

DYNAMICS OF *QUERCUS WISLIZENII* FOREST AND SHRUBLAND IN THE SAN BERNARDINO MOUNTAINS, CALIFORNIA

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ABSTRACT

Vegetation dominated by *Quercus wislizenii* (interior live oak) in the San Bernardino Mountains may be classified as chaparral or hardwood forest, depending on its structure and composition. Structure, dynamics, and species composition are described differently for *Q. wislizenii* forest and chaparral, but relationships among these types are not always clear. This leads to uncertainty in classification and management. We sampled *Q. wislizenii* stands in the San Bernardino Mountains, then used multivariate techniques to group plots and to distinguish among characteristics of *Q. wislizenii*-dominated chaparral and forest. We identified and described one forest type and two distinct shrubland types. We conclude that one of the shrubland types, occurring with sprouting chaparral species on steep mountain sides, is best recognized as interior live oak chaparral. The other type, occurring on more moderate slopes, is better considered an early-developmental interior live oak forest. About half of the sample plots remained unclassified, indicating floristic and structural continua rather than discrete categories. Structural and floristic characteristics of the three types are used to clarify relationships between *Q. wislizenii* chaparral and forest, and to describe development of forest from shrublands that resemble chaparral. We recommend consideration of these relationships in management decisions.

The intent of vegetation classification is to document repeating patterns in natural vegetation. Unlike biological taxa, species assemblages do not share genetic heritage, and vegetation ecologists do not expect every stand to correspond unambiguously to a single described type. Nevertheless, management policies often differ according to vegetation (e.g., San Bernardino National Forest 1988), and therefore rely on correct identification of vegetation types.

Quercus wislizenii A. DC. (interior live oak) occurs in forest and shrubland throughout cismontane California. Stands dominated by this species may be classified as either forest or chaparral, depending on canopy height, density, and on understory composition. Conversely, *Q. wislizenii* shrubland and forest might be seen as structural or developmental phases of a single vegetation type. We examined

Q. wislizenii stands in the San Bernardino Mountains to determine (1) whether important floristic or structural differences could be used to distinguish *Q. wislizenii* chaparral and forest, and (2) whether chaparral and forest are best recognized as distinct types or as developmental phases of a single type.

Quercus wislizenii occurs throughout much of California and in northern Baja California. A shrubby variety, *Q. wislizenii* var. *frutescens* Engelm., is evidently sympatric with *Q. wislizenii* var. *wislizenii* throughout much of its range (Tucker 1993). We did not attempt to distinguish between varieties in this work. *Quercus wislizenii* occurs as a dominant component in many vegetation types. Allen et al. (1989) described six interior live oak associations in the Sierra Nevada and Coast Ranges, including associations with hardwood trees (*Arbutus menziesii*, *Quercus douglasii*), a conifer (*Pinus sabiniana*), shrubs and subshrubs (*Arctostaphylos*, *Rhamnus*, *Heteromeles arbutifolia*, *Toxicodendron diversilobum*, *Eriodictyon californicum*, *Ceanothus cuneatus*), grasses, and herbs. Barbour (1988) included it as a characteristic species in a "nonconiferous phase" of cismontane California mixed evergreen forest. Patric and Hanes (1964) described a mature forest stand in the San Gabriel Mountains dominated by *Q. wislizenii*. Holland (1986) implied a developmental relationship between *Q. wislizenii* forest and chaparral. He described interior live oak chaparral as a distinct type, similar to forest, but prone to more frequent fire, calling it a "fire disclimax." Interior live oak forest, in Holland's description, is "not a fire type" but may burn periodically and resembles chaparral after fire. He noted that *Q. wislizenii* resprouts vigorously and "recovers rapidly after fire."

Minnich (1976) described vegetation of the San Bernardino Mountains. Two of his types, "mixed chaparral" and "oak chaparral," sometimes include *Q. wislizenii* as a dominant or important species. Obligate sprouting shrubs (Keeley 1986) are predominant in both types, and both types correspond roughly to Hanes' (1977) description of chaparral on north-facing slopes. Minnich also described an "oak woodland," dominated by *Q. chrysolepis*, with a "solid umbrella-like canopy" and an understory of "patches of winter annuals in openings and small shade-tolerant shrubs, including *Rhamnus crocea*, *Rhus ovata*, *Ribes malvaceum* and *Toxicodendron diversilobum*." His description matches Holland's (1986) canyon live oak forest, and corresponds to composition and physiognomy of other authors' forest descriptions (Sawyer et al. 1977; Barbour 1988).

