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Old-Growth Forests in the Sierra Nevada: By Type in 1945 and 1993 and Ownership in 1993

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Abstract

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This report presents estimates of old-growth forest area in the Sierra Nevada by forest type in 1993 and 1945 and by old-growth stand characteristics as they existed in 1993. Ecological old-growth definitions for each forest type are used.

Keywords: Old growth, inventory, forest stands, forest area, California, National For ests, Douglas-fir, white fir, red fir, Jeffrey pine, ponderosa pine, lodgepole pine, mixed conifer, mountain hemlock, mixed subalpine.

Summary

In 1993, old-growth coniferous forests in the Sierra Nevada covered about 1.6 million acres, 15 percent of the total area of coniferous forests. Three-quarters of the old growth was in high-elevation forest types, the forests that generally have been least affected by logging, mining, development, and catastrophic fire. Of the 4.8 million acres of mixed-conifer forests in the Sierra Nevada, 371 thousand acres (8 percent) were old growth. Almost all the old growth was in Federal ownership, mostly National Forests and National Parks. Surprisingly, most of the old growth in National Forests was outside designated wildernesses. Less than 2 percent of the 3 million acres of privately owned coniferous forests was old growth.

For the 85 percent of the forested landscape outside parks and wilderness, the old growth area estimate was based on inventory data collected from a statistical sample of 2,455 ground plots measured in 1991-93. Each plot was classified into a Society of American Foresters forest type and then screened against the ecological definition of old growth for that type to see if it qualified as old growth. Old-growth definitions were developed by California ecologists for each of the forest types and up to three site classes. The definitions used stand structure characteristics (number of large trees, snags, and logs per acre).

A statistical sample of ground plots was not available for National Forest wildernesses; Bureau of Land Management wildernesses; Lassen, Sequoia-Kings Canyon, and Yosemite National Parks; and state and county parks. These reserves compris e 15 percent of the forested landscape. The estimate of old growth in the parks and Bureau of Land Management wildernesses (about 7 percent of the landscape) was obtained from a map developed by the Sierra Nevada Ecosystem Project in its 1996 assess ment of late-successional forests in the Sierra Nevada. An estimate of old-growth area in National Forest wildernesses (about 8 percent of the landscape) was derived by applying the proportion of each stratum of each National Forest planning unit that was classified as old growth (based on the ground sample of forests outside the wilderness areas) to the same stratum inside the wilderness areas of that particular National Forest.

From a 1945 mapping project, it was determined that old-growth stands at that time amounted to 45 percent of the pine, fir, and mixed-conifer forests in the Sierra Nevada. In comparison, old growth amounted to 11 percent of these types in 1993. The change is considered approximate because of procedural differences between past and current inventories. Other changes between 1945 and 1993 included a marked increase in the true fir type and a comparable decrease in the pine type.

Contents

Introduction

Old-growth forests were given prominence in the reports of the first comprehensive forest assessments of California, Oregon, and Washington that were conducted over 50 years ago (Andrews and Cowlin 1940, Cowlin and others 1942, Wieslander and Jensen 1946), and well they should have. Half of the forest area in these three states was occupied by old growth. In California, the first inventory, completed in 1945, showed that 9.5 million acres-48 percent of the total "timber cropland" in the state-were occupied by virgin old growth. The term "virgin" was used by Wieslander and Jensen (1946) not for poetic purposes, but to distinguish these impressive uncut forests from the 3.8 million acres of forests partially logged or disturbed by mining activities (Gruell 1996), or otherwise affected by insects, disease, fire, and storms, and still containing a signifi cant component of old growth-20 to 50 percent of the canopy. In other words, forests containing old-growth trees amounted to 13.3 million acres or 66 percent of California's "timber cropland".

The primary interest in old-growth forests in the first half of the 20th century had to do with commodity values, and as late as the mid-1970s the emphasis of forest manage ment on private and nonreserved public lands in the Pacific Coast States was on "conversion" of old-growth forests to managed forests harvested at relatively short intervals. As the area of old growth decreased, interest in these forests for noncommod ity values increased dramatically (Haynes 1986). Relatively few scientists had been concerned with unders tanding the ecology and dynamics of old forests, because it had been assumed by most decisionmakers that old growth soon would be confined mostly to parks and wilderness. Policy changed rather suddenly in the mid-1980s as the focus shifted from old-growth conversion to maintaining old growth for wildlife habitat, biological diversity, and other ecosystem values. With the change in policy came the need for scientific information, including old-growth inventory data (Ruggiero and others 1991). Most owners or managers of old-growth forests kept inventory records, but there were gaps, and a remarkable inconsistency in what different people considered to be old growth, even for the same forest type in the same area. An interim old-growth definition was developed for Douglas-fir and mixed-conifer forests' in California, Oregon, and Washington (Old-Growth Definition Task Group 1986). This definition was used to make the first approximation of old-growth area on Federal lands. Still, in responding to a 1992 congressional request for area of old growth in all ownerships in reserved and unreserved areas, Bolsinger and Waddell (1993) found more than 10 different defini tions applied to one forest type. Some agencies had used the ecological definition available at the time, but others had simply classified by age. Stands as young as **150 and 160** years were defined by two agencies as old growth. Others drew the line at 200 years but did not use stand structure elements in the definition. One agency, with several small parcels of forest, classified old growth based on casual drive-by and walk-through examination. Ecological definitions are now available for most West Coast forest types. Their application usually requires some detailed information available only from ground-level examination, although aerial photographs and satellite imagery can provide a gross estimate of the outside limits of old-growth area.

Estimating old-growth area, and tracking changes in old-growth area over time are more straightforward in the Douglas-fir forests of northwestern California and western Oregon and Washington than in the mixed-conifer forests of the Sierra Nevada. Much of

'Scientific names for all plant species are given in appendix C.

the old-growth Douglas-fir has been harvested by clearcutting, and the change from late to early successional stage in such areas is unequivocal and obvious from any angle or altitude. In the mixed-conifer forests of the Sierra Nevada, however, forests are primarily harvested by tree selection, and many stands in which trees have been removed one to several times over the decades still contain many large trees. These stands often appear to be old growth from the air and from adjacent hillsides (Gruell 1996) and could be classified as old growth on the basis of age of the residual dominant trees. Bolsinger and Waddell (1993) found 1.2 million acres of such stands statewide in private ownerships; Wieslander and Jensen (1946) found 2.0 million acres of such stands in private ownership in 1945.

This study presents the results of applying ecological old-growth definitions to 2,455 forest plots where the elements of the ecological old-growth definitions were measured. Plots on National Forest land were established by the Pacific Southwest Region of the USDA Forest Service, and plots on lands outside National Forests and parks were established by the USDA Forest Service, Pacific Northwest (PNW) Research Station. These plots contain detailed measurements of trees, snags, down logs, and understory vegetation and are established as permanent locations. Remeasurement of these plots could provide information on change in old-growth area over time as well as change in species composition and stand structure.

Study Area and Forest Land Categories

The study area is shown in figure 1. It consisted of all public and private land. Forest land was defined as land capable of growing at least 10 percent cover of trees and not developed for nonforest use. The study concentrated on the coniferous forests; old growth in the oak and pinyon-juniper woodlands within the study area was not assessed. Coniferous forest was defined as forest land capable of growing 10 percent cover of conifer species, excluding juniper and pinyon pine. Reserved land included forest land in National Forest wildernesses, Bureau of Land Management (BLM) wildernesses; Lassen, Sequoia-Kings Canyon, and Yosemite National Parks; and other public and private reserves. About 15 percent of the forested landscape in the Sierra Nevada is in these reserved areas.

Figure 1—The Sierra Nevada study area in California.

Methodologies for the Current Assessment

Unreserved Lands

The data for unreserved land in the study area (85 percent of the forested landscape) came from the most current National Forest inventories conducted by the Forest Inventory and Analysis (FIA) program (USDA Forest Service 1994) and the recent PNW Research Station inventory of private and public unreserved lands outside National Forests (Waddell and Bassett 1997a,1997b,1997c).

The National Forest inventories-Forest inventories of the Eldorado, Inyo, Lassen, Modoc, Plumas, Sequoia, Sierra, Stanislaus, and Tahoe. National Forests and Lake Tahoe Basin Management Unit were conducted between 1991 and 1995 (USDA Forest Service, 1994). These National Forests covered about 40 percent of the forested landscape of the Sierra Nevada study area. Although different types of plots were used in these inventories, the designs were similar in the following ways: All inventories used a stratified random sampling design, and information on trees, down logs, snags, and understory vegetation was collected on all plots. Vegetation was mapped by using remote sensing methods, including the classification of 30-meter thematic mapper imagery, geographic information systems (GIS) modeling, and photo editing using 1:15,840 or larger scale color aerial photography. Plantations, harvest, and fire areas were mapped with Systeme Probatoire d'Observation de la Terre (SPOT) 10-meter panocromatic imagery, which was combined with the vegetation maps by using GIS integration methods. Land in National Forest ownership was divided into homogenous stands of 5 acres or larger. Each stand was labeled as to major land class, forest type, tree crown size, and tree crown closure. These characteristics defined the stratum. A total of 1,907 ground plots sampled the unreserved coniferous forest strata in the National Forests. The area expansion for each plot was determined by dividing the number of acres in the stratum of a particular National Forest by the total number of plots in that stratum. These plots and their expansion factors were used to compile the area of coniferous forests by size class and type and to estimate the extent of old growth on unreserved lands in the National Forests.

In all the National Forest inventories, species, diameter at breast height (d.b.h.), and height of trees and snags were measured or estimated into size classes; and species, large-end diameter, and length of down logs were measured or estimated into size classes. For shrubs, forbs, and grasses, percentage of cover and height were recorded for the three most abundant understory species. Site index was determined for each stand.

The field plot design for the Modoc, Lassen, and Inyo National Forests consisted of a five-point cluster of points that covered an area of about 2.5 acres. At each point, a variable-radius prism plot was used for tallying trees 5 inches and greater in diameter, a 1/100 of an acre circular fixed-area plot for trees less than 5 inches in diameter; a 1/8 of an acre circular fixed-area plot for dead trees between 5 and 19.9 inches in diameter and down logs 10 inches and greater in diameter; and a 1/4 of an acre circular fixedarea plot for very large trees (the minimum size depended on the basal area factor used for the variable-radius prism plot), snags 20 inches in diameter and greater, and understory vegetation.

The Plumas, Eldorado, Stanislaus, Tahoe, Sierra, and Sequoia National Forests and Lake Tahoe Basin Management Area were inventoried with a field plot design that consisted of a 10-point cluster of points covering an area of about 5 acres. At each point, a variable-radius prism plot was used for tallying trees 5 inches and greater in diameter; a 1/8 of an acre rectangular fixed-area plot for dead trees between 8 and 19.9

inches in diameter and down logs 10 inches and greater in diameter; a 1/4 of an acre rectangular fixed-area plot for snags 20 inches and greater in diameter; and a 1/2 of an acre circular fixed-area plot for understory vegetation. In the Plumas, Eldorado, Sierra, and Lake Tahoe Basin inventories, a 1/100 of an acre circular fixed-area plot was added for trees less than 5 inches in diameter and for dead trees between 1 and 7.9 inches in diameter.

Current tree level inventory data were not available for the Toiyabe National Forest, where about 178,000 acres of coniferous forests are within the study area. For this National Forest, plot-level timber inventory data developed for the 1992 Resources Planning Act assessment was used. This information was compiled from an inventory in the mid-1980s (Powell and others 1994).

The PNW Research Station inventory-The source of data for information on unreserved land outside National Forests in the Sierra Nevada study area was the PNW Research Station 1992-94 statewide multiresource inventory (Waddell and Bassett, 1997a, 1997b, 1997c). This inventory covered about 45 percent of the forested landscape of the Sierra Nevada study area and employed a double sampling for stratification design (Cochran 1977). A 0.85-mile grid was extended across the state, and within each square a plot was randomly located. The plots made up the primary sample. Each was classified by owner, land class, and timber volume. These characteristics provided the basis for stratification and expansion weights for the secondary sample of field plots. One out of 16 of the primary samples was selected for the secondary sample, which in the Sierra Nevada study area was 1,524 plots. Secondarysample plots were visited on the ground. In the Sierra Nevada study area, 548 ground plots were classified as coniferous forest. These plots, and their stratum expansion factors, were used to estimate the area of coniferous old-growth forest on unreserved lands outside National Forests.

