Northwest California Oak Woodlands: Environment, Species Composition, and Ecological Status[1]

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Abstract

This paper describes the oak woodland plant communities of Northwest California and their ecological status using data from 446 ecology plots collected on federal lands in Humboldt, Trinity, Siskiyou, Mendocino, Tehama, Glenn, Colusa and Lake Counties. Geographically, oak woodlands lie between the coastal mixed evergreen forests and the valley grasslands of the Central Valley. They were found in small patches nested within a mosaic of annual grasslands and conifer forests, and hence contain species common to both of these vegetation types. The oak woodlands of northwest California were primarily included in three vegetation series: Oregon white oak (*Quercus garryana*), black oak (*Quercus kelloggii*) and blue oak (*Quercus douglasii*). Valley oak (*Quercus lobata*) was also found in the study area, but because of its limited extent and insufficient samples, it will not be described here. Due to their history of grazing and their proximity to annual grasslands, many of the Northwest California oak woodlands contained high cover of non-native species. In some types, non-native grass and/or forb cover far exceeded that of native species. The forb and grass layers differed from one another based on the general shift of moderate overall cover of non-native grasses to native forbs. Species diversity in these oak woodland systems is a controversial subject because of perceived losses of biological diversity. After the introduction of invasive non-native, annual, Mediterranean species, many of the native species were displaced. Species composition of oak woodlands and annual grasslands will be compared with special attention paid to the cover of non-native species. The ecological status of oak woodlands in Northwest California will be discussed from several perspectives. These include species composition of grasses and forbs, comparisons of cover, species counts, annual and perennial species and native and non-native species. The long-term successional status of these systems will be described using assigned seral species status. Noxious and invasive weeds found in these oak woodlands will also be described and compared to annual grasslands.

Introduction

California's oak woodlands play a prominent role in the natural and cultural history of the State (Pavlik and others 1991). They provide shelter and food for wildlife, as well as wood and fuel for humans and feed for livestock. Oak woodlands are key elements of our California biological diversity. They contain some of the highest species diversity found in our native communities (Jimerson and others 2000). Statewide threats to oak woodlands are many, including: urbanization, conversion to agriculture, fragmentation, low rates of regeneration, competition from

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introduced exotic species and sudden oak death. Studies such as this one can help us identify site-specific risks to oak woodlands and help us to develop strategies to combat them.

The northwest California portion of the State's oak woodlands lie geographically between the coastal mixed evergreen forests and the valley grasslands of the Central Valley (Griffin 1988). They were found in small patches (averaging 29.3 acres/patch), nested within a mosaic of annual grasslands (Jimerson and others 2000) and conifer forests, and hence contain species common to both of these vegetation types. Their extent on National Forest lands within the study area has been estimated at over 725,000 acres. This paper will describe the oak woodland plant communities of Northwest California along with their ecological status and compare them to the annual grasslands found in close proximity.

Methods

The study area included the National Forest lands in Humboldt, Trinity, Siskiyou, Mendocino, Tehama, Glenn, Colusa and Lake Counties. Vegetation maps, past vegetation sampling and local knowledge of oak woodland locations were used to stratify the study area. Four hundred and forty-six plot samples were collected throughout the study area. Only federal lands were sampled for purposes of this study, which reduced the quantity of blue oak woodlands available for sampling.

Sampling methods followed the USDA Forest Service protocol (Allen 1987, Allen and Diaz 1986) used in earlier vegetation classifications completed in northwest California (Jimerson 1994, Jimerson and others 1995, Jimerson and others 1996). These methods included identification of all species for each stratum (tree, shrub, forb and grass) along with their cover and density. Species nomenclature followed Hickman (1993). Environment was described for all plots (location, elevation, aspect, slope, micro-position and landform) and selected plots had soil profiles described (parent rock, soil type, depth, texture, coarse fragments, diagnostic horizons).

Classification methods followed earlier studies in Northwest California (Jimerson 1994, Jimerson and others 1995, Jimerson and others 1996). Initial classification was accomplished using the polythetic divisive classification technique, Two-way Indicator Species Analysis (TWINSPAN) (Hill 1979). TWINSPAN was paired with the ordination techniques Detrended Correspondence Analysis (Hill 1979) and Canonical Correspondence Analysis (Ter Braak 1992) to define the final classification. The final veg types were compared using discriminant function analysis (DFA) (Jennrich and Sampson 1985) to identify the significant environment variables that distinguish each veg type from one another.