Chaparral is described typically as dense evergreen shrubland with a closed canopy about one to six m tall, contiguous nearly to the ground, and without significant understory (Hanes 1977). Hardwood forest is taller (to 15 m), with a closed or open canopy, and with a relatively open structure beneath the canopy (Sawyer et al. 1977;

Barbour 1988). In California, hardwood forest structure typically includes shrubs and perennial herbs in the understory.

Chaparral and forest in southern California are both influenced by periodic fire (Kilgore 1981; Minnich 1988). A fire may kill nearly all above-ground biomass (a stand-replacement fire) or may burn at lower intensity through the understory without incinerating or top killing canopies (a stand-altering fire, or low-intensity surface fire). Chaparral normally burns in the stand-replacement pattern: above-ground vegetation is entirely replaced following fire (e.g., Patric and Hanes 1964; Hanes and Jones 1967). Dominant shrubs regenerate from surviving underground structures (James 1984) or from seed, and stands often redevelop their pre-fire composition within a few years. Forests may undergo either stand-replacement fires or stand-altering fires, depending on stand characteristics and fire conditions. In the San Bernardino Mountains, *Q. wislizenii* stands seem to burn only in the stand-replacement pattern. Canopies usually burn completely but stems are intolerant of fire at their bases and are top-killed by low-intensity surface fire (Plumb 1980). We have seen no evidence of *Q. wislizenii* stems that have survived historic fires.

Most descriptions of chaparral dynamics have indicated little recruitment of new shrubs or herbs after the first few years and little or no understory beneath established shrub canopies. In contrast, mature hardwood forests often have an understory of shade-tolerant saplings which can recruit into the canopy (e.g., McDonald and Littrell 1976). Yet chaparral and hardwood forest dynamics are not so sharply distinct from one another. Structure and development in some chaparral stands, especially those in which obligate sprouting taxa occur, may resemble those of hardwood forests. Hanes (1971) noted open structure beneath the canopy in long-unburned chaparral on north-facing slopes, and Patric and Hanes (1964) found greater species diversity in older north-slope stands, perhaps indicating germination and recruitment of species absent from the post-fire environment. Keeley (1992) showed abundant recruitment of seedlings and asexually-produced stems into long-unburned chaparral canopies. We conclude here that *Q. wislizenii* forests in the San Bernardino Mountains develop from shrublands resembling chaparral, providing further evidence of similarities in structure and function of forest and chaparral.

METHODS

We analyzed 91 *Q. wislizenii* plots, including 75 0.1 ha plots sampled for this report (Fig. 1) and 16 0.04 ha plots provided by the US Forest Service (USFS) from its Southern California Ecosystems Classification project. We sampled stands with at least 30% *Q. wislizenii* cover (estimated from outside the stand; recorded cover was

