus/Cynosurus* type. Two other *Quercus* dominated types were also listed but differ from those described above due to a dense shrub layer. These include the *Quercus-Arbutus/Rhus/Cynosurus* type, and the *Quercus/Rhus/Dactylis* type.

Fire, Grazing, and Annual Grasses

Fire suppression is a major factor in the dynamics of these woodlands. Most stands we sampled were even-sized trees with few scattered larger individuals and little regeneration. This is consistent with descriptions by early European settlers that fires were frequent in the valleys, thereby maintaining most valley bottomlands and foothills as grasslands or open savannas (Thilenius 1968). Active fire suppression over the last century has converted open savannas and grasslands to woodlands, and initiated the recruitment of conifers (Thilenius 1968). Atzet and McCrimmon (1990) note that fire in oak woodlands in the Umpqua River drainages was frequent prior to suppression. These fires burned with low intensity which confined fire to the woodlands, without entering the adjacent dense forested sites.

Fire eliminates conifer seedlings and affects stem density, form, and species composition of the remaining overstory (Plumb and McDonald 1981). Fire also stimulates coppice regeneration of *Q. garryana*. This form of stand regeneration can be more effective than seedling establishment from acorns (Fowells 1965, Sugihara and Reed 1987).

Livestock grazing in these woodlands has influenced the process of change by damaging or destroying oak sprouts, shrubs, and the native grasses which allowed weedy annual grasses to become established. For example, season-long grazing in the Bald Hills of Redwood National Park lowered species richness by reducing the number of kinds of perennials (Saenz and Sawyer 1986). In addition, cattle avoided grazing *Cynosurus*, no doubt aiding its establishment and dominance in these woodlands (Saenz and Sawyer 1986). Decreasing livestock numbers or protecting these woodlands from grazing may cause an increase in the number of perennial grass species with a concurrent decrease in annual grasses (Hektner *et al.* 1983). *Bromus carinatus*, a native perennial which provides good forage, will increase under slight to moderate disturbance but is susceptible to aggressive competition (Crampton 1974). Some nonnative annuals are such strong competitors that even under complete protection from grazing they can maintain dominance.

Early-season grazing may decrease competition for soil moisture and nutrients between annual grasses and oaks. Early growing winter annuals may germinate in the fall and begin utilization of soil resources following adequate precipitation (Matsuda and McBride 1986, Gordon *et al.* 1989). Replacement of native perennial grasses by annual flora shifts the period of soil water utilization from February through July to February through May (Jackson and Roy 1986, Gordon *et al.* 1989). Competition for soil resources, particularly water, shifts from a primarily spatial pattern to a temporal pattern (Welker and Menke 1987). This may cause seedling suppression in drought years and may account, in part, for the decline in *Q. garryana* regeneration (Reed and Sugihara 1987).

Maintenance of *Q. garryana* woodlands in the landscape will require active management. Prescribed burning or thinning is needed to stimulate coppicing and reduce competition with conifers. Grazing management that emphasizes timing of grazing to coincide with phenology of undesirable annual grasses may promote *Quercus* seedling establishment and favor recruitment of perennial grasses. In the bald hills of northwestern California, concern has heightened as many oak woodlands have succeeded to conifers because of fire suppression (Reed and Sugihara 1987). Additional acreage is continually lost to agriculture and suburban development. Without changes in land management a distinctive feature of southern Oregon's landscape will diminish.

Acknowledgments

We especially thank Jacqueline Greenleaf and Steven Harris for their field work. The Forestry Intensified Research (FIR) program at Oregon State University provided financial support. We thank Tom Atzet, ecologist, and David Wheeler, former associate ecologist, for the Rogue, Siskiyou, and Umpqua National Forests, for sharing their knowledge of southwest Oregon vegetation. Tom Atzet, Paul Doescher, Pam Muick, Neil Sugihara, and two anonymous reviewers provided valuable comments which improved this manuscript. Personnel of the Medford and Roseburg Districts of the USDI Bureau of Land Management provided assistance in locating suitable stands.

Literature Cited

Atzet, T., and L. A. McCrimmon. 1990. Preliminary plant associations of the southern Oregon Cascade Mountain province. USDA For. Serv. Pacific Northwest Region, Siskiyou Nat. For.

Atzet, T., and D. L. Wheeler. 1982. Historical and ecological perspectives on fire activity in the Klamath geologic province of the Rogue River and Siskiyou National Forests. USDA For. Serv. Region 6, Portland, OR R6-Range-102-1982.

Braun-Blanquet, J. 1963. Pflanzensoziologie. Grundzuege der vegetationskunde. 3rd ed. Springer, Wien.

Crampton, B. 1974. Grasses in California. Univ. of Calif. Press, Berkeley.

Fowells, H. A. 1965. Silvics of Forest Trees of the United States. USDA For. Serv. Agric. Handbk. No. 271.

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

Franklin, J. F., C. T. Dyrness, and W. H. Moir. 1970. A reconnaissance method for forest site classification. Shinrin Richi XII:1-14.

Froehlich, H. A., D. H. McNabb, and F. Gaweda. 1982. Average annual precipitation, 1960-1980, in southwest Oregon. Oregon State Univ. Ext. Serv., Corvallis. EM 82:020.

Gordon, D. R., J. M. Welker, J. W. Menke, and K. J. Rice. 1989. Competition for soil water between annual plants and blue oak (*Quercus douglasii*) seedlings. Oecologia 79:533-541.