Species diversity assessment is a tool in the examination of plant communities and their ecological context. We believe it is a necessary part of this classification analysis and will discuss it here at various scales, particularly in light of 1) the controversy surrounding the effects of non-native species on native species diversity, and 2) the utility of classification as a tool in managing for the maintenance of species diversity.

Species diversity is composed of two components: (1) richness (the total number of species), and (2) evenness (how the data are distributed among the species) (Ludwig and Reynolds 1988). These diversity measures were calculated for each plot using the program PC-ORD (McCune and Mefford 1999).

Oak woodlands and annual grasslands have differing degrees of non-native plant invasion that are primarily limited to herbaceous species (Saenz and Sawyer 1986). Annual grasses are the primary non-native invaders of oak woodlands, although a few non-native forbs are important invaders as well. These non-native invaders have the potential to alter ecological relationships and processes (Mooney and others 1986).

The ecological status of northwest California oak woodlands can be described from several perspectives. First, comparisons can be made of cover and species counts of grasses versus forbs, annuals versus perennials and native versus non-native species using one-way analysis of variance (SPSS Inc. 2000). Second, plant species are often used as indicators of ecological status (early, mid or late seral) since they tend to reflect site potential, site history and past management activities (USDA 1997). Species are designated here as indicators of early-seral, mid-seral or late-seral conditions as defined below:

- Early-seral species are associated with very disturbed or young associations (pioneer species), with low abundance in stable associations, but invasive with high abundance in unstable associations (examples, *Aira caryophyllea*, *Briza minor*, and *Cynosurus echinatus*).
- Mid-seral species abundance increases significantly with increased disturbance and maintains high abundance in recovered, stabilizing associations (examples, *Danthonia californica*, *Elymus glaucus*, and *Poa pratensis*).
- Late-seral species are typically found in undisturbed associations that decrease or maintain low abundance with increased disturbance (examples, *Achnatherum lemmonii*, *Festuca idahoensis*, and *Melica harfordii*).

Oak woodland ecological status will be assessed by combining the factors described above. For example, sites with high cover of annual and perennial, non-native species, in early-seral states would point toward a low ecological status. In contrast, those sites with high cover of perennial, native species, in late-seral states would be described as in a high ecological status.

Results

Vegetation Series

The classification of 446 oak woodland plots in northwest California identified three primary vegetation series: Oregon white oak (*Quercus garryana*), black oak (*Quercus kelloggii*) and blue oak (*Quercus douglasii*). They were found in nearly pure stands dominated by white oak, black oak or blue oak, or in association with other tree species such as Douglas-fir (*Pseudotsuga menziesii*), Ponderosa pine (*Pinus ponderosa*), gray pine (*Pinus sabiniana*), canyon live oak (*Quercus chrysolepis*), California buckeye (*Aesculus californica*) and bigleaf maple (*Acer macrophyllum*). Collectively these woodland communities fit under what Griffin (1977) called the northern oak woodlands. Previous oak woodland plant community classification in northwest California and southwest Oregon was completed by Atzet and others (1996), Jimerson and others (1988), Leitner and Leitner (1988), Parker and Matyas (1979), Reigel and others (1991), Stuart and others (1996), and Sugihara and others (1987). Currently, the plot data collected in this study is being described in a plant association classification for oak woodlands in northwest California.

The northwest California oak woodland series were compared using discriminant function analysis (DFA) (Jennrich and Sampson 1985) to identify the significant environmental variables that distinguish each series from one another. Highly significant variables are compared by series in *table 1*. Precipitation is a key discriminant variable, highest in the black oak series and significantly lower in the blue oak series. Since rainfall in northwest California decreases from west to east and north to south, the black oak series was more often found on more westerly sites in the northern portion of the study area, while the blue oak series was found on the most inland sites in the southern portion of the study area. The white oak series, on the other hand was found throughout the study area.