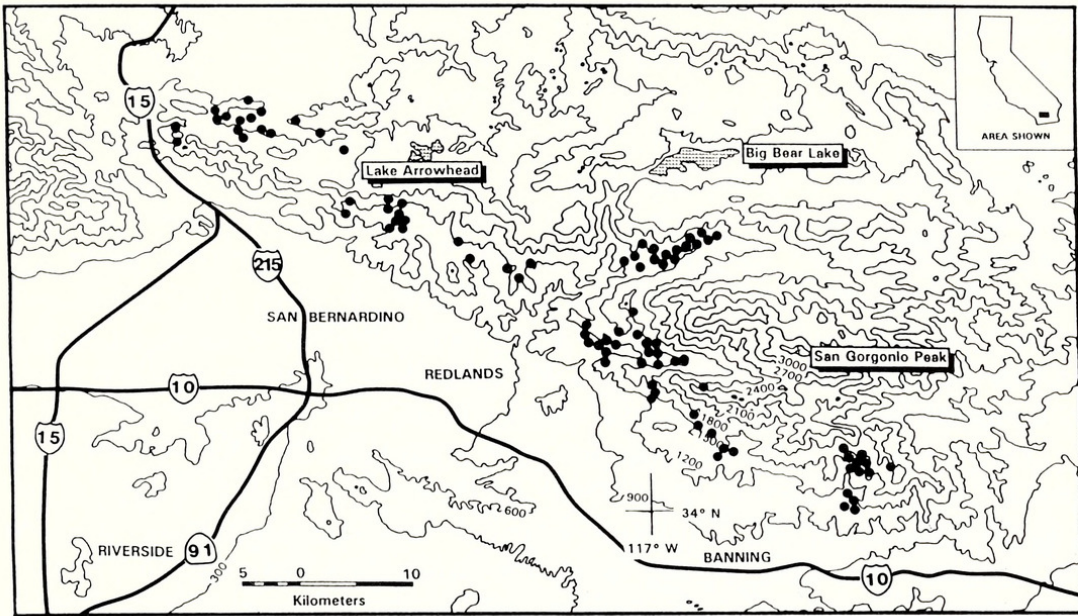


FIG. 1. Plot locations. Contour lines at 300 m intervals.

sometimes as low as 20%) and without obvious human-associated disturbance (evidence of grazing or woodcutting was found in some plots). Plot locations were chosen subjectively, and sampling was not stratified by vegetation structure or composition. USFS plot locations were originally selected by presence of vegetation structurally resembling chaparral and absence of obvious human-associated disturbances. The 16 USFS plots used here were selected from 190 chaparral plots, based on 20% or greater cover of *Q. wislizenii*, as recorded in the data.

Site characteristic data (location, elevation, slope, aspect) were noted for all plots. Detailed soil descriptions were collected for the USFS plots; in our plots, soil was simply characterized as either alluvial-colluvial or residual. Floristic data included a census of woody plant species with estimated percent cover and average height for each species. Total canopy cover (defined as total cover of all plants sharing the *Q. wislizenii* overstory stratum or emerging above it) was estimated. Seedling and sapling numbers were estimated for each species and recorded separately in our 75 plots; seedlings and saplings were not distinguished from canopy plants in USFS plots. In our plots, total herbaceous cover was estimated visually but cover values were not recorded by species. USFS data included a census of herbaceous plants and estimates of cover values for each species.

In our 75 plots, but not in the USFS plots, basal stem diameters and numbers per *Q. wislizenii* individual (genet) were recorded for 20 oaks in each plot. Genets were not randomly selected, and tended to be grouped at plot centers. Up to five stems were measured for

each selected oak (all stems were measured where five or fewer occurred). Stem diameters were measured near their bases (above basal swellings) using a forester's dbh tape except where stems were inaccessible; these diameters were estimated visually. It was often difficult to judge whether a group of stems represented a single genet or a clonal extension of an adjacent oak because *Q. wislizenii* reproduces asexually from fallen limbs and from below-ground structures. We considered genets to be distinct if their above-ground structures were separated by at least one-half meter from adjacent stems. We did not excavate roots or burls to verify these judgements, and we undoubtedly attributed some stems to wrong genets.

For analyses, stem diameters were arranged into 5 cm interval classes. Plot aspect was converted to its cosine so that slopes with similar solar exposure would have similar values. Shapiro and Wilke's W statistic was used to test data for normality (Engelman 1990a). Univariate analysis of variance, using Welch's separate group t-test, was used to analyze mean slope values among plot categories (Dixon et al. 1990). Cluster Analysis of Cases (Engelman 1990b), using the sum of squares coefficient of similarity, and K-Means Cluster Analysis of Cases (Engelman and Hardigan 1990), were used to classify plots into categories.

No variables were normally distributed. Most were highly leptokurtic (peaked distribution curve) and skewed to the right. Cosine of plot aspect, percent slope, and *Q. wislizenii* cover were bimodally distributed. Skewed frequency distributions resulted in many small, dissimilar, clusters in cluster analyses of raw floristic data. To generate clusters of related plots, we grouped species according to structural and life history characteristics and treated these groups as new variables (Table 1). *Quercus wislizenii* cover was retained as a separate variable.

