Inventory of Oaks on California's National Forest Lands[1]

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Abstract

California has 18+ million acres of land owned by the USDA Forest Service. This is almost 20 percent of the area of the state. From 1994-2000 the Region 5 Remote Sensing Lab collected forest, vegetation and fuels inventory data from thousands of permanent monitoring plots established on diverse sites on Forest Service lands throughout the region. The plots are stratified among 165 vegetation types, or strata. Collectively, these data are known as the Regional Forest Inventory and Analysis (FIA) database. An analysis of the plot data for California's oak, including species, distribution and stocking is presented.

These wild lands are rich in many species of oak. Based upon the FIA survey, there are 433 million (+/– 1 percent) oak trees over 5 inches in diameter on Forest Service lands in California. Eleven percent of all trees on the Region 5 ownerships are species of the genus *Quercus* or *Lithocarpus*. They can be expected to be encountered on 87 strata which collectively occupy 11.5 million acres of land. Sixty-three strata, together comprising 6.6 million acres, have combined average oak basal area greater than 5 square feet per acre.

Introduction

The Region 5 Remote Sensing Lab of the USDA Forest Service, in accord with directives of the National Environmental Policy Act and the 1998 Farm Bill, collected consistent forest, fuels and vegetation inventory data from a sampling grid of cluster plots throughout the national forest lands in California. This program is known as Regional Forest Inventory and Analysis (FIA). The Region 5 FIA database for California, completed in 2000, is the only extensive, systematic and consistent region-wide dataset of its kind. The database is available to the public in compiled and raw formats and is useful for a wide variety of vegetation survey and data analysis applications.

Methods

Data were collected across the landscapes on all forest types at 18,435 sample point locations on approximately 3,800 "cluster plots." Each 1-hectare cluster plot includes 4-5 sample point locations. At each point vegetation cover type, tree data,

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understory vegetation data, and duff/woody debris data were recorded. A global positioning system (GPS) location was collected at the center point of each plot where possible. Once completed, quality control teams of experienced foresters and biologists visited a random sample of more than 10 percent of the plots to assure accurate data collection. Detailed methodology is described in the Region 5 FIA Field Manual (USDA 1999).

USFS Remote Sensing Lab (RSL) personnel assigned vegetation type strata labels to every sample point. The strata labeling is based on CALVEG, a vegetation type map developed from LandSat Thematic Mappper data (30 meter) using image processing techniques developed at RSL, Boston University and San Diego State. In forested strata the overall vegetation cover types were further refined via aerial photo interpretation, field data interpretation, and ground verification. For conifer types strata labels were assigned which consist of a Regional CALVEG Type label, a crown size class label and a density designation (USDA Forest Service 2001). For hardwood, shrub and other non-forest types the first letter of the stratum label characterizes the vegetation form (shrub, tree, rock, etc.) and the latter 2 letters are the CALVEG type code (USFS 2001, see *table 1* footnote). Overall accuracy of the final maps was determined via an independent accuracy assessment. One hundred sixty-five strata distributed over 18,555,998 acres were identified by the USFS image processing and mapping team. There is a direct crosswalk between Wildlife Habitat Relations (WHR) and CALVEG labels and so the stratified maps and field data can be used in both contexts.

Based on the mapping team's efforts, we used the Geographic Information System (GIS) database to calculate total acreage for each of the 165 strata. Thirty-two of these strata comprise less than 10,000 acres each and, together, they make up less than 0.75 percent of the land area. These strata were removed from the analysis because of high standard errors resulting from low sample size. Another 131,000 acres of lakes was removed from the sampling area, leaving a total of 18,297,000 acres made up of 132 strata listed below *(table 1)*. Together they include 99.25 percent of Region 5's land ownership.