The ground plot consisted of five subplots distributed over about 5 acres. At each subplot, a variable-radius prism plot was used to sample trees and snags 7 to 35 inches in diameter. A 10-foot fixed-radius plot was used to sample trees smaller than 7 inches in diameter, and a 56-foot fixed-radius plot was used to sample trees larger than 35 inches in diameter. Species, d.b.h., age, height, crown class, and crown size were among the items collected for each tree. A16-foot fixed-radius plot at each subplot center was used to measure understory vegetation. For shrubs, herbs, and grasses, the species, height, and percentage of cover were recorded. Two 56-foot line transects radiating from each subplot center were used to sample down logs within the subplot. Species, diameter at transect and small and large ends, length, and decay class were recorded for each log tallied. In the current study, we used the diameter at the large end for logs to be consistent with National Forest coarse woody debris measursements. Species, d.b.h., height, and decay class were measured for each snag tallied. Site index and management or disturbance history were recorded for each plot.

Old-growth definitions and classification methods-For the 2,455 ground plots in unreserved coniferous forests, we used the old-growth definitions developed by a team of scientists (Fites and others 1991 a, 1991 b; Potter 1992a, 1992b, 1992c, 1992d; Smith 1991; Smith and others 1991) for the following Society of American Foresters (SAF) (Eyre 1980) forest types in the Sierra Nevada study area:

SAF code	Forest type
245	Pacific ponderosa pine
237	Interior ponderosa pine
243	Mixed conifer
211	White fir
207	California red fir
247	Jeffrey pine
218	Lodgepole pine
256	Mixed subalpine
	· western white pine subtype
	· mountain hemlock subtype
	· white fir-Jeffrey pine subtype

The purpose of the old-growth definitions is to identify by site class and forest type structural characteristics that indicate the onset of an old-growth stage. Each of the old-growth definitions included the following structural attributes: stand age, size and density of the large trees, size and density of large snags and logs, variation in canopy layers and tree diameters, and the presence of decay in live trees. A detailed description of the development of each old-growth definition can be found in the.individual reports (Fites and others 1991 a, 1991 b; Jimmerson 1991 a, 1991 b; Potter 1992a, 1992b, 1992c, 1992d; Smith 1991; Smith and others 1991). A brief summary of the methods used to arrive at the definitions and a table of the key components of each old-growth definition (table 13) used to classify the inventory plots are in appendix A.

Each plot in unreserved coniferous forests was typed into a SAF forest type by using the key in appendix B. The key uses the relative basal area of each tree species tallied on a plot and, for some types, the geographic location of the plot. Each plot was then classified according to how well it met the key structural attributes of old growth for the SAF forest type as classified in the first step. Old-growth stands had to have a sufficient density of large live trees, large snags, and logs per acre. These old-growth plots were used to describe the stand characteristics of the different old-growth forest types. For the old-growth definitions, a "large" tree was defined for each old-growth forest type and each site class (see table 13, appendix A). The mean tree diameter for each plot was computed to estimate the area of coniferous stands that had a quadratic mean tree diam eter greater than 9 inches (sawtimber by Forest Service definitions) and greater than 21 inches (large sawtimber by Forest Service definitions). For some of the forest types in the Sierra Nevada, most notably lodgepole pine, several old-growth plots had a mean diameter of less than 21 inches.

Reliability and quality of data for lands outside National Forests and parks-The inventory conducted by the PNW Research Station on lands outside National Forests and parks (45 percent of the forested landscape) was designed to provide sampling errors consistent with national standards set by the USDA Forest Service. The sampling error (at the 68-percent probability level) for total coniferous forest land area outside National Forests and parks in the Sierra Nevada is 2 percent. Thus, our estimate of 3.225 million acres of coniferous forestland on these lands is within the range of 3.161 and 3.290 million acres. Our estimate of 65,000 acres of old growth outside National Forests and parks has a 14-percent sampling error. This means that at 68percent probability, our estimate lies between 56,000 and 74,000 acres.

Measures were taken to ensure high-quality data in this inventory. Field crews attended a 2-week intensive training session to learn data collection procedures. About 10 per-cent of the field plots were revisited, and all items were remeasured to check accuracy and consistency in classification, plot layout, tree measurements, and species identification. Each person's work was audited about five times during the field season. If consistent errors were detected, crews were informed and retrained as necessary. Data were edited extensively by using computer programs in both the field and the office. The edits were checked for reasonableness of tree measurements in relation to other measurements on the tree, and questionable data were sent back to the field for verification and correction if necessary.

Reliability and quality of data for National Forests-The basis of stratification for the National Forest inventories is a map. Because each Forest is entirely mapped and classified, there is no sampling error associated with the National Forest inventories. The reliability of the map depends on how well the ground data match the classification given each mapped polygon. Map accuracy assessments have been completed for the Inyo, Lassen, Modoc, Stanislaus, Plumas and Eldorado National Forests. At a life-form level (conifers, hardwoods, shrubs, grass, barren, water, agriculture, and urban), the accuracy of these maps is 80 to 90 percent. At the level of the classification of California vegetation forest type (CALVEG; USDA Forest Service 1981), the maps have a 75to 90-percent accuracy rate. Because SAF forest types are broader than CALVEG types and inclusive of CALVEG types, the reliability of these maps for SAF forest type is higher than for CALVEG types.

The Forest Service inventory data collection is directly supervised by a registered professional forester, licensed to work in California. Plot installation is done under strict protocols. A minimum of 10 percent of the work is inspected by a designated USDA Forest Service contracting officer's representative, or a designated inspector. The plots are submitted in batches for inspection purposes. To pass, each batch must be 90 percent correct, or better, in each category: site data, tally tree data, and understory vegetation data. The contract specifies measurement tolerances for each data element. To be "correct," each tree record must meet all tolerances for all elements. There also are tolerances assigned for plot location, subplot spacing, borderline trees, and plot monumentation.

Reserved Lands

Comprehensive recent inventories based on ground plots did not exist for reserved areas-National Forest wildernesses, BLM wildernesses, National Parks, and state and county parks. These reserves comprise 15 percent of the forested landscape. The area of forest land, coniferous forest, and old-growth coniferous forest in these reserved areas was estimated as described in the following section.

For National Forest wildernesses, total area of forest land and coniferous forest were determined from National Forest type maps. An estimate of the area of old-growth forest within National Forest wildernesses was derived by applying the proportion of each stratum of each National Forest planning unit that was classified as old growth outside the wilderness areas to the same stratum inside the wilderness areas of that particular National Forest. This was possible because the wilderness lands were mapped by using the same stratification techniques described above for National Forest lands outside wilderness. This technique may have slightly underestimated the area of old growth in the National Forest wildernesses.

Area of forest land and coniferous forest by major forest type for Lassen National Park, Sequoia-Kings Canyon National Park, Yosemite National Park, BLM wildernesses, and state and county parks was obtained by communicating with the agencies managing these reserved areas. These reserved areas comprise about 7 percent of the forested landscape. The estimate of old-growth area within these reserved areas came from a map prepared by the Sierra Nevada ecosystem project (SNEP) as part of the assessment of late-successional forests in the Sierra Nevada study area (Fites-Kaufmann and Franklin 1996). The map, published as a GIS layer (SNEP 1996b), consists of polygons of 500 to 5,000 acres, typed and ranked as to their contribution to late-successional forests. The mapping project was based on aerial photos, maps of forest conditions, orthophotos, and inventory data. Resource specialists delineated polygons on orthophotos or maps that were logical landscape units with similar function and characteristics that could be contrasted from adjacent areas. These polygons were further subdivided into patches of homogenous types, and each patch was ranked by its level of late-successional forest attributes. The polygon ranking was a weighted average of the patch ranks. The ranks (0 to 5) of each patch were based on stand structural features such as forest type, number of large live trees, canopy closure, presence of decadence, and disturbance history. Quantitative standards were developed to help the resource specialists rank the patches (see SNEP 1996c: 636-646, for a description of these rankings). Patches ranked 0 to 2 were judged to make little to no contribution to late-successional function. Patches ranked 4 and 5 were considered to make a high contribution to late-successional function. Patches ranked 4 and 5 were considered the best examples of old-growth forests because of their density of large old trees, large snags and logs, and dense understories and because they had little or no human disturbance. A rank of 4 or 5 meant the patch, in general, had more than 6 trees, 40 inches in diameter or larger, per acre and 2 to 4 snags and logs per acre. In general, patches not ranked as 4 or 5 but having more than six trees, 30 inches in diameter, per acre would be given a rank of 3. Patches ranked 3 were considered to make a moderate contribution to late-successional function. Though individual scales for each forest type were developed, in their final analysis and in their published GIS layer, Fites-Kaufmann and Franklin (1996) decided to use one scale for all the forest types. The scale developed for the most productive forest types (mixed conifer, true fir and ponderosa pine) became the standard, even though the SNEP researchers acknowledged that certain subalpine forest types could never reach the structural complexity of the lower elevation mixed-conifer and true fir, types. To use the SNEP map for an estimate of old growth in National Parks, BLM wildernesses, and state parks that would be comparable to the definitions for the rest of the forested landscape, we decided for this report that mixed subalpine and lodgepole pine forest types in parks and BLM wildernesses with a SNEP ranking of 3 or greater would be considered old growth. All other forest types in the parks and BLM wildernesses were judged to be old growth if they had SNEP ranking of 4 or 5.

Reliability and quality of the data for the national, state, and county parks and the BLM wildernesses.—There was no sampling error associated with the SNEP estimates because the entire area was mapped, typed, and ranked. The reliability of the estimates depended on the quality of the patch classifications. Quantitative standards were provided to guide resource specialists in their ranking of patch types and polygons, and there was a continuous review of the mapping activity by team leaders. Field checks on conditions and rankings of polygons were concentrated in areas where adequate information was lacking. About 20 percent of the polygons were field checked, and 80 percent of all

polygons ranked 4 or 5 were field checked. Five percent of the polygons were revised after these field checks. Finally, an independent validation study was performed to assess the correlation between the assigned patch ratings and observed conditions on the ground (Langley 1996). The mixed-conifer type was sampled. In this forest type, the SNEP mappers were consistent about 60 percent of the time in making patch ranking assignments. The assignments of the lower ranks (1-3) were accurate 53 to 78 percent of the time. The reliability of assigning rank 4 was about 44 percent. There were only six plots to assess for patches having a rank of 5.

Results

Old-Growth Area in 1993

Old growth by forest type-In 1993, an estimated 1.6 million acres of old-growth forests were determined in the Sierra Nevada. This amounted to 15 percent of the 10.5 million acres of coniferous forests in the study area (table 1). Most of the old growth was in high-elevation forests. Indeed, nearly three-quarters of the old growth was in the California red fir, lodgpeole pine, mixed subalpine, and Jeffrey pine forest types, although together these high-elevation forest types comprised less than one-third of the coniferous forests in the Sierra Nevada (table 2). Except for California red fir, the existing stands in these higher elevation areas have been less disturbed by logging, mining, residential development, and fire than those at lower elevations. Over half of the high-elevation forests in the Sierra Nevada was in reserves.

There was relatively little old growth in the mid-elevation forests (mostly mixed conifer and white fir), which constituted over half of the coniferous forests in the Sierra Nevada study area (table 2). The mixed-conifer type is the most extensive forest type in the Sierra Nevada and the one with the highest complexity and species diversity. In 1993, 8 percent of the 4.8 million acres of mixed-conifer forests was old growth. Of the 1.3 million acres of white fir, less than 4 percent was old growth. The forest types with the least old growth were the Pacific ponderosa pine and interior ponderosa pine types (table 2). Both the mixed-conifer and the ponderosa pine types have been intensively logged. The interior ponderosa pine forests were first logged in the 19th century in connection with mining activities and railroad building, and because many of them are easily accessible, they continued to be selectively harvested throughout the 20th century (Beesley 1996).