Floristic and structural data were analyzed separately with both programs; thus, four independent cluster analyses were used. Forest plots were identified from structural data, and non-forest plots were clustered from floristic data. Plots which remained unclassified by cluster analyses were separated into two categories according to slope, using 30% slope as the breakpoint (the threshold corresponds to the node in percent-slope's bimodal distribution and separates plots on alluvial-colluvial soils almost perfectly from those on residual soils). The two new categories were named "unclassified-moderate" and "unclassified-steep." Stepwise discriminant function analysis (SDF; Jennrich and Sampson 1990) was used to identify variables providing the strongest discrimination between groups identified by cluster analysis. Only those floristic variables with means greater than 1.0 across all groups and occurring in 10 or more plots were used. Where pairs of remaining variables had correlation values of 0.6 or greater, only one member of the pair was retained.

TABLE 1. NUMBER OF OCCURRENCES OF EACH SPECIES IN SAMPLED STANDS. Arranged by stature and life history categories used in cluster analyses. Nomenclature follows Hickman (1993); fire responses follow Conrad (1987). ¹Included because of fire-initiated seed release from serotinous cones (Vogl et al. 1977). ²Species commonly observed beneath shaded canopies in San Bernardino Mountains.

Species	Occur- rences	Species	Occur- rences
Subshrubs		<i>Ceanothus</i> spp.	
<i>Chrysothamnus nauseosus</i>	4	<i>C. crassifolius</i>	2
<i>Eriodictyon trichocalyx</i>	27	<i>C. greggii</i>	3
<i>Eriogonum fasciculatum</i>	9	<i>C. integerrimus</i>	4
<i>Lupinus excubitus</i>	1	<i>C. leucodermis</i>	41
<i>Mimulus aurantiacus</i>	2	Vines	
<i>Opuntia basilaris</i>	1	<i>Clematis lasiantha</i> /	
<i>O. littoralis</i>	6	<i>C. pauciflora</i>	3
<i>O. parryi</i>	1	<i>Lonicera interrupta</i>	37
<i>Rhus trilobata</i>	29	<i>L. subspicata</i>	9
<i>Salvia apiana</i>	8	<i>Marah macrocarpus</i>	10
<i>S. mellifera</i>	1	Trees	
<i>Solanum xanti</i>	1	<i>Abies concolor</i>	2
<i>Trichostema lanceolatum</i>	2	<i>Fraxinus velutina</i>	7
<i>Yucca whipplei</i>	16	<i>Pinus coulteri</i>	9
Obligate sprouting shrubs		<i>P. jeffreyi</i>	4
<i>Arctostaphylos glandulosa</i>	18	<i>Platanus racemosa</i>	2
<i>Cercocarpus betuloides</i>	19	<i>Prunus virginiana</i>	4
<i>Garrya flavescens</i>	15	<i>Quercus chrysolepis</i>	30
<i>Heteromeles arbutifolia</i>	6	<i>Q. kelloggii</i>	5
<i>Prunus ilicifolia</i>	9	<i>Umbellularia californica</i>	9
<i>Quercus berberidifolia</i>	33	Shrub seedlings	
<i>Rhamnus ilicifolia</i>	18	<i>Amorpha californica</i>	2
<i>Sambucus mexicana</i>	5	<i>Arctostaphylos glauca</i>	1
Obligate seeding & facultative seeding/sprouting shrubs¹		<i>Cercocarpus betuloides</i>	1
<i>Adenostoma fasciculatum</i>	28	<i>Garrya flavescens</i>	1
<i>Arctostaphylos glauca</i>	14	<i>Prunus ilicifolia</i>	3
<i>A. patula</i>	4	<i>Quercus berberidifolia</i>	2
<i>A. pringlei</i>	2	<i>Rhamnus californica</i> /	
<i>A. pungens</i>	5	<i>R. tomentosus</i>	15
<i>Fremontodendron californicum</i>	3	<i>R. ilicifolia</i>	5
<i>Ericameria pinifolia</i>	4	<i>Sambucus mexicana</i>	1
<i>E. parishii</i>	2	<i>Styrax officinales</i>	2
<i>Pinus attenuata</i> ¹	4	Tree seedlings and saplings	
Forest understory shrubs²		<i>Acer macrophyllum</i>	1
<i>Amorpha californica</i>	8	<i>Fraxinus velutina</i>	3
<i>Keckiella cordifolia</i>	12	<i>Pinus jeffreyi</i>	1
<i>K. ternata</i>	17	<i>Prunus virginiana</i>	5
<i>Rhamnus californica</i> /		<i>Pseudotsuga macrocarpa</i>	1
<i>R. tomentosus</i>	23	<i>Quercus chrysolepis</i>	9
<i>Ribes roezlii</i>	2	<i>Q. kelloggii</i>	2
<i>Rosa californica</i>	2	<i>Q. wislizenii</i>	39
<i>Styrax officinales</i>	5	<i>Umbellularia californica</i>	7
<i>Symphoricarpos mollis</i>	2		
<i>Toxicodendron diversilobum</i>	7		