Table 1— *The 132 Selected Strata with Acreage of each.*

Stratum[4]	Acreage	Stratum	Acreage	Stratum	Acreage
A2P	41545	I3G	85308	P4P	25643
A3N	174328	I3N	12842	PNO	27583
A3P	226572	I3X	31847	R2N	23743
A3S	83783	IQC	417714	R2P	43119
A4N	14967	IQD	88724	R3G	89617
AXX	28460	IQG	76583	R3N	399754
C3N	26786	IQQ	21174	R3P	151765
C4N	35135	IQW	48437	R3S	23326
D2N	36208	J2S	12073	R4G	99258
D2P	36439	J3G	13193	R4N	138363
D3G	211768	J3N	130323	UAX	152115
D3N	334314	J3P	150674	UBA	753917
D3P	211060	J3S	38158	UBB	41525
D4G	549975	J4G	24303	UBS	626036
D4N	273039	J4N	46994	UDX	177356
D4P	43966	J4P	49887	UGR	46259
D4S	21284	K2N	34581	UHG	170721

Stratum[4]	Acreage	Stratum	Acreage	Stratum	Acreage
D5G	42641	L3G	16019	UHJ	30175
D5N	38587	L3N	146429	USB	136805
E2N	83625	L3P	40938	USS	86250
E2P	120142	L3S	40473	W2N	10857
E3N	324729	M0X	10127	W3G	29866
E3P	148680	M2N	103648	W3N	131558
E4N	23884	M2P	67045	W4G	36491
E4P	32714	M3G	268913	W4N	83919
F2G	10356	M3N	385551	XC1	24016
F2N	90621	M3P	91497	XCM	140415
F2P	41774	M3S	35317	XCV	33120
F3G	283750	M4G	495981	XCX	310964
F3N	769972	M4N	295068	XNO	299825
F3P	148447	M4P	54536	ZAX	15675
F3S	13835	M4S	28243	ZBB	102104
F4G	385210	M5N	20087	ZBL	144662
F4N	279152	MNO	45526	ZBM	107653
F4P	13095	N2N	76609	ZBS	412762
FNO	10584	N2P	156329	ZCA	303720
H2G	40113	N2S	60864	ZCC	190604
H3G	80040	NPJ	710226	ZCD	20694
H3N	26474	P2P	11949	ZCH	78959
H3X	18145	P3G	52471	ZCQ	1570426
HQK	152234	P3N	150149	ZCR	86614
HQT	61904	P3P	124066	ZCS	57370
I2G	89149	P4G	82492	ZCT	66746
I2N	114262	P4N	48869	ZCZ	98519

[4]Key to Strata Labels:

1. First digit: Regional CALVEG Type Label (for all strata)

A alpine	L lodgepole pine
C coulter pine	M westside mixed conifer
D Douglas-fir	N pinyon-juniper
E eastside pine	P ponderosa pine
F eastside mixed conifer	R red fir
H hardwood (productive)	U non-forest
I hardwood (non-productive or shrub)	W white fir
J jeffery pine	X shrub type (productive)
K knobcone pine	Z shrub type (non-productive)

2. For Conifer and Commercial Hardwood Strata:

Second digit: Size Class 0=seedling, 1=sapling, 2=small poles, 3=small sawtimber, 4=large sawtimber, 5=very large sawtimber

Third digit: Density Class 0=1-10% canopy cover S = 10-25% P= 25-39%
N = 40-59% G = 60%+

3. For non-productive Hardwood and Shrub Strata:
No size class and density is provided. The second and third letters are the CALVEG type labels (USDA Forest Service 2001).

Data for all trees greater than 5 inches diameter at breast height (dbh) were extracted from the statewide database. Raw data were broken down into 132 separate strata for analysis. Stratified data were then processed to yield number of live trees per acre and the basal area for all species encountered. We further calculated the basal area by position (Dominant, CoDominant, Intermediate/Suppressed), the standard error of the total basal area for each stratum, and the standard error of the

overall mean. A summary was created for each stratum, with estimates of variance, and coefficient of variation. Because the statistical summaries for some of the individual strata revealed some standard errors in the 12-20 percent range, all 18,000+ sample points distributed across the landscape were pooled to estimate total tree number of oaks by species, and the overall oak population.