Table 1—Area of forest land, coniferous forests, and coniferous forests that meet old-growth criteria, Sierra Nevada study area

Land class	Forest land[a]	Coniferous forests[b]	Old growth coniferous forests[c]	Old growth as percentage of coniferous forests
	Acres			*Percent*
Reserved forest land[d]	2,414,949	1,948,451	873,175	45
Unreserved forest land	13,487,022	8,585,155	727,771	8
Total	15,901,971	10,533,606	1,600,946	15

[a] Land at least 10 percent covered by crowns of live trees, or 50 percent crown cover in chaparral species; or land formerly having such cover and not currently developed for nonforest use. This area includes oak woodland, pinyon-juniper woodland, chaparral, and coniferous forests. An estimated 113,994 acres of the reserved forestland and 610,574 acres of the unreserved forest land are chaparral.
[b] Forest land capable of growing 10 percent cover of industrial conifer species.
[c] Coniferous forests that meet the old-growth criteria of a minimum number of large trees, snags, and logs.
[d] Reserved forest land is forest land dedicated to noncommodity use through statue, ordinance, or administrative order. It includes forest land in National Forest wildernesses; Bureau of Land Management wildernesses; national parks, monuments, and recreation areas; other public parks; and private reserves.

Table 2—Area of coniferous forests, and coniferous forests that meet old-growth criteria by forest type, Sierra Nevada study area

Forest type	Reserved[a]		Unreserved				Total coniferous forests[c]		
	Total	Old growth[b]	Total	Area having a mean stand diameter greater than 9 inches[c]	Area having a mean stand diameter greater than 21 inches[d]	Old growth	Total	Old growth	Forest type in old growth
	Acres								*Percent*
Interior ponderosa pine	1,207	0	548,787	327,411	36,727	15,425	549,994	15,425	3
Pacific ponderosa pine	13,864	0	165,637	58,648	25,341	0	179,501	0	0
Mixed conifer	410,076	210,641	4,382,194	3,455,710	849,351	160,171	4,792,270	370,812	8
White fir	18,707	2,692	1,301,139	1,189,434	326,325	39,958	1,319,846	42,650	3
California red fir	442,821	277,524	434,752	397,202	209,670	123,516	877,573	401,040	46
Jeffrey pine	170,771	24,572	927,019	686,753	138,545	187,786	1,097,790	212,358	19
Lodgepole pine	284,790	137,205	323,178	300,045	31,426	157,447	607,968	157,447	26
Mixed subalpine-western white pine			45,948	45,943	25,805	20,242			
Mixed subalpine-mountain hemlock			92,146	62,747	12,860	21,574			
Mixed subalpine-white fir/Jeffrey pine			6,111	4,835	3,424	1,652			
Total mixed subalpine[f]	510,612	220,542	144,205	113,525	42,089	43,468	654,818	401,214	61
Nonstocked and unclassified[g]	95,603	0	358,243	0	0	0	453,846	0	0
Total	1,948,451	873,176	8,585,155	6,528,728	1,659,473	727,771	10,533,606	1,600,946	15

[a] Reserved forest land is forest land that has been dedicated to noncommodity use through statue, ordinance, or administrative order. It includes forest land in National Forest wildernesses; Bureau of Land Management wildernesses; national parks, monuments, and recreation areas; other public parks; and private reserves. The source of the data on public parks and private reserves is the Sierra Nevada Ecosystem Project GIS layers (SNEP 1996b). The National Forest wilderness information is from the current inventory.

[b] Coniferous forests that meet old-growth criteria.

[c] Coniferous forests commonly called sawtimber.

[d] Coniferous forests commonly called large sawtimber.

[e] Forest land capable of growing 10 percent cover of industrial conifer species.

[f] Information on individual subalpine types was not available for reserved areas.

[g] This area was once stocked with conifer trees and has the potential to grow 10 percent cover of industrial wood species.

Presence of large trees in the landscape -In the forests of the Sierra Nevada, unlike those in much of the Cascade Range to the north, natural processes and human activities have resulted in many mixed-age stands. Some stands may be essentially of two ages with scattered old trees standing above younger trees, while others are of many ages with trees of various heights and diameters in clusters or as scattered individuals. Old-growth trees are present in many stands not qualifying as old-growth forest because the stands lack the required number of large trees or other structural features. Figures 2 and 3 show the area of unreserved coniferous forests by the density of large trees. Figure 2 shows the area by density of trees 40 inches and larger in diameter, and figure 3 shows the area by density of trees 30 inches and larger in diameter. Also shown are the densities at which the large trees are found. For example, 45 percent of the trees at least 40 inches in diameter in unreserved coniferous forests are found at densities less than 2 trees per acre. The mixed-conifer and white fir forest types, where most of the large trees were found, require at least six trees, 39 inches in diameter or larger, per acre on high and medium sites to be considered old growth (see table 13, appendix A).

Large standing trees are extremely important, dead or alive, and eventually as large woody debris on the forest floor. The best seed bearers are almost always the larger, taller trees. Hawks and other raptors favor trees taller than the average forest canopy for perching and nesting. Large trees may contain cavities large enough for bears and other mammals, and large snags and large logs are favored by carpenter ants (Camponotus spp.), an important food source of pileated woodpeckers (Dryocopus pileatus) and many other birds (Bull and others 1997, Vreeland, 1997).

Although old-growth stands were found on only 8 percent of the unreserved coniferous forest land (table 1), trees 30 inches in diameter and larger in densities of one or more per acre were found on 56 percent of the area (fig. 3), and trees 40 inches in diameter and larger in densities of one or more per acre were found on 21 percent of the area (fig. 2). Hardwood trees 30 inches in diameter and larger in densities of one or more per acre were found on 6 percent of the area. (fig. 4). Most of these hardwood trees were California black oak.

True firs (white and red) account for 41 percent of the trees 30 inches and larger in diameter and 43 percent of the trees 40 inches and larger in diameter (table 3). Ponderosa, Jeffrey, and sugar pines collectively account for 29 percent of the trees 30 inches and larger in diameter and 28 percent of the trees 40 inches and larger in diameter. California black oak, a very important wildlife species, accounts for 3 percent of the trees 30 inches and larger in diameter and 2 percent of the trees 40 inches and larger in diameter. All other hardwoods combined account for 1 percent of the trees 30 inches and larger in diameter and 0.5 percent of the trees 40 inches and larger in diameter.

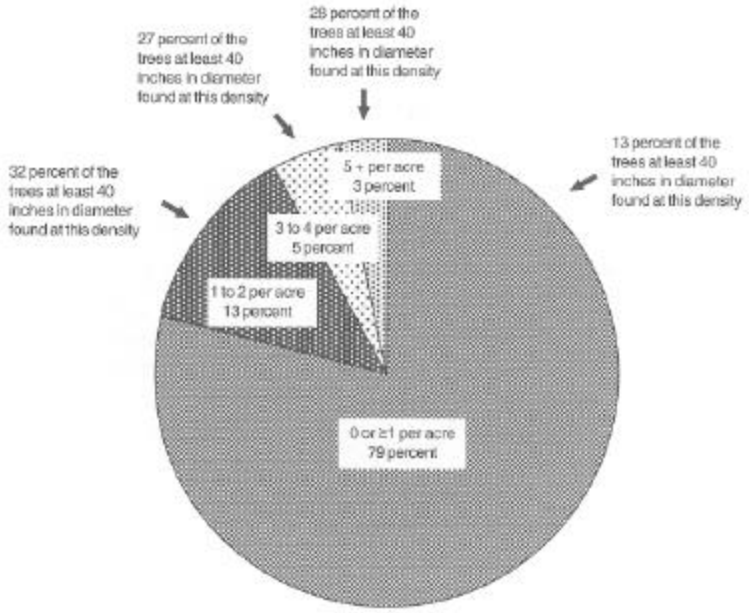


Figure 2—Area of unreserved coniferous forests in the Sierra Nevada by density of trees at least 40 inches in diameter.

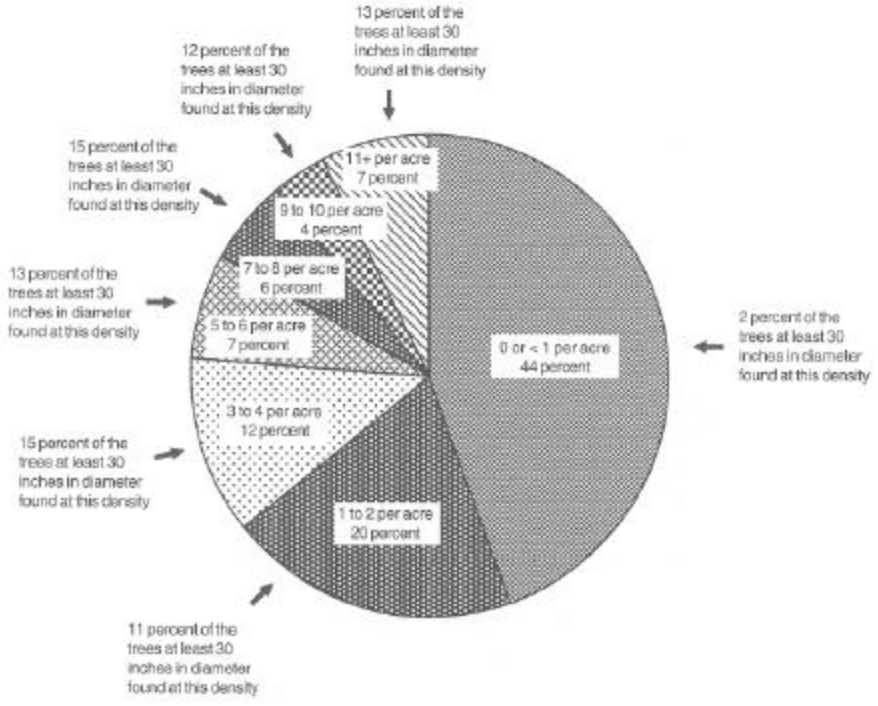


Figure 3—Area of unreserved coniferous forests in the Sierra Nevada by density of trees at least 30 inches in diameter.

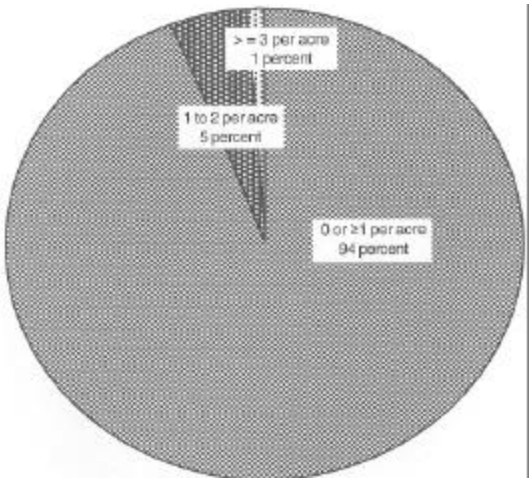


Figure 4—Area of unreserved coniferous forests in the Sierra Nevada by density of hardwood trees at least 30 inches in diameter.