Table 1—*Mean significant discriminant function analysis (dfa) variables identified in the oak woodland series comparison (df 2, 417).*

Variables	White oak	Black oak	Blue oak	f	dfa axis	sign.
Precip. (in.)	54.4	60.7	47.9	11.5	dfa 1	.001
Distance to ocean (mi.)	46.3	68.4	64.4	46.5	dfa 2	.001
North/south gradient	4498862.1	4508568.2	4405248.4	16.2	dfa 1	.001
Summer precip. (index)	7.7	7.8	7.2	27.2	dfa 1	.001
Slope (pct)	41	37	28	3.3	dfa 2	.038
Elevation (ft.)	3,217	3,184	2,229	7.5	dfa 2	.001
Forb cover (pct)	15	13	23	3.5	dfa 1	.030
Grass cover (pct)	33	18	43	23.8	dfa 1	.001
Tree cover (pct)	59	70	47	11.6	dfa 2	.001
Radiation index	.494	.478	.354	2.7	dfa 2	.010

Inland blue oak sites had the lowest tree cover, highest forb cover, highest grass cover and lowest elevation of the three oak woodland series. In contrast, the black oak series was found on sites with the highest mean rainfall, in the northern portion of the study area, on cool upland sites. These three factors help explain why black oak has the highest mean tree cover of the three oak woodland series. The white oak series generally was found on the highest elevation, warmest sites, with the highest mean slope.

The variables displayed in *table 1* largely explain the gross physical and environmental variability in oak woodland series field plots. Axis 1 (dfa 1) explained 56 percent of the variance in the oak woodland series, while axis 2 explained 44 percent of the variance. The highest correlation of each variable to a dfa axis is listed in *table 1*. The test of the hypothesis that the group centroids for dfa axis 1 and 2 were equal was rejected (chi-square 272.7, df 42, sign. 0.001). In other words the two discriminant functions differ significantly from one another.

The key species identified in the Detrended Correspondence Analysis (DCA) (Hill 1979) that best describe the plant communities and explain the environment variability in each series are described below in *table 2*. These species are closely related to key environment gradients. For instance, Douglas-fir was found on mesic sites within the white oak and black oak series, while California buckeye occupies warm, dry sites. Bigleaf maple was only found on moist, cool sites in the black oak series. Gray pine was most often found on soils derived from serpentine parent material. In the shrub layer, California juniper (*Juniperus californica*) was only found on harsh, dry, rocky, inland sites. In contrast, mock orange (*Philadelphus lewisii*) and hazelnut (*Corylus cornuta var. californica*) were only found in shaded, cool, riparian locations near streams. Grass layer indicator species include tall oat grass (*Arrhenatherum elatius*), which had its most extensive occurrence in the western part of the study area on cool, moist sites in close proximity to the Pacific Ocean. Hedgehog dogtail (*Cynosurus echinatus*) was found throughout the southern part of the study area on sites heavily disturbed by cattle. Blue wild-rye (*Elymus glaucus*) and California fescue (*Festuca californica*) appeared to have their highest abundance on sites with high canopy cover.

Table 2—*Tree, shrub and grass indicator species identified in each oak woodland series. X indicates presence.*

Species	Life form	White oak series	Black oak series	Blue oak series
Quercus garryana	tree	X	X	X
Pseudotsuga menziesii	tree	X	X	
Pinus ponderosa	tree	X	X	
Quercus chrysolepis	tree	X	X	
Pinus sabiniana	tree	X	X	X
Aesculus californica	tree	X		
Acer macrophyllum	tree		X	
Juniperus californica	shrub			X
Arctostaphylos patula	shrub	X		
Rhus diversiloba	shrub	X	X	X
Cercocarpus betuloides	shrub	X	X	
Ceanothus cuneatus	shrub	X	X	
Quercus garryana var. *breweri*	shrub	X	X	
Quercus wislizenii var. *frutescens*	shrub		X	
Corylus cornuta	shrub		X	
Philadelphus lewisii	shrub	X		
Arrhenatherum elatius	grass		X	
Bromus carinatus	grass			X
Vulpia microstachys	grass			X
Cynosurus echinatus	grass	X	X	X
Festuca californica	grass	X	X	
Melica harfordii	grass	X		
Elymus glaucus	grass	X	X	