Results

Although forest characteristics within a single stratum may indeed vary considerably due to diverse geographic, edaphic, ecological and climatic conditions, stratification provided a good means to calculate the statewide USFS oak population from real plot data evenly distributed and sampled from stands throughout each regional stratum.

Trees of all sizes were measured during the inventory and are available within the Region 5 FIA database. However, only those trees 5 inches in diameter at breast height are considered in this report. Therefore this analysis ignores the shrub oak populations, which are very common in the Southern California chaparral types.

Community associations of different oak species growing together are found at many sites. Ten types (1.15 million acres) support combined oak populations with basal areas of 50 square feet per acre and greater.

Black Oak

Black Oak (*Q. kelloggii*) appeared as greater than 5 percent of the stand basal area in 40 of the 132 types, together comprising 4,321,000 acres or 25 percent of Region 5 Forest Service lands. Although USFS has 152,000 acres of forest lands classified as a black oak stratum (HQK) it never represents more than 50 percent of the basal area in any stratum. In the HQK type black oak accounted for only 29 percent of the basal area, 27 percent by number of trees, and 52 trees per acre. On 939,000 acres of land black oak is greater than 20 percent of the total basal area. The overall stratified estimate is that there are 105 million (+/– 5.1 percent) black oak trees greater than 5 inches in diameter growing on California's Forest Service lands *(figure 1).*

Canyon Live Oak

Canyon live oak (*Q. chrysolepis*) is the most widely distributed oak on Region 5 lands. It occurs as more than 5 percent of the stand by basal area in 54 of the 132 strata, together occupying 6.9 million acres or 40 percent of Region 5 lands. In 21 types together occupying 2.3 million acres of land this species comprises greater than 20 percent of stand basal area. There are 417,000 acres of a hardwood canyon live oak type averaging 72 canyon live oaks and 29 black oaks per acre. In addition canyon live oak is abundantly represented in Southern California chaparral types, as an understory species on the west side of the Sierra Nevada and throughout the coast range (accounting for the very high "seedling" or advance regeneration count in this species). The inventory showed an overall population of 212 million (+/– 3.8 percent) canyon live oak trees 5 inches dbh (*figure 2*).

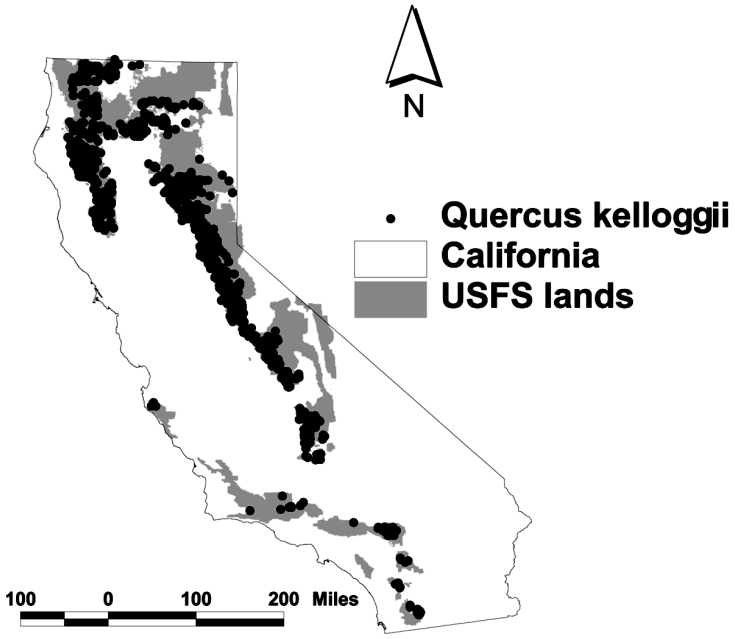

Figure 1—Black Oak on NFS Land.