Table 3—Proportion of all large trees by species in the unreserved coniferous forests in the Sierra Nevada

Species	Proportion of all trees ≥30 inches d.b.h.	Proportion of all trees ≥40 inches d.b.h.
	Percent	
Softwoods:		
White fir	24	22
California red fir	17	21
Incense-cedar	12	12
Jeffrey pine	10	10
Ponderosa pine	10	7
Douglas-fir	9	9
Sugar pine	9	11
Lodgepole pine	2	1
Mountain hemlock	1	<1
Western juniper	1	1
Western white pine	1	2
Bristlecone pine	<1	<1
Gray pine	<1	0
Grand fir	<1	<1
Giant sequoia	<1	<1
Limber pine	<1	0
Pinyon pine	<1	0
Whitebark pine	<1	0
Coulter pine	0	0
Foxtail pine	0	<1

Table 3—Proportion of all large trees by species in the unreserved coniferous forests in the Sierra Nevada (continued)

Species	Proportion of all trees ≥30 inches d.b.h.	Proportion of all trees ≥40 inches d.b.h.
Pacific yew	0	0
California nutmeg	0	0
Knobcone pine	0	0
Hardwoods:		
California black oak	3	2
Canyon live oak	1	<1
Bigleaf maple	<1	<1
Interior live oak	<1	<1
Pacific madrone	<1	<1
Red alder	<1	0
Tanoak	<1	<1
Valley oak	<1	0
White alder	<1	0
Black cottonwood	0	<1
Blue oak	0	0
California buckeye	0	0
California-laurel	0	0
Fremont poplar	0	0
Pacific dogwood	0	0
Oregon ash	0	0
Oregon white oak	0	0
Quaking aspen	0	0

Old growth area by broad ownership-In 1993, 95 percent of the old-growth forest in the Sierra Nevada study area was in Federal ownership: 57 percent in the National Forests and 38 percent in the National Parks (Yosemite, Lassen Volcanic, and Sequoia-Kings Canyon) (tables 4 and 5). Most of the old-growth forests in National Forests was outside designated wildernesses (table 5). This area presumably could be harvested for timber. Although almost one-third of the coniferous forests in the Sierra Nevada study area are privately owned, less than 2 percent of these forests were old growth (table 5). Scattered old-growth trees were present in many stands, however.

The estimated 925,000 acres of old growth in the National Forests in this study (table 6) compared with 886,000 acres of old growth determined from the SNEP map of these National Forests (SNEP 1996b). For this comparison, the area of mixed-subalpine and lodgepole pine forests ranked 3 and greater and all other forest types ranked 4 and greater were considered old growth on the SNEP map.

Table 4—Area of reserved forest land, coniferous forests, and coniferous forests that meet old-growth criteria, Sierra Nevada study area[a]

Owner group	Forest land[b]	Coniferous forests[c]		
		Total	Old growth[d]	Proportion that is old growth
	Acres			*Percent*
National Forest wilderness	1,189,675	972,920	262,158	27
Yosemite National Park	599,920	534,900	320,691	60
Lassen Volcanic National Park	93,000	83,400	44,133	53
Sequoia-Kings Canyon National Park	366,530	314,580	240,784	77
Bureau of Land Management	44,132	3,959	1,262	32
Other Federal[e]	54,645	15,600	0	0
State parks	44,767	21,812	4,147	19
County and city parks	900	780	0	0
Private reserves	21,380	500	0	0
Total	2,414,949	1,948,451	873,175	45

[a] Reserved forest land is forest land dedicated to noncommodity use through statue, ordinance, or administrative order. It includes forest land in National Forest wildernesses; Bureau of Land Management wildernesses; national parks, monuments, and recreation areas; other public parks; and private reserves. The source of the data on public parks and private reserves is the Sierra Nevada Ecosystem Project GIS layers (SNEP 1996b). The National Forest wilderness information is from the current inventory.

[b] Land at least 10 percent covered by crowns of live trees, or 50 percent crown cover in chaparral species, or land formerly having such cover and not currently developed for nonforest use. This area includes oak wood-land, pinyon-juniper woodland, chaparral, and coniferous forest land.

[c] Forest land capable of growing 10 percent cover of industrial conifer species.

[d] Coniferous forests that meet the old-growth criteria of a minimum number of large trees, snags, and logs.

[e] Includes Lava Beds National Monument, Devil's Postpile National Monument, Eastman Lake National Recreaton Area, Hensley Lake National Recreation Area, and the federally owned Auburn State Recreation Area.

Table 5—Area of unreserved forest land, coniferous forests by size class, and coniferous forests that meet old-growth criteria, Sierra Nevada study area

Owner group	Forest land[a]	Coniferous forests[b]				
		Total	Area having a mean stand diameter greater than 9 inches[c]	Area having a mean stand diameter greater than 21 inches[d]	Old growth[e]	Proportion that is growth
	Acres					*Percent*
National Forest (excl. wilderness)[f]	6,512,985	5,359,437	3,883,765	1,387,659	662,730	12
Bureau of Land Management	1,013,612	99,457	87,079	16,889	3,325	3
Other Federal	15,336	1,416	1,416	0	0	0
Native American	62,541	8,368	6,708	0	0	0
State	63,744	37,334	20,743	9,599	0	0
County and city	59,991	36,182	22,137	0	2,727	8
Forest industry	1,888,271	1,842,986	1,528,504	112,761	34,620	2
Other private	3,870,542	1,199,975	978,376	132,565	24,369	2
Total	13,487,022	8,585,155	6,528,728	1,659,473	727,771	8
		Percent				
Total unreserved coniferous forests		100	76	19	8	

[a] Land at least 10 percent covered by crowns of live trees, or 50 percent crown cover in chaparral species. Includes oak woodland, pinyon-juniper woodland, chaparral, and coniferous forest land.
[b] Forest land capable of growing 10 percent cover of industrial conifer species.
[c] Coniferous forests commonly called sawtimber.
[d] Large sawtimber area not available for the Toiyabe National Forest.
[e] Coniferous forests that meet the old-growth criteria of a minimum number of large trees, snags, and logs.
[f] Includes 173,000 acres of coniferous forests that are in pending wildernesses, scenic areas, or natural research areas.

Table 6—Area of coniferous forests and coniferous forests that meet old-growth criteria by National Forest, Sierra Nevada study area

National Forest	Unreserved		Reserved		Total National Forest		Proportion of coniferous forests that is old growth	Proportion of total National Forest old growth
	Coniferous forests[a]	Old-growth coniferous forests[b]	Coniferous forests	Old-growth coniferous forests	Coniferous forests	Old-growth coniferous forest		
	Acres						*Percent*	
Eldorado	437,785	53,458	50,232	21,310	488,018	74,769	15	8
Inyo	197,348	85,079	202,852	48,844	400,200	133,923	33	14
Lake Tahoe Basin[c]	102,845	38,466	8,164	3,346	111,008	41,812	38	5
Lassen	877,271	82,734	37,211	5,795	914,481	88,529	10	10
Modoc	597,870	38,219	31,298	3,307	629,168	41,526	7	4
Plumas	898,624	43,053	19,614	1,343	918,238	44,396	5	5
Sequoia	510,100	114,458	162,905	50,693	673,005	165,151	25	18
Sierra	481,600	72,875	284,830	76,003	766,430	148,878	19	16
Stanislaus	498,994	49,080	89,981	27,853	588,975	76,932	13	8
Tahoe	578,177	52,617	14,701	3,367	592,878	55,983	9	6
Toiyabe[d]	178,823	32,691	71,131	20,298	249,954	52,989	21	6
Total	5,359,437	662,730	972,919	262,159	6,332,355	924,888	15	100

[a] Forest land capable of growing 10 percent cover of industrial conifer species.
[b] Coniferous forests that meet the old-growth criteria of a minimum number of large trees, snags and logs.
[c] Includes only the portion of the Lake Tahoe Basin that is managed by the National Forest. 20 percent of the coniferous forests in the Lake Tahoe Basin are outside the National Forests and there is little old growth under these ownerships.
[d] Includes only the portion of the Toiyabe that is in California.

The Sequoia, Sierra, and Inyo National Forests contained nearly half of the old growth in National Forest ownership (table 6). The varying proportions of old growth in the National Forests seem to be related to the distribution of types, elevation, and to some extent, location in relation to historical activities. For example, about one-quarter to one-third of the coniferous forests in Inyo, Lake Tahoe Basin, and Sequoia were old growth compared to about 10 percent of Modoc, Lassen, Plumas, and Tahoe. A greater proportion of the Inyo and Sequoia forests is in wilderness and high-elevation forest types. The Modoc, Lassen, and Plumas forests consisted primarily of interior ponderosa pine and mixed conifer, the forest types most affected by logging. Although accessible forests of the Lake Tahoe Basin were heavily cut between 1860 and the 1880s to support the Comstock Lode silver mines, National Forest land in the basin, which has increased through purchase and land exchanges over the decades, has been managed primarily for conservation and recreation (SNEP 1996a). About 20 percent of the total land area of the Lake Tahoe Basin (197,000 acres) was old growth in 1993. Much of the area now comprising the Tahoe National Forest was heavily disturbed by logging, mining, and railroad construction (Verner and others 1992).

Change in Area of Old-Growth Forests from 1945 to 1993

The California Forest and Range Experiment Station conducted the first comprehensive statewide forest assessment in 1945 (Wieslander and Jensen 1946). For that assessment, area of forest land "having evident timber-cropland potentialities" was classified by density, age, and "timber type" and was plotted on a "timber cropland" type map. As part of the current study, the type map from the 1945 assessment was digitized and entered into a GIS database. From that database, it was possible to determine the area of timberland within the Sierra Nevada by forest type and broad age class, as determined in 1945, and to quantify-with some qualifications-change in area of old-growth forest by broad type between 1945 and 1993.

Source of data and definitions used in the 1945 assessment-Most of the map work for the 1945 assessment was based on aerial photographs taken from 1936 to 1944, except for Modoc County, where classification was based on a U.S. Bureau of Entomology and Plant Quarantine insect hazard inventory and Modoc National Forest type map; and Sequoia-Kings Canyon National Parks, where classification was based on National Park Service vegetation maps and early Forest Service land classification sheets. Mapping was done by trained personnel from the Experiment Station, the National Forests, National Park Service, and State Division of Forestry. Type boundaries based on older photographs and maps were updated to January 1945 to account for timber cutting and fires. The minimum area recognized in the 1945 typing was 500 acres (Wieslander and Jensen 1946).

Timber cropland as defined in 1945 included "...all areas, regardless of present cover, that appear to possess the climate and soil qualities essential for the production of commercial timber crops. Formerly timbered lands now cultivated for crops or urbanized are excepted" (Wieslander and Jensen 1946). Commercial forest types included forest land capable of supporting white and red firs; "timber pines"; and mixtures of firs, timber pines, and Douglas-fir (now called mixed conifer). Timber pines included ponderosa, Jeffrey, and sugar pines. Not included as timber cropland types in 1945 were lodgepole, whitebark, western white, foxtail, limber, knobcone, Monterey, Bishop, Coulter, gray and pinyon pines; cypresses; mountain hemlock; and hardwoods not in association with commercial conifers (Wieslander and Jensen 1946). The forest type definitions used in 1945 were fairly similar to the SAF definitions used for 1993 as shown in the following summary:

Type	1945 definition	1993 definition
Ponderosa pine	80 percent cover in ponderosa, sugar, or Jeffrey pine	80 percent basal area in ponderosa pine
Jeffrey pine	Included with ponderosa pine	50 percent basal area in Jeffrey pine
White fir and red fir	80 percent cover in white or red fir, or both	50 percent basal area in white *or* red fir; or 80 percent basal area in white *and* red fir
Pine–true fir–Douglas-fir (mixed conifer)	20 to 80 percent cover in pine, Douglas-fir, or true fir	None of above types and 50 percent basal area in a combination of above species plus incense-cedar, sugar pine, and black oak

Timber cropland in 1945 was segregated into the following density classes, based on the "percent of ground covered with timber growth" (Wieslander and Jensen 1946):

Dense and semidense-over 50 percent of cover
Open-20 to 50 percent of cover
Very open-5 to 20 percent of cover
Unstocked-less than 5 percent of cover

Timber cropland in 1945 in all but the unstocked density class was further segregated into broad age classes. Old growth was defined by Wieslander and Jensen as stands with "over 50 percent of the conifer canopy [consisting of] mature trees" (Wieslander and Jensen 1946: 55) and showing no evidence of being cut over. "Mature" was not defined but was equated with "virgin saw-timber" In addition, stand volume had to exceed the minimums shown in the following tabulation:

	Minimum board feet (Scribner) per acre in 1945 old-growth stands	
Density class	West-side Sierra	East-side Sierra
Dense and semidense	15,000	12,000
Open	10,000	7,000
Very open	5,000	3,000

Photographs of the various density and age classes were provided in Wieslander and Jensen (1946) to serve as or accompany the brief definitions.