Some of the species listed in *table 2* are indicators of altered disturbance regimes. For instance, high cover of Douglas-fir under an oak canopy is an indication of an altered fire regime. Northwest California oak woodlands would naturally be subjected to frequent low intensity fires that tend to kill invading Douglas-fir seedlings and saplings. Over the last 50 years the USDA Forest Service has practiced an aggressive fire suppression policy. The effect of this was an increase in cover of Douglas-fir on oak woodland sites. This can lead to the development of fuel ladders into the oak canopy that increase the potential for stand replacing fire and a reduction in forb and grass species diversity by shading. A second example involves hedgehog dogtail; this aggressive alien grass increases in cover on sites that have been overgrazed. Because of the open nature of this plant, it can affect soil cover and lead to increased surface erosion and reductions in species diversity. Tall oatgrass is an example of a non-native perennial grass species introduced in order to control bank erosion. This species can grow to seven feet in height and shade out native species through its tall stature and production of smothering thatch (Jimerson and others 2000).

Species Richness

A species richness comparison of annual grasslands, meadows, chaparral and oak woodlands found significant differences by vegetation type (Jimerson and others 2000). The oak woodland vegetation type had significantly higher richness (X=25.3 species/plot) than any other type.

Table 3—*Oak woodland series comparison of mean species life form counts.*

Life form	Oak woodland series	Mean species count	Std. error
Forb native	white oak	9.4	0.51
	black oak	7.5	0.56
	blue oak	11.5	1.21
	overall	8.8	0.37
Forb non-native	white oak	1.2	0.09
	black oak	1.0	0.11
	blue oak	2.9	0.51
	overall	1.2	0.07
Grass native	white oak	2.9	0.20
	black oak	2.2	0.20
	blue oak	3.7	0.49
	overall	2.7	0.14
Grass non-native	white oak	2.0	0.12
	black oak	1.5	0.12
	blue oak	4.6	0.62
	overall	1.9	0.10

A species richness comparison by oak woodland series also found significant differences (df=2, F=15.74, sig= 0.001). The highest mean number of species was found in the blue oak series (29.8 species/plot), while the lowest mean species richness was found in the black oak series (23.1 species/plot). A comparison of species counts by oak woodland series *(table 3)* shows the same trends. The blue oak series had significantly higher species counts (P=0.001) by lifeform than the white oak and black oak series. It appears that these differences in species richness are related to overstory tree canopy closure. For instance, when canopy closure was high, species richness was low and when canopy closure was low, species richness was high. This is exemplified by the high mean canopy closure found in the black oak series (73 percent cover), and its associated low species richness. The blue oak series, on the other hand, has low tree canopy closure (53 percent) and high species richness.

Species Diversity

The oak woodland samples indicate a relatively plant species rich environment when compared to other Northwest California vegetation series. A total of 714 species were identified from 446 ecology field plots. This included 28 tree, 106 shrub, 493 forb and 87 grass and grass-like species.

Thirty-four percent of the grass species identified were annuals and 66 percent were perennials. Ninety percent of the annual grasses were non-native. These included silver hairgrass (*Aira caryophyllea*), slender wild oat (*Avena barbata*), common wild oat (*Avena fatua*), soft chess (*Bromus hordeaceus*), hedgehog dogtail, and six-weeks fescue (*Vulpia myuros*). Of the perennial grasses, 82 percent were native species, including California brome (*Bromus carinatus*), blue wild-rye, California fescue, Idaho fescue (*Festuca idahoensis*), western fescue (*Festuca occidentalis*), Harford's melic (*Melica harfordii*), Pacific bluegrass (*Poa secunda*) and bottlebrush squirreltail (*Elymus elymoides*).