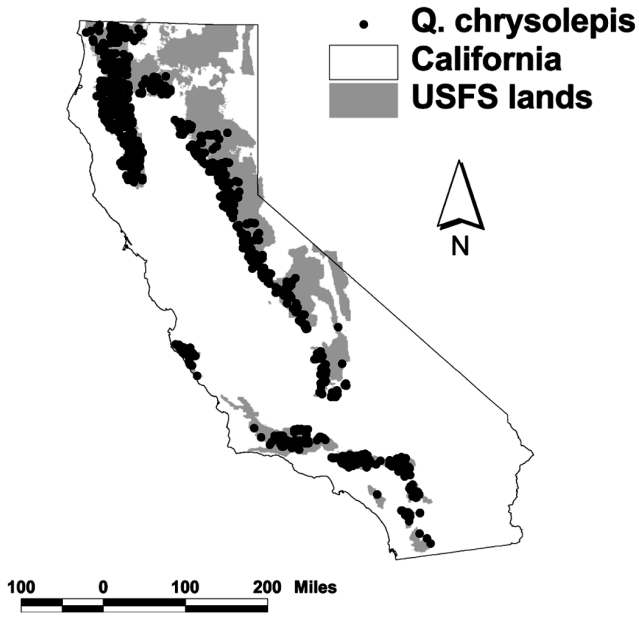

Figure 2—Canyon Live Oak on USFS Lands.

Interior Live Oak

Interior live oak (*Q. wislizenii*) is less widely distributed on Region 5 lands with an overall population of 20 million (+/– 11.4 percent) trees. There are 8 strata, totaling 1.17 million acres, where interior live oak represents greater than 5 percent of the total basal area and only a single type (IQD) of 88,000 acres where there is a basal area of more than 10 square feet per acre of interior live oak. The IQW type (48,000 acres) has a basal area in that species of only 6.5 square feet per acre. The species is mostly found with canyon live oak, blue oak, and black oak. It is rare in conifer stands (*figure 3*).

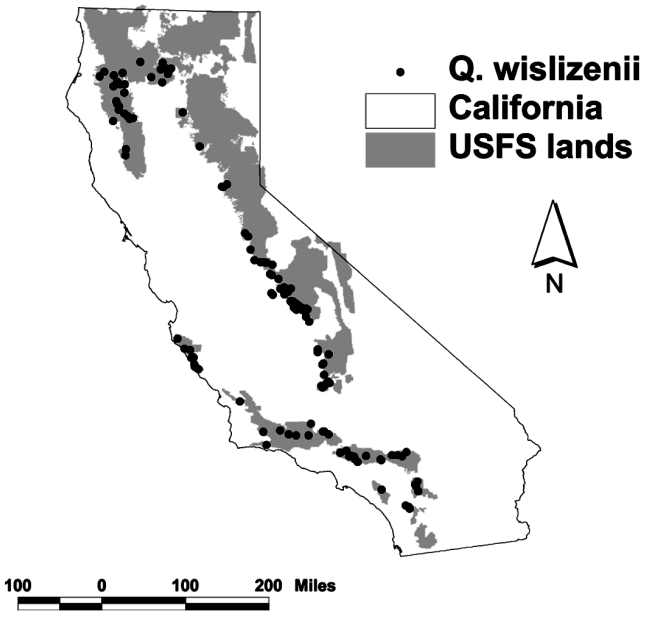

Figure 3—Interior Live Oak on USFS Lands.

Oregon White Oak

Oregon white oak (*Q. garryana*) forests occur sporadically in the IQG type on 76,000 acres of the project area, all in the north coast. Oregon white oak accounts for more than 5 percent of the basal area in 4 strata, together totaling 273,000 acres. There are also thickets of the shrub form, known as Brewer oak (*Q. garryana var breweri*), coded as brushlands, on the Sierra and Sequoia National Forests in the Southern Sierra, and in the northern Coastal Range forests. This species extends north throughout Oregon, Washington and into British Columbia. Interestingly Oregon white oak occurs very sparsely in a great variety of forest types in Northern California. The stratified inventory yielded 24.5 million trees (+/– 11.4 percent, *figure 4*).