Results-of-change analysis-In 1945, old-growth stands, as defined above, occupied an estimated 4,280,000 acres, or 45 percent, of the timber cropland in the Sierra Nevada. This estimate excluded lodgepole pine and subalpine types because they were not considered timber cropland in 1945. For that reason, these types were excluded for 1993 in the change analysis. In 1993, old-growth stands, as determined by applying

ecological definitions to inventory plot data, occupied 1,042,000 acres, or 11 percent, of the coniferous timberland, as shown in the following tabulation:

	Total area		Old-growth area	
Forest type group	1945	1993	1945	1993
		Thousand acres		
Mixed conifer	4,954	4,792	2,453	371
True firs	842	2,197	754	444
Pines	3,744	1,827	1,073	227
Total	9,540	8,816[2]	4,280	1,042
			Percent	
Percentage of total			45	11

Is some of the apparent change in old-growth area the result of different old-growth definitions being used in 1945 and 1993? It is possible that some of the very open stands classified as old growth in 1945 may not have qualified as old growth under the current definitions because they lacked the required number of large trees. For example, the minimum allowed stand volume for very open interior ponderosa pine to qualify as old growth in 1945 was 3,000 board feet per acre. The 1993 definitions require a minimum of 13 trees at least 21 inches in diameter for low-site interior ponderosa pine. A 21-inch ponderosa pine on low-site forest land contains as little as 350 board feet and as much as 650 board feet. Thus, total volume per acre could be as low as 7,350 board feet which is greater than the 3,000 board-foot minimum required in 1945. This suggests that some of the very open virgin sawtimber stands in 1945 would not have qualified as old growth under 1993 definitions. However, the average volume in the very open virgin sawtimber class in 1945 was 11,000 board feet. This leads to the conclusion that very little of the area would not have qualified as old growth based on the current ecological definition, but there is no way to verify that.

Another approach was tried to determine whether different old-growth definitions could make significant differences in old-growth estimates. The current inventory plots were rated by using the 1945 definitions. Plots representing 31,000 acres did not qualify as old growth with the current ecological definitions but would have qualified under the 1945 definitions. This is about 3 percent of the current estimated old-growth area.

Other possible sources of differences between the 1945 and 1993 estimates might include changes in forest type, differences in the minimum area classified, and errors resulting from mapwork.

z Excludes 454,000 acres of nonstocked forest land.

Changes in forest type-Forest composition has changed markedly over time in the Sierra Nevada, the result of logging, fire, insects, disease, weather, and natural succession. In some cases, a stand could change from old growth to non-old growth, or vice versa, as a result of change of type. For example, a Pacific ponderosa pine stand on a low site, to be classified as old growth, has to have two trees per acre that are 30 inches in diameter or larger. If white fir, which is often present, has increased, or the pines have dropped out, the stand could become either white fir, requiring at least six trees per acre 29 inches in diameter or larger, or mixed conifer, requiring five trees.

Total area and area of old growth by forest type group in 1945 and 1993, shown in the previous tabulation, reflect the result of all sources of change, including the application of different old-growth definitions when forest types have changed. The increase in true fir types, from 842,000 to 2,197,000 acres, is thought to be the result of the loss of the pines from the mixed-conifer and pine types and the decades of fire control, along with natural succession, which favor shade-tolerant true firs over the intolerant pines. Some pine stands also were converted to mixed conifer as the pines were cut to below the 80percent threshold (see appendix B). Sugar pine mortality caused by blister rust and other agents, as well as ponderosa and Jeffrey pine mortality caused by bark beetles and other agents, also played a role in the decreasing area of pine type and, to some degree, the shift of acres from mixed conifer to true fir.

The diminishing role of pines over the past 50 to 60 years has been noted throughout the Pacific Coast States (Andrews and Cowlin 1940; Bolsinger and others 1997; Cowlin and others 1942; McKay and others 1994; Waddell and Bassett, 1997a,1997b,1997c; Wieslander and Jensen 1946). Among the assumed environmental effects of the decrease in pines is that less of the forest will be open and sunny in character, which will alter understory vegetation and wildlife habitat, reduce the amount of pine seed important to many species of birds and mammals, and change the soil microbiology, hydrologic dynamics, and fire potential.

Differences in the minimum area classified-There are differences in the minimum area classified by the 1945 assessment and the current inventories. Whether this would result in more or less old growth at either occasion is not clear. If more old growth occurred in small patches in 1945 than in 1993, one might expect the older estimate to be lower than one made then with the current definitions. This would be offset, however, by any inclusions of non-old growth within the 500-acre types plotted i n 1945.

Errors in mapwork-Errors may have occurred in entering the 1945 type map into a GIS data base and in summarizing the polygon areas. A check of several points on the digitized 1945 map against exact known locations gave a root mean squared (RMS) error of 0.008, greater than the desired RMS of 0.003. A summary of old-growth area statewide from the GIS database gave the same area to tenths of a million acres (Wieslander and Jensen 1946). Total timber cropland area also agreed to the nearest tenth of a million acres, but area in pine type was off by about 5 percent. Pine type occurred in many small, often rather linear polygons, whereas timber cropland as a whole, as well as old growth, were contained mostly in large polygons. Determining the area contained in many small polygons is more error prone than for the same area contained within fewer, larger polygons. The area of old growth in the Sierra Nevada for 1945, as determined by GIS, is assumed to have some error, but probably less than 5 percent.

The proportion of old growth that could exist under a natural disturbance regime- In 1993, about 15 percent of the Sierra Nevada coniferous forests was old growth. In parks and wildernesses, which have been less altered by logging, mining, and development, 45 percent was found to be old growth in 1993-almost the same proportion that Wieslander and Jensen (1946) found over all ownerships and reserved categories. By 1945, a considerable area of forest land already had been disturbed by mining, logging, and other activities, but how much of that had previously been old growth is not known. Forty-five percent might be a rough estimate of the proportion of old growth that could exist under natural disturbance regimes in the Sierra Nevada. Whether this is feasible or desirable is not clear.

Old-growth recruitment-Any increase in old-growth area in the Sierra Nevada ecosystem, at least in the near future, would have to come mostly from the unreserved areas of the National Forests, because these forests contain most of the forests having a mean stand diameter greater than 21 inches (table 5). Of the 3 million acres of coniferous forests in private ownership (forest industry and other private), only 244,000 acres support stands having a mean diameter greater than 21 inches (59,000 acres of that was already old growth; table 5). Most of the area in private ownership is expected to be managed for non-old-growth values.

Characteristics of Old Growth in the Different Forest Types

The following section summarizes the characteristics of the different old-growth types in terms of species diversity, density of trees (table 7), snags and logs (tables 8 and 9), percentage of large trees by species (table 10), overstory and understory composition and height (table 11), and percentage of cover (table 12) of canopy layers. The descriptive statistics in these tables come from 396 old-growth stands.

Table 7—Density of large, medium, and small live trees in old-growth stands by forest type, Sierra Nevada study area

Forest type	Number of stands	$\bar{x}$ (se)[a b] by tree size: Large, ≥30 inches d.b.h.	Medium, 20-29 inches d.b.h.	Small, 6-19 inches d.b.h.
		Number of trees		
Interior ponderosa pine	4	4 (1.5)	26 (4.6)	128 (29.5)
Mixed conifer	65	12 (0.8)	12 (0.9)	123 (15.0)
White fir	12	16 (2.1)	19 (2.5)	97 (20.4)
California red fir	93	16 (0.6)	18 (1.0)	85 (6.3)
Jeffrey pine	91	6 (0.3)	10 (0.7)	78 (8.2)
Lodgepole pine	103	6 (0.4)	17 (0.8)	133 (11.1)
Mixed subalpine-western white pine	17	13 (1.1)	15 (1.3)	50 (9.2)
Mixed subalpine-mountain hemlock	9	14 (1.4)	23 (4.1)	121 (22.7)
Mixed subalpine-white fir/Jeffrey pine	2	6 (1.1)	4 (4.3)	57 (9.1)

[a] $\bar{x}$=mean number per acre.
[b] se=standard error.

Table 12—Percentage of cover of trees, shrubs, and forbs in old-growth stands by forest type, Sierra Nevada study area

Number	Number of stands	$\bar{x}$ (se)[a b]		
		Trees	Shrubs	Forbs
		Percent		
Interior ponderosa pine	4	68 (13.7)	15 (3.1)	13 (2.8)
Mixed conifer	65	72 (1.9)	23 (2.6)	13 (1.4)
White fir	12	78 (3.6)	19 (5.7)	18 (3.7)
California red fir	93	62 (1.6)	15 (1.8)	20 (1.9)
Jeffrey pine	91	57 (1.6)	33 (2.2)	18 (1.8)
Lodgepole pine	103	57 (1.4)	12 (1.3)	29 (2.3)
Mixed subalpine-western white pine	17	60 (3.2)	28 (6.8)	12 (2.2)
Mixed subalpine-mountain hemlock	9	72 (4.9)	4 (1.5)	20 (6.6)
Mixed subalpine-white fir/Jeffrey pine	2	46 (13.6)	66 (3.5)	13 (8.2)

[a] $\bar{x}$ =mean percentage of cover.
[b] se=standard error.

Interior ponderosa pine old growth-Old-growth interior ponderosa pine has widely spaced large ponderosa pine trees interspersed among dense clumps of smaller trees (fig. 5). Tree species diversity is low and ponderosa pine is generally the only large conifer present, though smaller trees sometimes are species other than pine. The largest tree tallied in our sample of old-growth plots was 48 inches in diameter and the tallest tree was 138 feet in height, although the tree canopy generally averaged about 74 feet. In our sample, tree canopy cover in interior ponderosa pine old growth averaged 68 percent.

The crowns of pine trees allow considerable light to reach the forest floor for regeneration and the development of a shrub and forb understory. Thus the old-growth type often has high vertical diversity. Although snags and logs are present in interior ponderosa pine old growth, there are not many of them. The type had the fewest large snags and logs of any of the old-growth types. The most common shrub found in this old-growth type was Mahala-mat; the most common forbs were star flower and bedstraw; the most common grasslike species were cheatgrass and sedge.

Mixed-conifer old growth-Mixed-conifer old growth has the greatest vertical and horizontal complexity of all the old-growth types in the Sierra Nevada because all sizes of trees are usually unevenly distributed across the landscape (fig. 6).

The largest trees in this old-growth type are often incense-cedar and white fir, although 12 different tree species with diameters at least 30 inches were found. It is in mixed-conifer forest type that the largest sugar pines (fig. 7) are found.

Figure 5—Interior ponderosa pine old growth

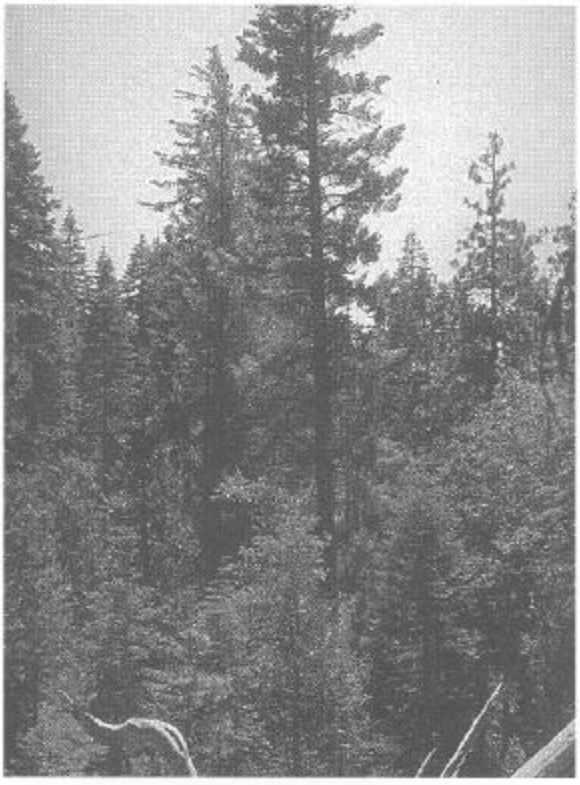


Figure 6—Diversity of tree sizes in mixed-conifer old growth.