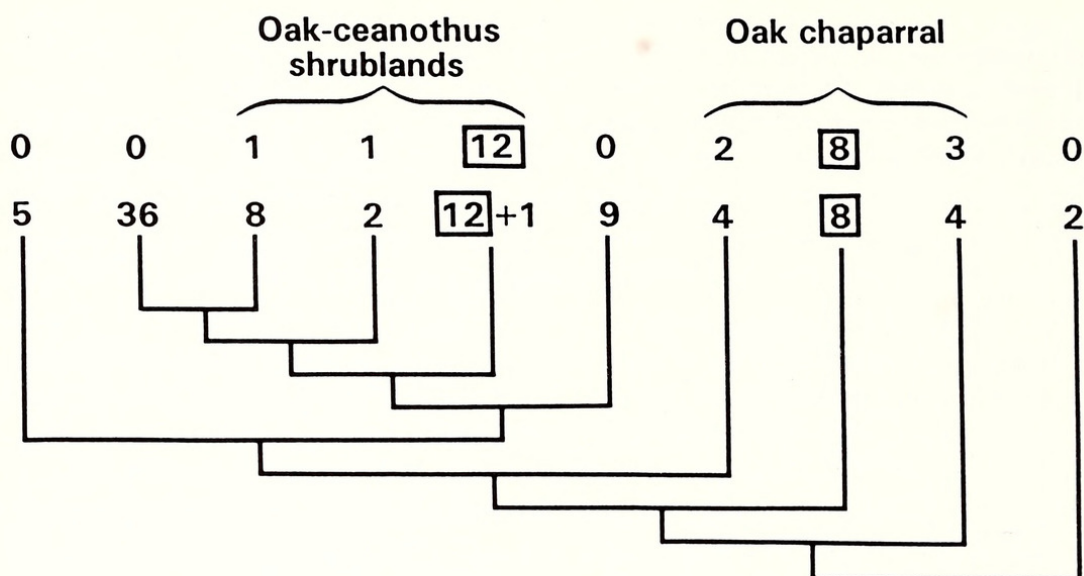


FIG. 2. Cluster analyses of floristic data (91 plots). Cluster Analysis of Cases (dendrogram) and corresponding selected K-Means clusters (brackets). Boxes indicate agreement by both programs; numbers indicate number of plots per cluster.

RESULTS

Both cluster methods identified two groups of non-forest plots from floristic data, agreeing on classifications of most plots (Fig. 2). Where both programs agreed on a plot's classification, we identified it as either "oak-ceanothus shrubland" (12 plots) or "oak chaparral" (8 plots) based on SDF analysis of floristic variables (below). None of these 20 plots clustered with forest plots in separate analyses of structural data.

Both programs identified two groups of forest plots from structural data, but disagreed on specific groupings. K-means clustering identified two groups with high frequencies in the largest stem size classes, distinguished from one another by frequency differences in smaller size classes. Cluster Analysis of Cases clustered most plots from the K-means groups together but recognized three plots with the largest stems in the data set as a distinct cluster (Fig. 3). Neither program clustered any plots already identified as oak chaparral or oak-ceanothus shrubland with forest plots. Both programs agreed on the classification of 27 plots into clusters characterized by large stem diameters, which we recognized as *Q. wislizenii* forest. Forty-four plots remained unclassified.