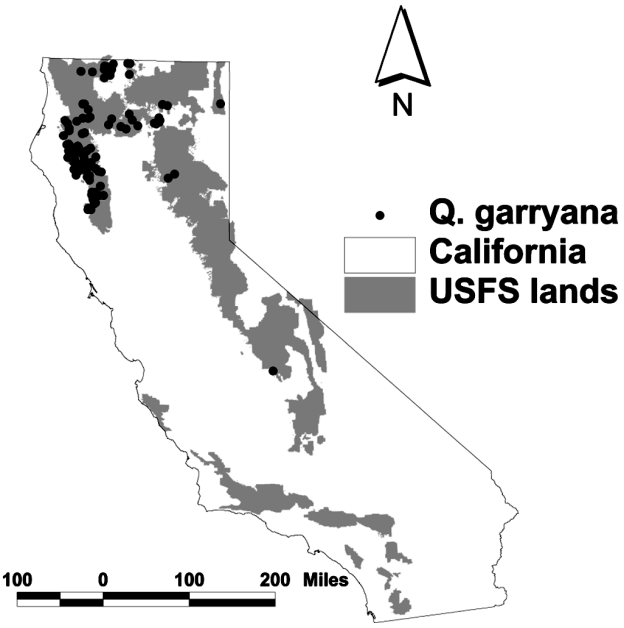

Figure 4—Oregon White Oak on NFS Lands.

Tanbark Oak

Tanbark oak (*Lithocarpus densiflorus*) forests occur at lower elevations on the Plumas and Tahoe National Forests where there are 62,000 acres in the hardwood stratum HQT. In all there are 11 strata, together totaling 928,000 acres of land, where tanbark oak is greater than 5 percent of total basal area. Tanbark oak also occurs as a shrub in the understory of a large variety of coniferous forest types. Tanbark oak occurs in far greater abundance along the more coastal areas of Northern California, where 100 percent stands of this species occur frequently. There are some such stands on USFS lands in the lower elevation forests of the Plumas National Forest in the Feather River basin near Oroville. In those locations the high density of tanbark oak is such that, although relatively minor in extent, there is an overall population of 59.5 million trees (+/– 15.4 percent >5 inches dbh, *figure 5*).

Blue Oak

Blue oak (*Q. douglasii*) is common on ranch lands in the Central Valley and adjacent foothill woodlands. The species does not reach significantly onto Forest Service lands, where it is very rare. The US Forest Service owns 88,000 acres of lands classified as blue oak woodland, located mostly in the lower Kings River and San Joaquin River basins. There are 48,000 acres of land classified as an interior live oak type (IQW) where blue oak is a minor component. Blue oak is also sparsely represented in isolated patches in some of the chaparral types. The stratified inventory yields 5.3 million trees (+/– 14.8 percent, *figure 6*).

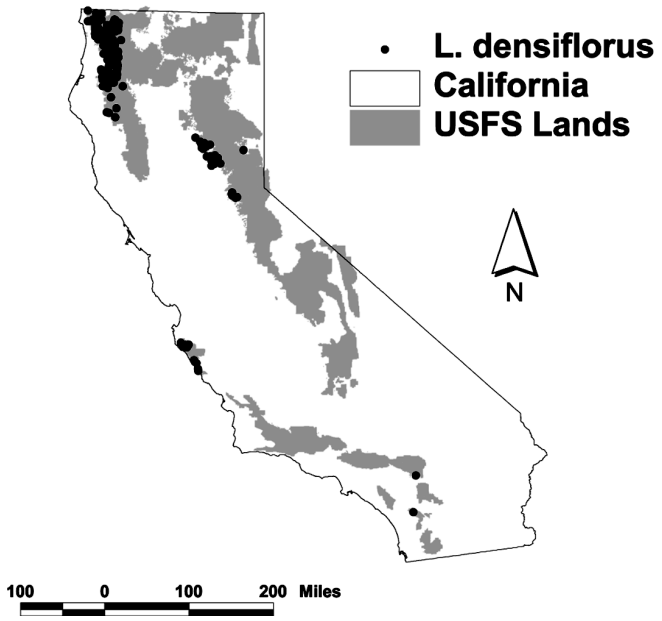

Figure 5—Tanbark Oak on USFS Lands.