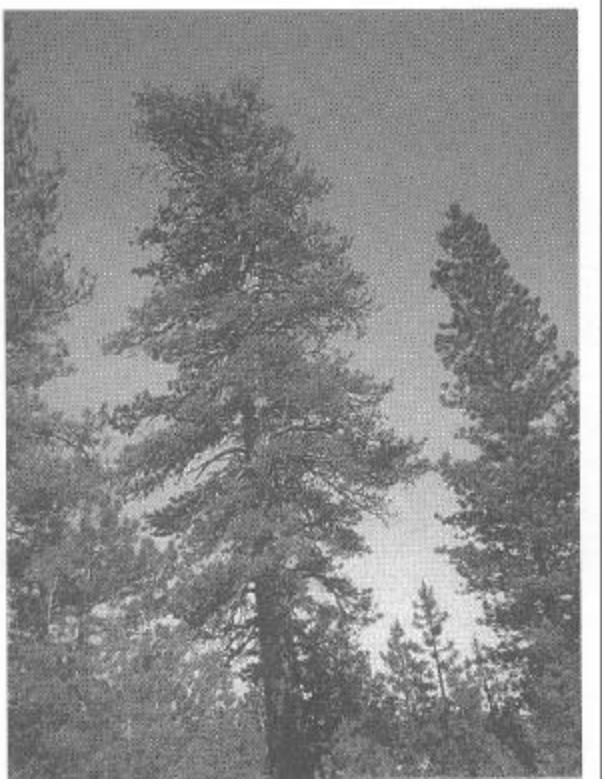


Figure 7-Sugar pine in mixed-conifer old growth.

The density of large- and medium-sized trees in this old-growth type is not as high as in the white fir and California red fir old-growth types. But the type has the largest and tallest trees in the Sierra Nevada. One of the most notable is the giant sequoia (fig. 8). In our sample, the largest giant sequoia tallied was 210 inches in diameter and 300 feet tall. The average canopy height of 97 feet in mixed-conifer old growth masks how high the canopy can be in some parts of the landscape. Many of the white fir, incense-cedar, and Douglas-fir trees were between 70 and 80 inches in diameter and over 150 feet tall.

Although the density of large trees in mixed-conifer old growth is not as great as in the true fir types, the crowns of the species found in mixed conifer are generally broader, thereby resulting in dense canopy cover (fig. 9). Another unique aspect of mixed-conifer old growth is the abundance of small trees and shrubs beneath this canopy cover (fig. 10). White fir and incense-cedar, the principal species in mixed-conifer old growth, are shade-tolerant species and can grow beneath the mixed-conifer overstory.

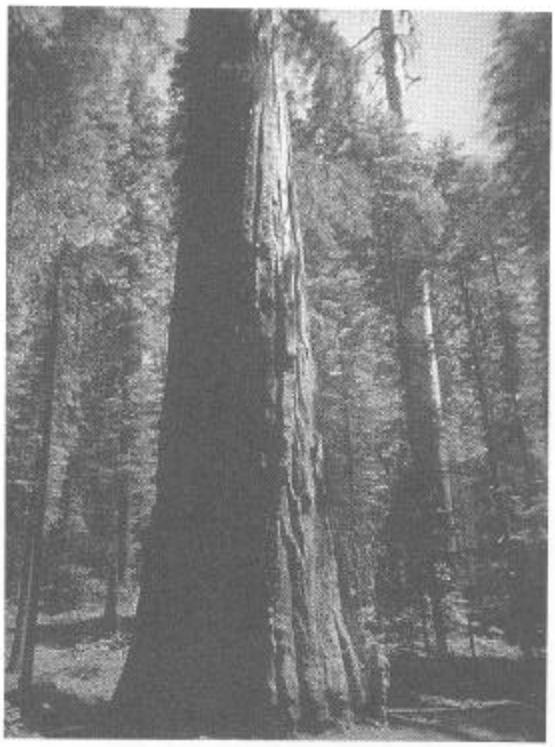


Figure 8—Giant sequoia in mixed-conifer old growth

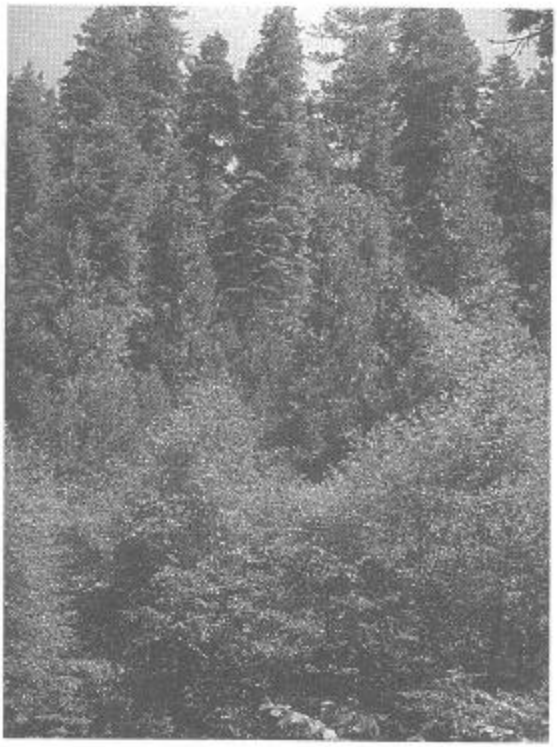
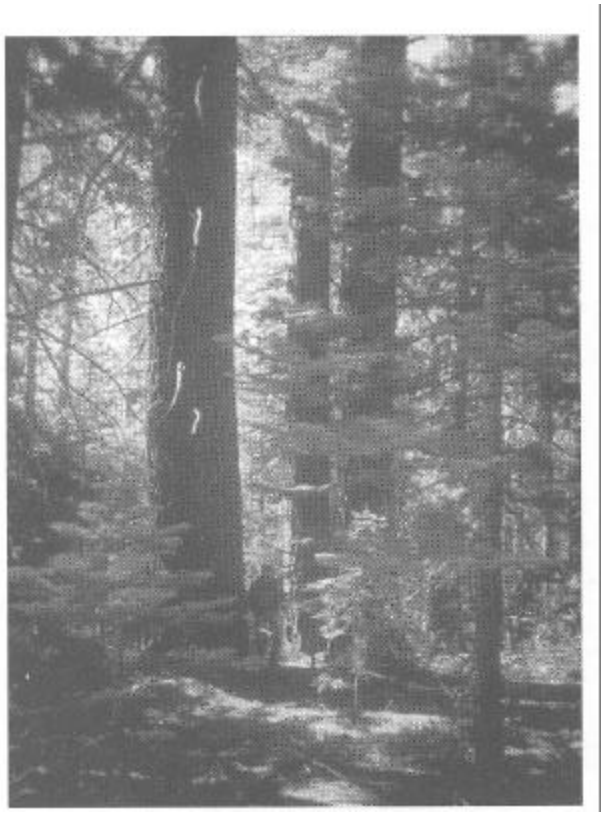


Figure 9—Large, full crowns in mixed-conifer old growth.



r-1fJ.Utd W ,-__1JUa~3c G'fiG&'Sicay ui ~ctauU-T~ucldiad CuG seedlings and saplings in mixed-conifer old growth.

The diversity in vascular plant species adds to the complexity in structure of mixedconifer old growth. Twenty-three different tree species were found in this type, 55 different shrub species, and 30 species of herbs. The most common shrubs were greenleaf manzanita, bush chinkapin, gooseberry, and whitethorn, which were found in over 40 percent of the old-growth stands. Bracken and lupine were the most common forbs found in mixed-conifer old growth.
Mixed-conifer old growth is the only old-growth forest type in the Sierra Nevada with a significant hardwood component. Common hardwood species were canyon live oak, bigleaf maple, and California black oak. Some of these hardwoods can get as large in diameter as many of the conifers. In our sample, 3 percent of the trees at least 30 inches in diameter in m ixed-conifer old growth were black oak (fig. 11).

Figure 11—California black oak in mixed-conifer old growth.

White fir old growth-White fir old growth has a high density of large-and medium-size trees and a tall, continuous canopy cover (figs. 12 and 13). In our sample, the stands had an average of 35 trees at least 20 inches in diameter per acre, and the canopy averaged 110 feet in height with 78 percent of cover. The largest white fir tree tallied was 78 inches in diameter; the tallest was 203 feet. Although in 1993, there was little old-growth white fir type in the Sierra Nevada (3 percent of the type), large white fir trees and their derivatives (snags and logs) were present in many of the old-growth forest types. White fir was considered an inferior timber species in earlier periods and often was left by loggers. Many of the white fir trees still standing are rotten, as indicated by large fungus sporophores (conks) on their boles, scars, and "catfaces" showing decayed wood (Kimmey 1961), because they often were classified as "cull" trees by loggers.

White fir old growth has one of the highest density of snags and logs of all sizes of any of the old-growth forest types. The forest floor can be covered with logs, sometimes two to several layers deep. This, coupled with a dense overstory, makes for a sparse understory. Only 11 species of shrubs were found in white fir old growth overall. The most common shrubs were snowberry, gooseberry, bush chinkapin, and huckleberry oak, and the most common forbs were bracken and lupine.

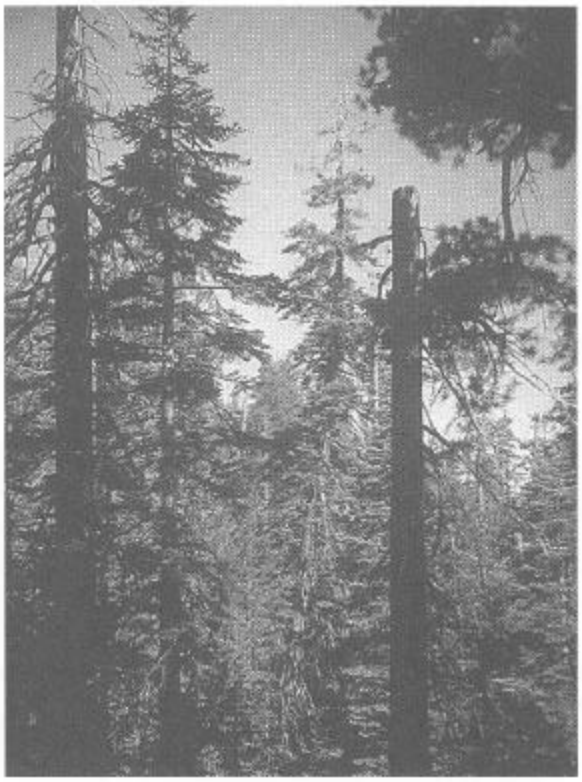


Figure 12—Dense continuous canopy of white fir old growth.

Figure 13—High density of large- and medium-sized trees in white fir old growth.

California red fir old growth-Much like white fir old growth, California red fir old-growth stands have a high density of large- and medium-sized trees and snags and logs. However, the large trees are not as evenly distributed as in white fir old growth (fig. 14). They are often in clumps, which is why the overall canopy cover tends to be somewhat lower in old-growth California red fir. Californa red fir is one of the largest true firs in the world. The largest tree tallied in this study was 84 inches in diameter; the tallest was 200 feet.

Lodgepole pine, Jeffrey pine, western white pine, and white fir were found in association with California red fir with a constancy greater than 20 percent, but the stands are dominated mostly by California red fir. Nine shrub species and two forb species were found in California red fir old-growth stands with a constancy greater than 10 percent. The most common shrubs were gooseberry and pinemat manzanita; the most common forbs were lupine and mule ears.