Percent slope was the only site variable identified by SDF analysis as useful in discriminating among chaparral, shrubland and forest clusters: forest and oak-ceanothus shrubland groups occur on relatively moderate slopes, while chaparral plots occur on steeper slopes. Unclassified plots occurred on both moderate and steep slopes. Univariate ANOVA found no significant differences among mean slope

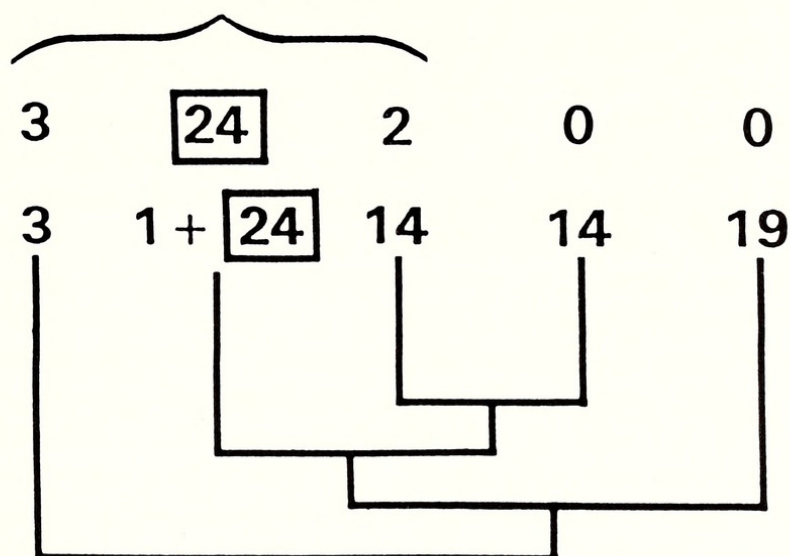
Quercus wislizenii**forest plots**

FIG. 3. Cluster analyses of structure data (75 plots). Cluster Analysis of Cases (dendrogram) and corresponding combined K-Means forest clusters (brackets). Boxes indicate agreement by both programs; numbers indicate number of plots per cluster.

of oak-ceanothus shrubland, *Q. wislizenii* forest, and unclassified-moderate plots at the 95% confidence interval. Similarly, mean slopes of oak chaparral and unclassified-steep plots did not differ significantly. All other comparisons among categories were significant at the 95% confidence level, and most were significant well above the 99% interval.

SDF analysis identified *Ceanothus leucodermis* cover and total obligate sprouting chaparral shrub cover as the floristic variables most useful in discriminating among the five groups. Discriminant models based on these variables identified oak chaparral and oak-ceanothus shrubland with high success, but did not discriminate well between *Q. wislizenii* forest plots and the two unclassified categories. Comparative site, structure and floristic characteristics of the categories are shown in Table 2. SDF analysis identified three structural variables (stem frequency in the 15–20 cm and >20 cm size classes, and *Q. wislizenii* height) which discriminated well between forest plots and other categories. SDF analysis of structural data did not discriminate well between oak-ceanothus shrubland and unclassified groups.

Shrub canopy in chaparral and oak-ceanothus shrubland plots is dense, usually exceeding 80%, and canopy height ranges from 1.3 to 5 m. There is little or no herb cover. Forest understory shrubs (Table 1) occur occasionally but at very low cover in both types. No

TABLE 2. COMPARISON OF OAK CHAPARRAL, OAK-CEANOOTHUS SHRUBLAND, INTERIOR LIVE OAK FOREST, AND UNCLASSIFIED CATEGORIES.

Variable	Oak chaparral		Oak-Ceanothus shrubland		Interior live oak forest		Unclassified	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Site characteristics								
Elevation (m)	1486	302	1330	177	1362	168	1345	247
Cos aspect	-0.28	0.69	-0.32	0.88	-0.05	0.68	-0.7	0.8
% slope	45	13	28	18	20	18	39	21
Structure								
Canopy height (m)	3.2	1.3	2.6	1.0	5.9	1.6	4.0	1.6
Total canopy cover (%)	88	5.6	97	2.8	68	18	82	13
Total herb cover (%)	1.2	1.7	0.7	1.0	14	18	5	10
% cover, by category (Table 1)								
Seeding and facultative								
chaparral shrubs	2.0	3.4	3.2	3.3	1.0	1.5	2	5
Subshrubs	1.8	2.4	3.8	4.8	6	6	4	8
Obligate sprouting shrubs	43	11	3.2	4.2	4	4	5	7
Understory shrubs	0.5	0.8	0.8	1.2	4	6	3	8
Trees	1.9	3.0	0.4	1.0	8	12	2	6
% cover of key species								
<i>Ceanothus leucodermis</i>	11	13	36	18	0.3	0.7	2.0	4
<i>Quercus wislizenii</i>	30	8	52	15	58	17	66	23
Seedling and sapling numbers								
Shrubs	n/a		0.3	0.7	5	9	5	11
Trees (excluding <i>Quercus wislizenii</i>)	(data avail. for only 2 plots)		0	—	7	12	0.2	0.7
<i>Quercus wislizenii</i>			0.4	1.3	10	11	1.4	5