The forb layer had the same ratio of annual to perennial species as the grass layer. Thirty-four percent of the forbs identified were annuals and 66 percent were perennials. Seventy-nine percent of the annual forbs were native; they included California hedge parsley (*Yabea microcarpa*), miner's lettuce (*Claytonia perfoliata*), Clarkia (*Clarkia rhomboidea*), goose grass (*Galium aparine*), common madia (*Madia elegans*), slender tarweed (*Madia gracilis*), sweet cicely (*Osmorhiza chilensis*) and tonella (*Tonella tenella*). Important non-native forb species included the thistles (*Cirsium* spp.) and European hedgeparsley (*Torilis arvensis*). Of the perennial forbs, 95 percent were native species; including common yarrow (*Achillea millefolium*), spearleaf agoseris (*Agoseris retrorsa*), soap root (*Chlorogalum pomeridianum*), Collomia (*Collomia grandiflora*), Pacific houndstongue (*Cynoglossum grande*), white hawkweed (*Hieracium albiflorum*), iris (*Iris* spp.), wild pea (*Lathyrus* spp.), swordfern (*Polystichum munitum*), western buttercup (*Ranunculus occidentalis*), purple sanicle (*Sanicula bipinnatifida*), gembleweed (*Sanicula crassicaulis*), American vetch (*Vicia americana*) and Shelton's violet (*Viola sheltonii*).

Existing Conditions

Vegetation cover in the oak woodlands was usually high when compared to other vegetation types in Northwest California. The tree layer accounted for 64 percent mean cover, shrub layer 22 percent, grass layer 26 percent and forb layer contributed an additional 14 percent mean cover. Grass cover was evenly split between native (14 percent) cover and non-native species (13 percent). Native cover consisted of 13 percent perennial and 1 percent annual species *(table 4)*. Non-native cover consisted of 11 percent annual and 2 percent perennial species. This shows the effects of long-term competition from aggressive non-native species introduced to these sites through livestock grazing.

The forb layer, on the other hand, had a mean cover of 10 percent natives compared to non-native cover of 2 percent *(table 4)*. Annual and perennial native species accounted for 3 percent and 7 percent mean cover, respectively. However, the annual native forb category differed significantly by vegetation series (P=0.001). Non-native forb species were much reduced, contributing 2 percent annual and < 1 percent perennial forb cover. Both of these categories differed significantly (P=0.001) between vegetation series.

Table 4—*Comparison of lifeform cover percent for forbs and grasses in oak woodlands and annual grasslands.*

Life form	Oak woodlands pct. cover (std. er.)	Annual grasslands pct. cover (std. er.)
Forb annual native	3.2 (0.2)	24.1 (1.5)
Forb annual non-native	1.8 (0.2)	7.3 (0.9)
Forb perennial native	6.9 (0.3)	8.7 (0.6)
Forb perennial non-native	0.4 (0.1)	3.6 (0.4)
forb native	10.1 (0.5)	32.8 (1.3)
Forb non-native	2.2 (0.2)	10.9 (0.7)
Total forb cover	12.3 (0.8)	43.7 (1.4)
Grass annual native	0.3 (0.1)	0.2 (0.1)
Grass annual non-native	11.2 (0.8)	57.0 (1.8)
Grass perennial native	13.4 (0.9)	5.4 (0.8)
Grass perennial non-native	1.7 (0.4)	5.7 (1.0)
Grass native	13.7 (0.9)	5.6 (0.7)
Grass non-native	12.8 (0.9)	63.7 (1.5)
Total grass cover	26.5 (1.2)	69.3 (1.4)

In a lifeform comparison between oak woodlands and annual grasslands *(table 4),* significant differences were found in several categories. Annual grasslands had significantly higher cover in all forb categories and in non-native annual and perennial grasses. In contrast, oak woodlands had higher cover of native perennial grasses.

Seral Status

The seral status of Northern California oak woodlands is a living record of disturbance, i.e. grazing, fire, drought and competition from invasive species. Overall, the oak woodland plot samples were dominated by low mean grass cover in both the early-seral (8 percent) and late-seral stages (10 percent), with less grass cover in the mid seral stage (4 percent) *(table 5).* This is in stark contrast to the annual grasslands where overall early seral cover (61 percent) far exceeded all other seral stages *(table 5).* In reference areas, where disturbance was primarily natural and cattle grazing was absent, the grass seral status was often dominated by cover in the late seral category. When the current seral status is compared to these reference areas, it points toward an overall conclusion that some of our northwest California oak woodland communities are now in a non-equilibrium condition; i.e., are very disturbed or young associations dominated by invasive species.