Figure 14—Clumps of trees in California red fir old growth.

Jeffrey pine old growth-Jeffrey pine old growth has a low density of trees of all sizes and very few snags and logs. In this type, large Jeffrey pine are fairly evenly and widely distributed across the landscape (fig. 15) The open stands of Jeffrey pine old growth have a dense cover of shrubs and forbs between the large trees, and granitic outcroppings often are associated with this type (fig. 16).

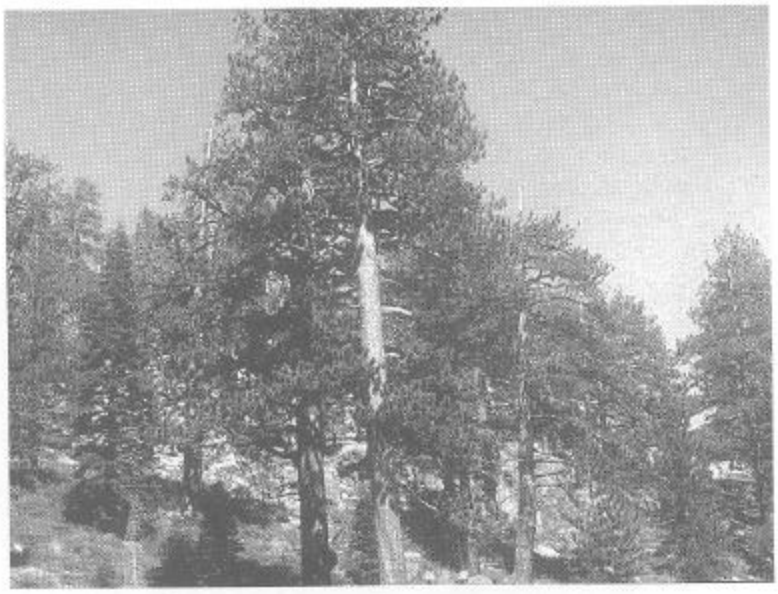


Figure 15—Open stands of Jeffrey pine old growth.

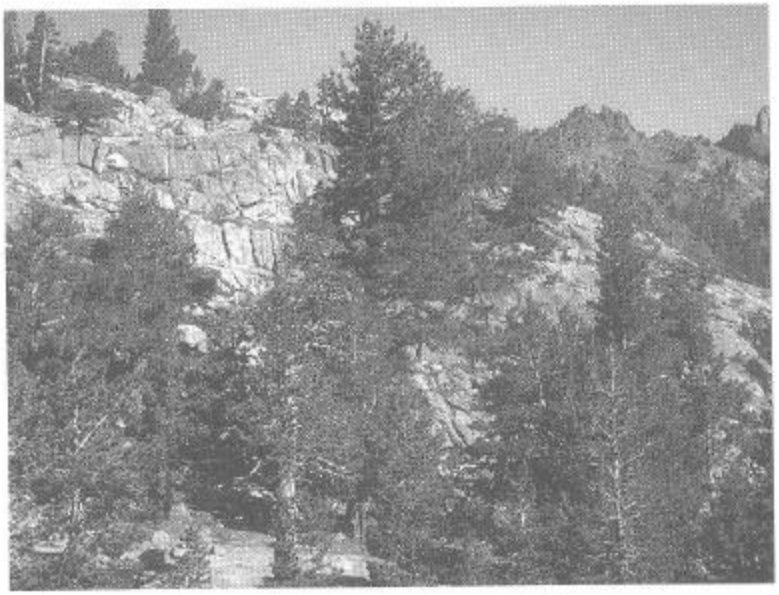


Figure 16—Rocky outcroppings in Jeffrey pine old growth.

Many of the trees in Jeffrey pine old growth in this study had diameters over 60 inches and reached over 130 feet tall. On average the old-growth Jeffrey pine canopy was, however, 15 to 20 feet lower than that of the mixed-conifer, white fir, or California red fir types. Tree canopy cover averaged 57 percent in our old-growth stands, and shrub cover averaged 33 percent. Eighteen tree species were found in Jeffrey pine old-growth stands. Trees of a number of these species were 30 inches or more in diameter, although only white fir and incense-cedar occurred in more than 20 percent of the stands. There was a high diversity of shrubs, forbs, and grasses in the Jeffrey pine old-growth type. Thirtyeight shrub species were found overall, and 16 had a constancy greater than 10 percent. The most common shrubs were greenleaf manzanita and bitterbrush; the most common forbs and grasses were lupine, buckwheat, phlox, and wheatgrass.

Lodgepole pine-Lodepole pine is a relatively short-lived species (Lotan and Critchfield 1990), and some old-growth surveys have excluded it entirely (Bolsinger and Waddell 1993). In this study, much of the old-growth lodgepole pine area had a mean diameter of less than 21 inches. California red fir is found in association with lodgepole pine and it has a longer life span. Often the largest, tallest trees in lodgepole pine old growth are California red fir (figs. 17 and 18). The largest tree tallied in lodgepole pine was a California red fir, 76 inches in diameter; the largest lodgepole pine was 62 inches in diameter. On average, the canopy height in lodgepole pine old growth was only 80 feet.

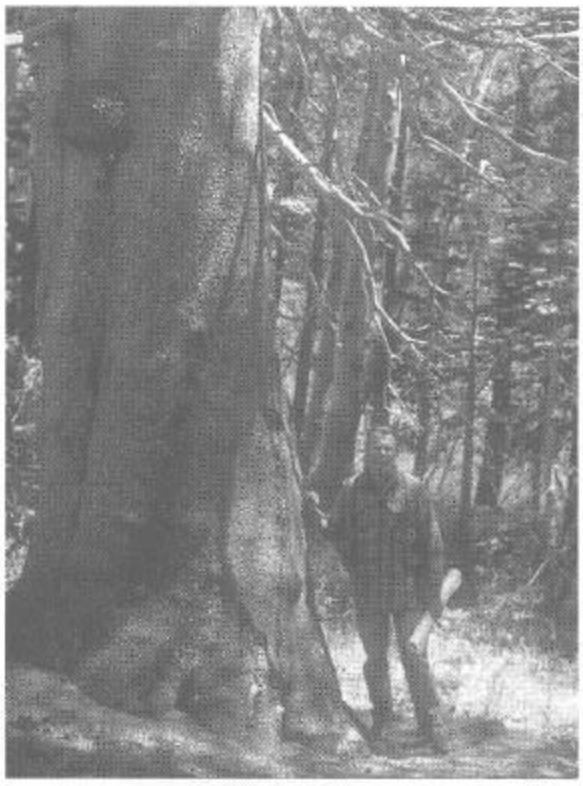


Figure 17—Lodgepole pine old growth.

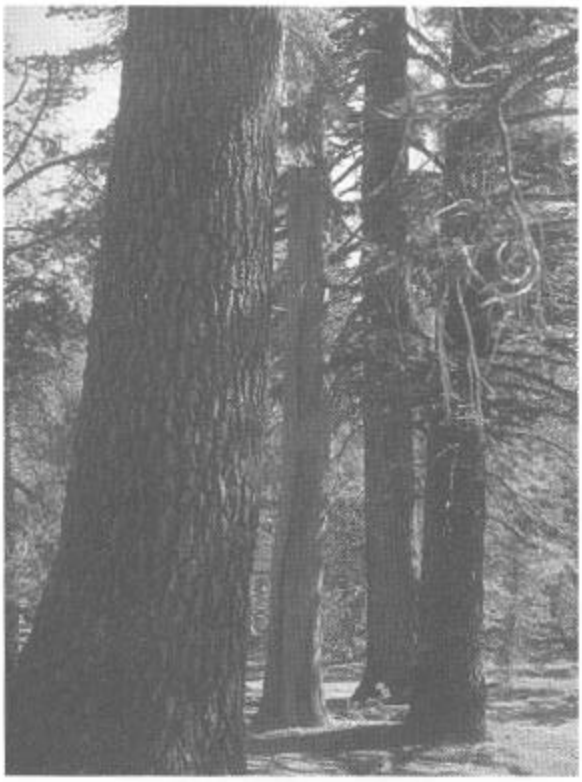


Figure 18—Red fir in lodgepole pine old growth.

Although there is little tree species diversity in lodgepole pine old growth, there is a high diversity of shrubs and herbs, perhaps because the lodgepole pine forest type often is found near meadows and streams. We found 38 shrub species and 37 species of forbs in old-growth lodgepole pine. The most common shrubs were gooseberry, willow, and pinemat manzanita; the most common forb was lupine.

Mixed-subalpine types-The mixed-subalpine forest types have some of the oldest, slowest growing trees in the Sierra Nevada. Although many of the trees in the mixed subalpine forest types may be smaller and shorter than those of lower elevations, they often are older. Western white pine has been aged at 800 years and foxtail pine at 2,000 years old.

The mountain hemlock and western white pine old-growth subtypes are fairly dense, and where the soil is deep, trees attain large sizes (fig. 19). Along with a high density of large trees, there also is a fairly high density of snags and logs in mountain hemlock and western white pine old growth. In this study, these types had a per-acre average of 13 to 14 trees 30 inches in diameter. As with the California red fir old-growth type, there were large gaps between dense groups of trees. The canopy cover averaged 60 to 72 percent. The largest mountain hemlock tallied was 63 inches in diameter; the largest western white pine was 81 inches in diameter.

Diversity of shrubs and forbs tends to be low in the mixed subalpine old-growth types. The most common shrubs found in mixed subalpine old growth were pinemat manzanita, gooseberry, and willow; the most common forbs and grasses were lupine, mule ears, crownbeard and goose grass.

Figure 19—Mountain hemlock old growth.

Acknowledgments

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Appendix A

Old-Growth Definitions

Source of data-The primary source of data for the old-growth definitions was Pacific Southwest Region ecosystem classification plots (Fites and others 1991 a, 1991 b; Potter 1992a, 1992b, 1992c, 1992d; Smith 1991; Smith and others 1991). Plots consisted of a cluster of three points. At each point, trees were tallied on a variable-radius prism plot. Species, d.b.h., age, and height were recorded for all trees. Plant species and percentage of cover of all canopy layers-tree, shrub, herb, and grass-were recorded, and subjective information on structural features and canopy layers was noted. Points were from 66 to 132 feet apart. Thus, a plot covered, at minimum, about 1 acre. There was no limit for the size of the stands. On many ecosystem classification plots, snags, logs, and tree decay were not recorded. For that reason, separate data sets were used to supplement the ecosystem classification plots for these structural attributes. Supplemental data sets came from the existing timber inventories for each National Forest. This data set was similar in design to the ecology plots, but used a five-point L-shaped cluster plot, all other tree and snag data being essentially the same. No logs were collected in the timber inventories.

Techniques used to develop old-growth definitions-The plots were stratified by SAF type and site class. The age of the oldest tree measured was used to represent the age of the stand. Trend analysis was employed to determine at what age most of the structural attributes changed from mature to old growth. The age where this occurred was the cutoff from which statistics were calculated by site class for the key structural attributes of old growth. In some old-growth definitions, the plots were stratified by site and age class, and discriminant analysis was used to identify those variables that could best discriminate old growth from mature stands.

The key structural characteristics of old-growth definitions-Table 13, lists the minimum criterion for each of the three primary components (density and size of trees, snags, logs) of the old-growth definitions. Note that some of the components are further subdivided by size. Thus, in the high-site interior ponderosa pine forest type, the minimum criterion for live trees is at least 15 trees per acre ? 21 inches d.b.h. including 3 trees per acre >30 inches d.b.h. For many of the types, the minimum snag criterion or log criterion was reported as zero. This would seem to indicate that the component was not useful in distinguishing old growth from mature sawtimber. The methods to collect snags (often variable-radius prism plots) on the cluster plots used for classification, however, may have been too small to sample snags, which occur in low density. The result was a high variance for estimates of number of snags per acre. In addition, the number of samples available for estimating coarse woody debris (logs) was much smaller than that used for live trees and may have been insufficient to give an adequate minimum criterion for this component.