shrub or tree seedlings were recorded in oak chaparral plots (data available for only two plots) and seedlings were rare in oak-ceanothus shrubland. No chaparral or shrubland plots have *Q. wislizenii* stems approaching diameters characteristic of forest plots (about 15 cm).

Oak chaparral is distinguished from oak-ceanothus shrubland by its occurrence on residual soils of 30% or greater slope, high cover (30–65%) of sprouting chaparral species (Table 1), and relatively low *Q. wislizenii* cover (20–40%), though these values overlap the ranges of the other types described here.

Oak-ceanothus shrubland occurs primarily on soils of alluvial and colluvial origin on slopes less than 30%. It has low obligate sprouting shrub cover (0–13%) and does not overlap the minimum value in oak chaparral. *Ceanothus leucodermis* cover ranges from 15% to 70%.

Quercus wislizenii forest is defined by structure. Canopy height averages 6 (3–10) m. At least five stems exceeding 15 cm diameter occur in every plot, and most have five or more exceeding 20 cm diameter. *Quercus wislizenii* cover (35–85%) is similar to oak-ceanothus shrubland, and higher than oak chaparral. Average total canopy cover (about 70%) is lower than oak chaparral and oak-ceanothus shrubland. Forest stands have little or no cover of *C. leucodermis*, obligate seeding, or obligate sprouting chaparral shrubs (Table 1). Forest understory species and hardwood trees occur occasionally but none are strongly correlated with forest plots. Forest stands occur primarily on alluvial and colluvial soils with slopes less than 30%, but occasionally much steeper, including one plot on a 90% slope.

Floristically, unclassified groups were not distinguished from forest, but their structure was not distinguished from chaparral and shrubland groups. When unclassified plots were separated into slope categories, slope was the only variable useful in discriminating between the new categories. Unclassified-steep plots and oak chaparral occur on similar steep sites. Unclassified-moderate plots, forest, and shrubland all occur on moderately sloping alluvial-colluvial sites.

DISCUSSION

Distributions of most floristic variables are skewed. Species (other than *Q. wislizenii*) tend to occur in a few plots at high cover, and in many plots at low cover. We believe this reflects distributions of woody plants in the San Bernardino Mountains, rather than sampling bias. The bimodal distributions of slope and aspect probably reflect topography rather than sampling bias. These mountains are steep and are comprised primarily of east-west oriented ridgelines dissected by moderately sloping washes and drainages. Slopes intermediate between moderate drainages and steep mountainsides

are uncommon. *Quercus wislizenii*-dominated stands occur on residual and on alluvial-colluvial soils and on all aspects. *Quercus wislizenii* cover is bimodal, but is not strongly correlated with site or structure variables. Several other species are negatively correlated with high *Q. wislizenii* cover, but there is little correlation among their cover values, and they do not explain the bimodal distribution.

Our descriptions of oak chaparral and oak-ceanothus shrubland are encompassed by Holland's description of interior live oak chaparral (1986); most plots are also encompassed by Minnich's oak chaparral (1976), though some match his mixed chaparral better.

Our description of interior live oak forest compares well to Holland's (1986) description. Most of these stands have the closed canopy and sparse understory resembling *Q. chrysolepis* forests (Minnich 1976, 1980; Holland 1986). A few plots classed here as forest have relatively open canopies, suggesting woodland structure, but they invariably occur on sites influenced by grazing or woodcutting. The association of forest plots with moderate slopes is consistent with Keeler-Wolf's (1990) description of mature *Q. wislizenii* stands on alluvial-colluvial slopes in the southeastern San Bernardino Mountains.