Grieg-Smith, P. 1983. Quantitative plant ecology. 3rd edition. Univ. of Calif. Press, Berkeley.

Griffin, J. R. 1977. Oak woodlands. *In* M. G. Barbour and J. Major (eds.). Terrestrial vegetation of California. Wiley Interscience, NY. Pp. 384-415.

Griffin, J. R., and W. B. Critchfield. 1972. The distribution of forest trees of California. USDA For. Serv. Res. Pap. PSW-82.

Hektner, M. M., R. W. Martin, and D. R. Davenport. 1983. The Bald Hills prairies of Redwood National Park. *In* C. Van Riper III, L. D. Whittig, and M. L. Murphy (eds.), Proceedings of the first biennial conference of research in California's national parks. Cooperative Park Serv. Studies Unit, Univ. of Calif., Davis. Pp. 70-78.

Hill, M. O. 1973. Diversity and evenness: a unifying notation and its consequences. Ecology 54:427-432.

________. 1979a. TWINSPAN—A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ecology and Systematics, Cornell University, Ithaca, NY.

________. 1979b. DECORANA—A FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ecology and Systematics, Cornell University, Ithaca, NY.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Washington Press, Seattle, WA.

Jackson, L. E., and J. Roy. 1986. Growth patterns of Mediterranean annual and perennial grasses under simulated rainfall of southern France and California. Oecol. Plant. 7:191-212.

Matsuda, K., and J. R. McBride. 1986. Difference in seedling growth morphology as a factor in the distribution of three oaks in Central California. Madroño 33:207-216.

McNabb, D. H., H. A. Froehlich, and F. Gaweda. 1982. Average dry-season precipitation in southwest Oregon, May through September. Oregon State Univ. Ext. Serv., Corvallis. EM 82:026.

Munz, P. A. 1973. A California flora and supplement. Univ. of Calif. Press, Berkeley.

Overton, W. S., B. G. Smith, and C. D. McIntire. 1987. The AID package: manual and user guide. Dept. of Statistics, Oregon State Univ., Corvallis.

Plumb, T. R., and P. M. McDonald. 1981. Oak management in California. USDA For. Serv. Gen. Tech. Rep. PSW-54.

Received 30 April 1990
Accepted for publication 23 October 1991

Raven, P. H. 1977. The California flora. *In* M. G. Barbour and J. Major (eds.), Terrestrial vegetation of California. Wiley Interscience, New York. Pp. 109-137.

Reed, L. J., and N. G. Sugihara. 1987. Northern oak woodlands—ecosystem in jeopardy or is it already too late? *In* T. R. Plumb and N. H. Pillsbury (eds.), Proceedings on the Symposium on Multiple-Use Management of California's hardwood resources. USDA For. Serv. Gen. Tech. Rep. PSW-100. Pp. 59-63.

Saenz, L., and J. O. Sawyer. 1986. Grasslands as compared to adjacent *Quercus garryana* woodland understories exposed to different grazing regimes. Madroño 33(1):40-46.

Schreiber, D. 1977. Kritische betrachtung zu den Klimadiagrammen von Walter und Lieth und verbesserungsvorschlaege zur genaueren beschreibung von humiditaet und ariditaet. *In* H. Dierschke (ed.), Vegetation und Klima. J. Cramer, Stuttgart. Pp. 391-405.

Smith, W. P. 1985. Plant association within the interior valleys of the Umpqua River Basin, Oregon. J. Range Manage. 38:526-530.

Stearns-Smith, S. C., and D. W. Hann. 1986. Forest soil associations of southwest Oregon. Forest Research Laboratory, Corvallis, OR. map.

Stebbins, G. L., and J. Major. 1965. Endemism and speciation in the California flora. Ecol. Monogr. 35:1-35.

Sugihara, N. G., and L. J. Reed. 1987. Prescribed fire for restoration and maintenance of Bald Hills oak woodlands. *In* T. R. Plumb and N. H. Pillsbury (eds.), Proceedings on the symposium on multiple-use management of California's hardwood resources. USDA For. Serv. Gen. Tech. Rep. PSW-100. Pp. 446-451.

Sugihara, N. G., L. J. Reed, and J. M. Lenihan. 1987. Vegetation of the Bald Hills woodlands, Redwood National Park, California. Madroño 34:193-208.

Thilenius, J. F. 1968. The *Quercus garryana* forest of the Willamette Valley, Oregon. Ecology 49:1124-1133.

Walter, H. 1985. Vegetation of the Earth and ecological systems of the geo-biosphere. 3rd ed. Springer-Verlag, New York.

Waring, R. H. 1969. Forest plants of the eastern Siskiyous: their environmental and vegetational distribution. Northw. Sci. 43:1-17.

Welker, J. M., and J. W. Menke. 1987. *Quercus douglasii* seedling water relations in mesic and grazing-induced xeric environments. Proceedings of international conference on measurement of soil and plant water status. Vol. 2, Pp. 229-233.

Wells, F. G., and D. L. Peck. 1961. Geologic map of Oregon west of the 121st meridian. USDI Geo. Surv. Misc. Geol. Inv. Map I-325.

Westhoff, V., and E. van der Maarel. 1978. The Braun-Blanquet approach: *In* R. Whittaker (ed.), Classification of plant communities. Dr. Junk, The Hague. Pp. 287-399.

Whittaker, R. H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecol. Monogr. 30:279-338.