Table 13—Key structural characteristics of the definitions of old growth in timberland forest types, Sierra Nevada

Forest type	Site class[a]	Minimum stand age	Live trees		Snags		Logs		
			Diameter	Minimum	Diameter	Minimum	Diameter	Length	Minimum
		Years	*Inches*	*No. per acre*	*Inches*	*No. per acre*	*Inches*	*Feet*	*No. per acre*
White fir	High(1a-1)	143	39	7			10 and 20	10	6.1 and 5.2
	Medium(2-3)	188	39	6			10 and 20	10	6.1 and 5.2
	Low(4-5)	239	29	6			10 and 20	10	6.1 and 5.2
California red fir	High(1a-3)	150	30	12			30		0.1
	Low(4-5)	200	30	7			30		0.6
Pacific ponderosa pine	High(1a-1)	125	30[b] 15[c]	11	any size	2	any size		1
	Low(2-5)	145	30[b] 15[c]	2	any size	2	any size		1
Interior ponderosa pine	High(1a-3)	150	21[d] and 30	30 3					
	Low(4-5)	200	21	13					
Jeffrey pine	High (1a-3)	150	30	4.3					
	Low(4-5)	200	30	2.2					
Lodgepole pine	High(1a-3)	150	25	10					
	Low(4-5)	200	25	3					
Mixed-conifer	High(1a-1)	188	39	8					
	Medium(2-3)	253	39	6					
	Low(4-5)	256	29	5					
Mixed subalpine:									
Western white pine	High(1a-3)	150	30	5					
	Low(4-5)	200	30	7					
Mountain hemlock	High(1a-3)	150	30	8					
	Low(4-5)	200	30	7	30	0.1			
White fir/Jeffrey pine	High(1a-3)	150	30	7	30	0.1			
	Low(4-5)	200	30	3	30	0.3			

[a] Site classes in parentheses are used by the PSW region of the Forest Service (USDA 1994). They are based on Dunnngs site index curves for height at 300 years. Roughly, a class 1a >= 182; class 1 = 157 to 181; class 2 = 132 to 156; class 3 = 108 to 131; class 4 = 84 to 107; class 5 = <84.

[b] 30 inches for conifers.

[c] 15 inches for hardwoods.

[d] 30 trees 21 inches in diameter, and 3 trees 30 inches in diameter.

Appendix B

Key to SAF Forest Types in California

1. If more than 33 percent total basal area is redwood, then type is
   SAF 232 redwood.

2. If more than 33 percent total basal area is Port-Orford-cedar, then type is
   SAF 231 Port-Orford-cedar.

3. If more than 25 percent total basal area is lodgepole pine and lodgepole pine has the plurality of the basal area stocking of species other than California red fir, then type is
   SAF 218 lodgepole pine.

4. If more than 80 percent total basal area is ponderosa pine and plot is east of the Sierra crest, then type is
   SAF 237 interior ponderosa pine.

5. If more than 80 percent total basal area is ponderosa pine and plot is west of the Sierra crest, then type is
   SAF 245 Pacific ponderosa pine.

6. If more than 50 percent total basal area is Jeffrey pine, then type is
   SAF 247 Jeffrey pine.

7. If more than 80 percent total basal area is comprised of ponderosa pine and Jeffrey pine:

   - If plot is east of Sierra crest and there is more ponderosa pine than Jeffrey pine, then type is
     SAF 237 interior ponderosa pine.
   - If plot is east of Sierra crest and there is more Jeffrey pine than ponderosa pine, then type is
     SAF 247 Jeffrey pine.
   - If plot is west of Sierra crest and there is more ponderosa pine than Jeffrey pine, then type is
     SAF 245 Pacific ponderosa pine.
   - If plot is west of Sierra crest and there is more Jeffrey pine than ponderosa pine, then type is
     SAF 247 Jeffrey pine.

8. If plot consists solely of ponderosa pine and juniper and more than 50 percent total basal area is in ponderosa pine, then type is
   SAF 237 interior ponderosa pine.

9. If more than 50 percent of total basal area is white fir and plot is in the Six Rivers National Forest or in the Ukonom, Happy Camp, or west Salmon River districts of the Klamath National Forest, then type is
   SAF 211 white fir-a.

10. If more than 60 percent of total basal area is white fir and plot is NOT in the Six Rivers National Forest or in the Ukonom, Happy Camp, or west Salmon River districts of the Klamath National Forest, then type is
    SAF 211 white fir-b.

11. If more than 10 percent total basal area is comprised of western white pine, whitebark pine, mountain hemlock, aspen, or (oxtail pine:

    - If more than 60 percent of the total basal area is comprised of white fir, California red fir, and Jeffrey pine, then type is
      SAF 256-c mixed subalpine-white fir/Jeffrey pine
    - If more than 50 percent of the total basal area is comprised of western juniper, then type is
      SAF 256-d mixed subalpine-western juniper.
    - If more than 50 percent of the total basal area is comprised of aspen, then type is
      SAF 256-a mixed subalpine-aspen.
    - If more than 30 percent of the total basal area is comprised of mountain hemlock, and the mountain hemlock basal area exceeds western white pine, then type is
      SAF 256-b mixed subalpine-mountain hemlock.
    - If more than 20 percent of the total basa/area is comprised of western white pine, then type is
      SAF 256-a mixed subalpine-western white pine.
    - If more than 20 percent of the total basal area is comprised of foxtail pine, or whitebark pine, or Brewer spruce, then type is
      SAF 256-b mixed subalpine-mountain hemlock (by proxy).

12. If more than 50 percent of total basal area is California red fir, then the type is **SAF 207 California red fir.**

13. If more than 80 percent of total basal area is comprised of California red fir and white fir:

    - If there is more California red fir than white fir, then type is
      SAF 207 California red fir.
    - If there is more white fir then California red fir and plot is in the Six Rivers National Forest or the Ukonom, Happy Camp, or west Salmon River districts of the Klamath National Forest, then type is
      SAF 211 white fir-a.
    - If there is more white fir than California red fir and plot is NOT in the Six Rivers National Forest or the Ukonom, Happy Camp, or west Salmon River districts of the Klamath National Forest, then type is
      SAF 211 white fir-b.

14. If more than 50 percent of total basal area is Douglas-fir (or if Douglas-fir is the sole conifer) and evergreen hardwoods (tanoak, Pacific madrone, canyon live oak) comprise at least 10 percent of total basal area and white fir is absent, then type is **SAF 234 Douglas-fir/tanoak.'**

15. If more than 50 percent of total basal area is Douglas-fir and evergreen hardwoods (tanoak, Pacific madrone, canyon live oak) comprise less than 10 percent of the total basal area or white fir is present, then type is
    SAF 229 Pacific Douglas-fir.

' The Douglas-fir forest types are not recognized to occur in the Sierra Nevada.

16. If more than 50 percent of the total basal area is comprised of a combination of Douglas-fir, ponderosa pine, white fir, incense-cedar, sugar pine, black oak, Jeffrey pine, or California red fir, then type is SAF 243 **mixed-conifer.**

Appendix C

Common and Scientific Names of Trees, Shrubs, and Forbs

Names of plant species follow the nomenclature used by the USDA Natural Resource Conservation Service.

Common name	Scientific name
Softwood trees:	
Bishop pine	*Pinus muricata* D. Don
Bristlecone pine	*Pinus longaeva* D.K. Bailey
California nutmeg	*Torreya californica* Torr.
California red fir	*Abies magnifica* A. Murr.
Coulter pine	*Pinus coulteri* D. Don
Cypress	*Cupressus* sp. L.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Foxtail pine	*Pinus balfouriana* Grev. & Balf.
Giant sequoia	*Sequoiadendron giganteum* (Lindl.) Buchh.
Grand fir	*Abies grandis* (Dougl. ex D. Don) Lindl.
Gray pine	*Pinus sabiniana* Dougl. ex Dougl.
Incense-cedar	*Libocedrus decurrens* Torr.
Jeffrey pine	*Pinus jeffreyi* Grev. & Balf.
Knobcone pine	*Pinus attenuata* Lemmon
Limber pine	*Pinus flexilis* James
Lodgepole pine	*Pinus contorta* Dougl. ex Loud.
Monterey pine	*Pinus radiata* D. Don
Mountain hemlock	*Tsuga mertensiana* (Bong.) Carr.
Pacific yew	*Taxus brevifolia* Nutt.
Pinyon pine	*Pinus edulis* Engelm.
Ponderosa pine	*Pinus ponderosa* P. & C. Lawson
Port-Orford-cedar	*Chamaecyparis lawsoniana* (A. Murr.) Parl.
Redwood	*Sequoia sempervirens* (Lamb. ex D. Don) Endl.
Sugar pine	*Pinus lambertiana* Dougl.
Western juniper	*Juniperus occidentalis* Hook.
Western white pine	*Pinus monticola* Dougl. ex D. Don
White fir	*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.
Whitebark pine	*Pinus albicaulis* Engelm.
Hardwood trees:	
Bigleaf maple	*Acer macrophyllum* Pursh
Black cottonwood	*Populus trichocarpa* Torr. & Gray ex Hook.
Blue oak	*Quercus douglasii* Hook. & Arn.
California buckeye	*Aesculus californica* (Spach) Nutt.
California black oak	*Quercus kelloggii* Newberry
California-laurel	*Umbellularia californica* (Hook. & Arn.) Nutt.
Canyon live oak	*Quercus chrysolepis* Liebm.
Fremont popular	*Populus fremontii* S. Wats.
Giant chinkapin	*Castanopsis chrysophylla* (Dougl. ex Hook.) A. DC.

Interior live oak	*Quercus wislizenii* A. DC.
Oregon ash	*Fraxinus latifolia* Benth.
Oregon white oak	*Quercus garryana* Dougl. ex Hook.
Pacific dogwood	*Cornus nuttallii* Audubon ex Torr. & Gray
Pacific madrone	*Arbutus menziesii* Pursh
Quaking aspen	*Populus tremuloides* Michx.
Red alder	*Alnus rubra* Bong.
Tanoak	*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.
Valley oak	*Quercus lobata* Née
White alder	*Alnus rhombifolia* Nutt.

Shrubs, forbs and grasses:

Bedstraw	*Galium* sp. L.
Bitterbrush	*Purshia tridentata* (Pursh) DC.
Bracken	*Pteridium aquilinum* (L.) Kuhn
Buckwheat	*Eriogonum* spp. Michx.
Bush chinkapin	*Castanopsis sempervirens* (Kellogg) Dudley ex Merriam
Cheatgrass	*Bromus tectorum* L.
Crownbeard	*Venegasia carpesioides* DC.
Currant	*Ribes* sp. L.
Gooseberry	*Ribes roezlii* Regel
Goose grass	*Eleusine* spp. Gaertn.
Greenleaf manzantia	*Arctostaphylos patula* Greene
Huckleberry oak	*Quercus vacciniifolia* Kellogg
Lupine	*Lupinus* sp. L.
Mahala-mat	*Ceanothus prostratus* Benth.
Mule ears	*Wyethia* spp. Nutt.
Phlox	*Phlox dispersa* C.W. Sharsmith
Pinemat manzanita	*Arctostaphylos nevadensis* Gray
Sedge	*Carex* spp. L.
Snowberry	*Symphoricarpos albus* (L.) Blake
Starflower	*Trientalis latifolia* Hook.
Wheatgrass	*Elymus* spp. L.
Whitethorn	*Ceanothus cordulatus* Kellogg
Willow	*Salix* sp. L.

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This report presents estimates of old-growth forest area in the Sierra Nevada by forest type in 1993 and 1945 and by old-growth stand characteristics as they existed in 1993. Ecological old-growth definitions for each forest type are used.

Keywords: Old growth, inventory, forest stands, forest area, California, National Forests, Douglas-fir, white fir, red fir, Jeffrey pine, ponderosa pine, lodgepole pine, mixed conifer, mountain hemlock, mixed subalpine.

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