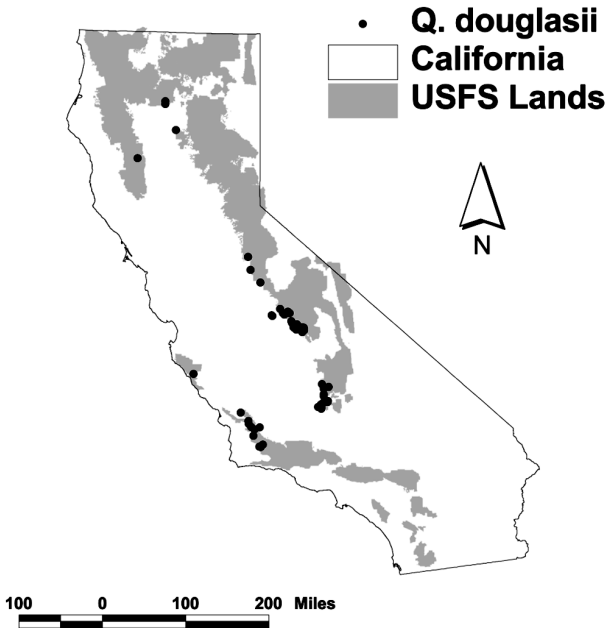

Figure 6—Blue Oak on USFS Lands.

Coast Live Oak

Coast live oak (*Q. agrifolia*) comprises more than 5 percent of the basal area on 7 woodland strata which together occupy approximately 342,000 acres. Of that, the species is sparsely represented in the Southern and Central California chaparral and coastal scrub (Los Padres National Forest) on 201,000 acres of open and canyon hardwood lands characterized by low basal area. These are the I2G, I3G, and C3N types where coast live oak basal area varies from 10-23 square feet per acre. Coast live oak is a very minor component of an additional 1.12 million acres within 8 other chaparral and conifer strata, mostly on the Southern California National Forests, where it occurs sporadically in clumps less than one hectare in size, below the size of the minimum mapping unit. The inventory yielded 6.5 million trees (+/– 14.2 percent >5 inches in dbh, *figure 7*).

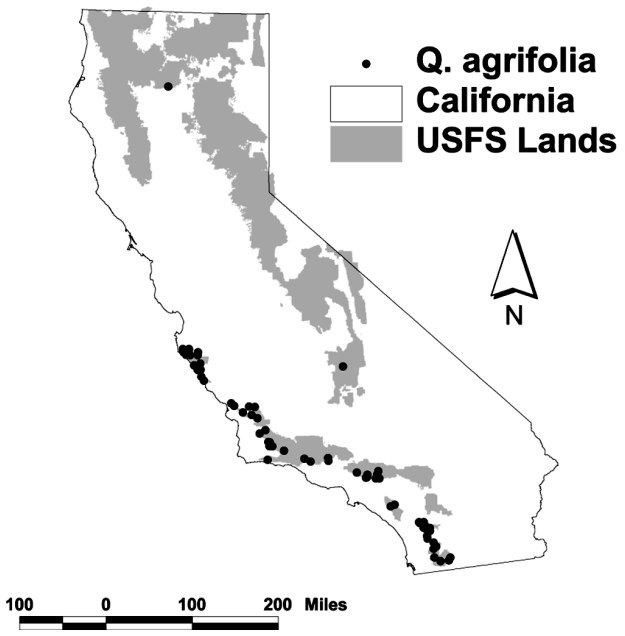

Figure 7—Coast Live Oak on USFS Lands.