When the seral status was analyzed by oak woodland series, significant differences were found between series for early seral grass cover (P=0.001) and late-seral cover (P=0.001) *(table 5).* The blue oak series had the highest early-seral cover (32 percent) followed by the Oregon white oak series (10 percent). There was no significant difference in mid-seral grass cover. Late-seral cover was highest in the Oregon white oak series (14 percent), followed by the blue oak (8 percent) and black oak series (6 percent).

Table 5—*Mean percent grass cover and standard error for seral state by oak woodland series.*

Vegetation series	Early-seral pct		Mid-seral pct		Late-seral pct	
	mean	std. error	mean	std. error	mean	std. error
Oregon white oak	10.3	1.1	4.3	0.6	14.2	1.4
Black oak	4.6	0.9	2.7	0.5	5.9	0.8
Blue oak	31.9	4.7	6.2	3.9	7.9	2.7
Oak woodlands (all)	8.1	0.7	3.6	0.4	9.9	0.8
Annual grasslands	61.5	1.9	2.8	0.5	2.4	0.6

Forb cover was found to be significantly different for all seral stages by oak woodland series and in a comparison to annual grasslands. However, I believe that only the early-seral category (P=0.001) was ecologically significant because of the very low mid seral and late seral cover in each series. Early-seral forb cover was higher in the blue oak series (15 percent) than the Oregon white oak series (6 percent) and black oak series (4 percent) *(table 6).*

Table 6—*Percent mean forb cover and standard error for seral state by oak woodland series.*

Vegetation series	Early-seral pct		Mid-seral pct		Late-seral pct	
	mean	std. error	mean	std. error	mean	std. error
Oregon white oak	6.2	0.5	5.0	0.3	2.5	0.2
Black oak	4.1	0.4	3.2	0.3	1.8	0.2
Blue oak	15.1	3.7	6.8	1.6	1.9	0.4
Oak woodlands (all)	5.4	0.3	4.2	0.2	2.2	0.1
Annual grasslands	30.0	1.4	9.5	0.7	4.1	0.6

Noxious and Invasive Weeds

The noxious and invasive (invasive) weeds identified in the northwest California oak woodlands and annual grasslands are displayed in *table 7.* Overall, invasive weeds occurred relatively infrequently in oak woodlands (27 percent of the plots) when compared to annual grasslands. Twelve percent of plots contained only 1 percent invasive weed cover, with an additional 9 percent of the plots containing 2-5 percent cover. The remaining plots (6 percent) contained 6-22 percent invasive weed cover. This is in sharp contrast to the annual grasslands where 78 percent of the plots were found to contain invasive weeds (Jimerson and others 2000). Invasive weed cover on annual grasslands included 15 percent of the plots with 1 percent cover, 21 percent with 2-5 percent cover, 27 percent with 6-20 percent cover and 14 percent of the plots with 21-95 percent cover. Clearly, invasive weed cover in annual grasslands was significantly higher than in oak woodlands and is likely related to continued disturbance from cattle grazing. Unfortunately, because of the proximity of annual grasslands to oak woodlands, they provide a potential threat of invasive weed invasion into oak woodlands. Also, cattle tend to rest in the shade of oak woodlands and both ruminate and defecate in place, serving as a vector for these weeds.

Noxious and invasive weed species composition in oak woodlands and annual grasslands was almost identical, only the frequency of occurrence and percent cover differed. Cheatgrass (*Bromus tectorum*) had the highest frequency of occurrence in both oak woodlands (20 percent) and annual grasslands (45 percent). Medusahead (*Taeniatherum caput-medusae*) was second in frequency of occurrence, 26 percent in the annual grasslands and < 1 percent in oak woodlands. Klamathweed (*Hypericum perforatum*) was third in frequency of occurrence. It was found in 15 percent of the annual grassland plots and 4 percent of the oak woodlands. Yellow starthistle (*Centaurea solstitialis*) was found in 8 percent of the annual grasslands and 2 percent of the oak woodlands. Bull thistle (*Cirsium vulgare*) was the only invasive weed found with higher frequency in the oak woodlands (5 percent), compared to annual grasslands (1 percent) *(table 7)*. The shade intolerance of most of these species acts as a limiting factor to their success in oak woodlands.