We conclude that chaparral described here matches traditional descriptions of chaparral structure, and we have no evidence that its dynamics differ from other chaparral types dominated by sprouting species. More important, we conclude that oak-ceanothus shrubland, and perhaps unclassified plots on moderate slopes, are early-developmental *Q. wislizenii* forest. They occur on sites indistinguishable in this analysis from forest sites; oaks are shorter and have smaller-diameter stems; and *C. leucodermis*, which dies out of chaparral stands about 40 years after fire (Hanes 1971), occurs as a codominant. We avoid the term "chaparral" for these stands to emphasize the distinction from traditional descriptions of chaparral dynamics. The pattern of interior live oak forest development from a dense oak-ceanothus shrubland parallels Minnich's (1976) description of *Q. chrysolepis* forest development from shrublands with *C. leucodermis* and *C. integerrimus* as codominants.

We classified plots conservatively, assigning plots to categories only when both cluster programs agreed on their classification. This approach is partly responsible for the large number of unclassified plots. But the unclassified plots are also evidence of a continuum between the types described here: shrubland and forest are related through time, while both may be related to chaparral through structure and floristic composition. Some unclassified plots seem to be intermediate between *Q. wislizenii*-dominated vegetation and other types not considered in this analysis (e.g., several plots have high *Q. chrysolepis* cover).

One hypothesis for the predictable occurrence of interior live oak forests on moderate alluvial-colluvial slopes and the contrasting occurrence of oak chaparral on steeper, residual sites presumes that development of mature structure requires relatively long fire intervals. We did not age *Q. wislizenii* stands, but we find strong evidence that interior live oak forest is older and develops over time from oak-ceanothus shrubland. If long fire intervals allow interior live oak forest development, two alternative explanations might argue that *Q. wislizenii* forests should be recognized as long-unburned chaparral.

First, fire may have missed forest-like stands by chance. But the strong correlation of *Q. wislizenii* forest plots with moderate slopes shows that forest distribution is not random. Fire intensity and rate of spread increase with increasing slope (Rothermel 1983). Fire intervals should be shorter on steep slopes than on moderate slopes because ignitions in *Q. wislizenii* stands on steep slopes should establish and spread during a broader range of conditions (e.g., fuel moisture and wind speed) than ignitions on moderate slopes. Stands may also increase their resistance to fire once they reach forest stature, due to vertical fuel arrangement, as Minnich (1980) describes in *Q. chrysolepis* stands. If deep alluvial-colluvial soils allow faster growth than residual soils, then stands on moderate slopes could reach fire-resistant stature at younger ages, further reducing the likelihood that fire will spread through them.

Second, mature *Q. wislizenii* stands may be an artifact of modern fire suppression. Fire intervals and burning patterns in southern California have been altered from a combination of lightning-caused and anthropogenic fires without suppression, to today's pattern dominated by anthropogenic fire with effective suppression of most ignitions (Minnich 1988). Pre-European fire intervals in California are unknown. Present-day human impacts to fire frequency and behavior are complex, involving new ignition sources, suppression of natural ignitions, timing of ignitions (lightning usually occurs during rain or high humidity while human-caused ignitions may occur at any time) and introduction of non-native herbs (e.g., *Bromus*) which ignite and carry fire more readily than native shrubs (D'Antonio and Vitousek 1992). Interaction of human influences with natural fuel characteristics confounds comparison of present-day and historic burning patterns. We cannot reject the hypothesis that *Q. wislizenii* forest is an artifact of fire management, but we find no evidence in its support.

We recommend that land managers in the San Bernardino Mountains recognize distinct *Q. wislizenii* types in policy planning and application. In fire management planning and prescribed burn planning, long fire intervals should be recognized as a normal pattern in

interior live oak forests. Where management directs conversion of chaparral to other vegetation types (e.g., non-native grassland fuel-breaks or conifer plantations), then oak-ceanothus shrubland should be distinguished from chaparral and managed accordingly. Where policy directs management for increased wildlife habitat value, then the forest characteristics of *Q. wislizenii* stands should be recognized (e.g., arboreal nesting habitat, availability of shaded cover, production of acorn mast and basal shoots). Interior live oak forest and oak-ceanothus shrublands should not be managed as chaparral.

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