Crown Position

Black oak, canyon live oak and interior live oak are often observed crowded among faster growing conifers, where they are gradually losing access to direct sunlight. By basal area 12 percent of these trees were in dominant positions relative to their immediate neighbors in the stand while 61 percent were co-dominant and the remaining 27 percent were intermediate or suppressed. By comparison, when white fir, incense cedar and sugar pine (the most shade tolerant species and low to mid-elevations) were evaluated, 34.6 percent of those trees were in dominant positions and 45.6 percent more were in co-dominant positions. These data suggest that oaks may be struggling to retain their vigor in stands where they grow among the more aggressive conifers. Shade tolerant conifers such as white fir (*Abies concolor*) and incense cedar (*Calocedrus decurrens*) in mixed conifer stands, and invasive Douglas-fir (*Pseudotsuga menziesii*) in oak woodlands, seem to outcompete oaks of all

species. This is most likely due to fire suppression and a changing climate, which is yielding hotter, moister years throughout the Region, probably not favoring oak species.

The Census

Overall, oak trees over 5 inches in diameter can be expected to be encountered in 87 strata together comprising 11,552,000 acres, or almost 2/3 of California's national forest lands. Because oak trees were sampled infrequently on many of these strata, the standard error of the basal area estimate had high variance in some of the strata with very minor oak populations. However, there are 63 strata with combined average oak basal area greater than 5 square feet per acre, together comprising 6.66 million acres of Region 5 lands. The overall oak population (of trees 5 inches and larger) on those lands is 394,422,000 trees with a weighted by basal area average of 9.8 inches dbh. When the data are processed on a non-stratified basis (e.g. all the plots combined and processed as a unit) they show a total oak population also of 433 million oak trees (*figure 8*). This estimate has a standard error of 3.0 percent. This indicates that, although stands are highly variable, the more than 18000 sample points create a stratified inventory of high precision when queried for aggregate population estimates.

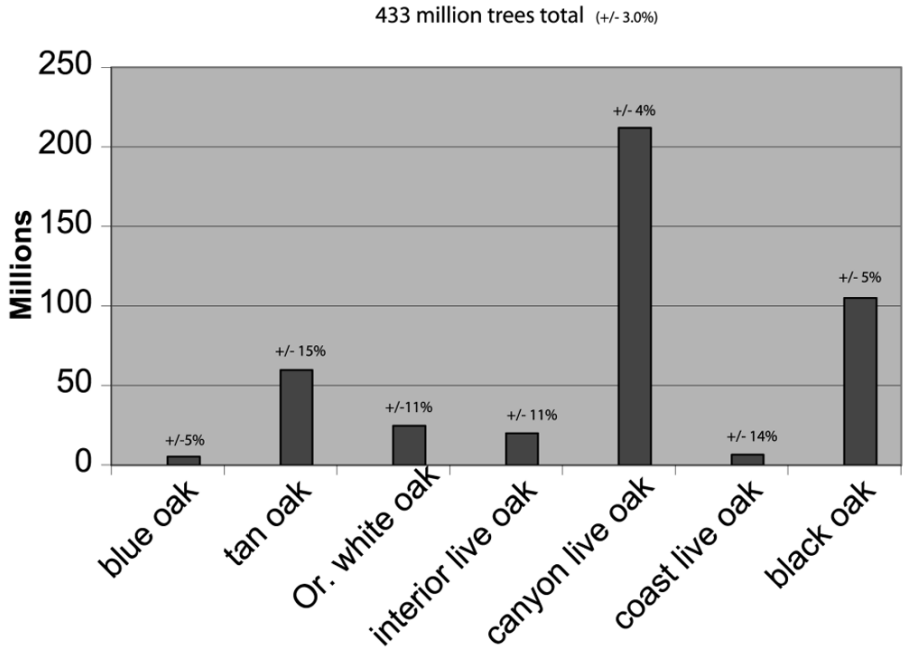

Figure 8—Number of Oaks >5 inches dbh on USFS Region 5 Lands.

Diameter Distribution

Processing the data by diameter class reveals that 18.5 trees per acre, or 74.2 percent of the oaks, are in the 5-10 inch diameter classes *(figure 9)*. A further 5.6 trees, or 22.7 percent are, in the 10-20 inch diameter classes. In the larger size classes

2.5 percent of the trees, as measured by number of trees (not by basal area) are in the 20-30 inch classes. A tiny fraction (0.5 percent) is in the 30+ inch group. This is the typical J-curve, however it falls off exceedingly rapidly, indicating the importance of preserving large oak trees in our native California forest.