No significant difference (P=0.175) in invasive weed cover was found by oak woodland series. However, when plant associations within the series were compared, significant differences in invasive weed cover were noted (P=0.001). Plant associations containing gray pine and hedgehog dogtail had higher frequencies of invasive weed occurrence than all other types.

Oak woodland sites containing noxious and invasive weeds had significantly higher bare ground (P=0.05), higher surface gravel and rock cover (indicative of disturbed surfaces) (P=0.009), thinner A horizons (P=0.017), lower available water holding capacity (P=0.05), as well as lower canopy cover (P=0.001) and higher cover of early seral grass species (P=0.002). These attributes increase the potential for successful noxious and invasive weed encroachment.

The low frequency and cover of invasive weeds in oak woodlands is likely due to the low extent of surface disturbance and higher canopy cover, particularly when compared to annual grasslands. Management that maintains high litter cover or limits the development of bare ground will likely reduce the potential for new infestation sites. Where small colonies exist, they can be controlled through a variety of strategies. These might include direct removal of plants, use of fire, biological controls, seasonally timed, close livestock grazing, and use of herbicides.

Table 7—*List of noxious and invasive weeds found in northwest California oak woodlands and annual grasslands, including frequency of occurrence.*

Layer	Species name	Oak woodlands pct of plots	Annual grasslands pct of plots
Forb	*Centaurea melitensis*	0.2	1
Forb	*Centaurea solstitialis*	2	8
Forb	*Cirsium vulgare*	5	1
Forb	*Convolvulus arvensis*	0.2	4
Forb	*Euphorbia* sp.	0.2	0
Forb	*Hypericum perforatum*	4	15
Forb	*Melilotus alba*	0.5	0
Forb	*Mentha pulegium*	0.7	0.5
Forb	*Verbascum thapsus*	1	0
Grass	*Bromus tectorum*	20	45
Grass	*Taeniatherum caput-medusae*	0.7	26

Discussion/Conclusions

The oak woodlands of northwest California were found to be dominated by white oak, black oak or blue oak. They were found in near pure to mixed stands that had high diversity in species, particularly in the forb and grass layers. This was reflected in some of the highest species richness found in the northwest corner of the State. Specifically, oak woodlands had significantly higher species richness than annual grasslands, meadows or chaparral vegetation types. Species richness in oak woodlands appeared to be influenced by overstory canopy cover and was highest in the blue oak woodlands, the vegetation series with the lowest mean canopy closure.

The oak woodland series were arrayed along moisture and temperature gradients that included precipitation, distance to the ocean, position along the north/south gradient, summer precipitation, slope percent, elevation and radiation index. These significant environmental variables best explained the diversity in the oak woodland series.

The oak woodlands had both higher cover of native grasses and lower cover of non-native grasses when compared to annual grasslands. In contrast, the oak woodland forb layer had lower cover of both natives and non-native species. Overall, oak woodlands had low cover in both late and early seral grass and forb species. However, oak woodland seral status was much higher than for annual grasslands, where most of the cover was in early seral species.

Oak woodlands had a much lower frequency of invasive weeds when compared to annual grasslands. If treated while their numbers remain low, they have a much higher potential for control than in annual grasslands. Overall oak woodland ecological status would be rated as moderate due to the near equal cover of grasses in the native and non-native species categories and the variable early seral cover and low late seral cover of both forbs and grasses. However, when oak woodlands are compared to annual grasslands, oak woodlands are clearly in a much higher ecological state because of their higher ratio of native to non-native species and lower cover of early seral species. The same conclusion was drawn in the comparison of invasive weed cover in oak woodlands and annual grasslands.

Although site specific threats to northwest California oak woodlands are fewer than those identified in annual grasslands, several were identified in this study. These include:

- Potential loss in biodiversity as a result of competition from invasive non-native species and understory invasion by conifer species;
- Potential soil productivity loss as a result of surface disturbance from livestock grazing and non-native grass species invasion;
- Increased cover of noxious weeds in conjunction with b; and
- Potential negative impacts on ecological processes through altered fire regimes.

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