When the data are processed by species the oak trees range in average diameter, weighted by basal area, from 8.8 inches (interior live oak) to 13.9 inches (coast live oak).

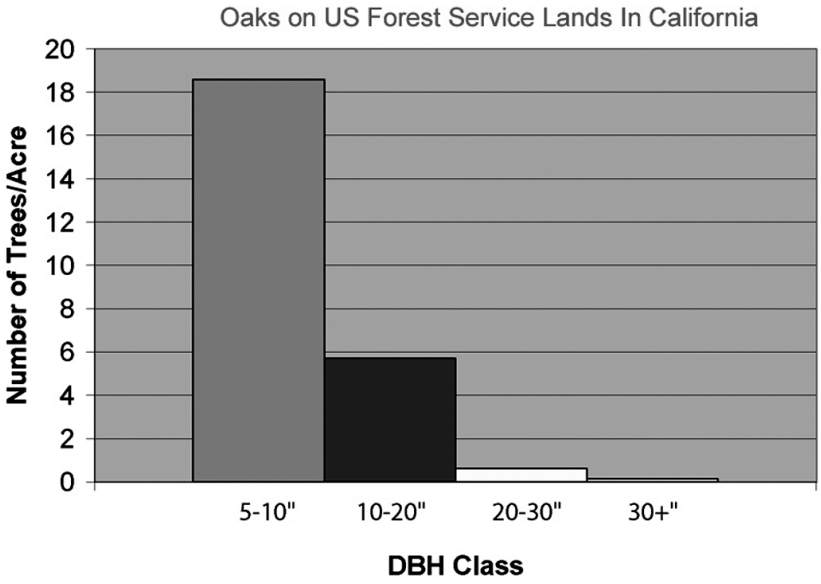

Figure 9—Oak Diameter Distribution.

Largest Trees

Analysis of the data shows that the largest trees actually measured during the inventory project were as indicated below:

Species	Max DBH (inches)
Black oak	60.6
Coast live oak	68.8
Canyon live oak	68.0
Interior live oak	39.2
Oregon white oak	54.2
Tanbark oak	50.5

Regeneration

Combining regeneration data across the entire region confirms our field observations that oak regeneration, while highly variable, is very common in the

forest understory. Most abundant are canyon live oak with an average of 57 trees (less than 1 inch in diameter and greater than 6 inches in height) per acre and California black oak with an overall regeneration of 28 trees per acre. Both of these species range throughout California's National Forestlands except in the high Sierra and the east side types. Regeneration of other species was encountered irregularly. Having visited thousands of these survey points, it is clear to us that that there is abundant "advanced regeneration" of oak seedlings that can respond to fire or other canopy removing events.

Comparisons with Other Inventories

The Pacific Northwest Research Station (PNW) conducted independent inventories of private lands in California in the 1990's (Waddell and Bassett 1997). Although their figures are published only for timberland by county groupings known as "Resource Areas," the data are readily consolidated in a spreadsheet. A review of that inventory for black oak and canyon live oak (by far the most abundant oaks) on private timberland in 3 applicable Resource Areas (totaling 40 California counties) indicates an estimate of 142 million oak trees on 4.7 million acres, or just over 30 oaks per acre. That estimate is consistent with our estimate (25 trees per acre) as presented here considering the fact that the 18+ million Forest Service acres of our review area includes non-stocked and poorly stocked shrub lands, generally of lower site, that were not included in the PNW "timberland" inventory.

Summary

This report generalizes oak populations for U.S. Forest Service lands in California where oaks account for 11 percent of all the trees. This analysis does not consider tree ages, smaller oak trees or shrub types. Further regional analysis of the FIA oaks data is certainly necessary. More detailed analysis of oaks or other species by forest, ranger district or other area can be generated using ForestServer shareware by Gaman (2000).

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