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# SITE PREPARATION AS RELATED TO GROUND COVER DENSITY IN NATURAL REGENERATION OF PONDEROSA PINE

D. TACKLE and D. F. ROY

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SITE PREPARATION AS RELATED TO GROUND COVER
DENSITY IN NATURAL REGENERATION OF PONDEROSA PINE

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Surface disturbance of the forest floor by mechanical means is recognized as a cultural measure for aiding establishment of conifer seedlings. Present harvesting practices in the ponderosa pine type create favorable seedbed conditions to a limited extent during the normal course of logging, but purposeful seedbed preparation has not been the rule. More information on the effect of competing vegetation on germination and early establishment of pine would aid greatly in planning treatments for adequate restocking.

## The Experiment

Accordingly, a study was designed as a preliminary test in securing natural regeneration of ponderosa pine (*Pinus ponderosa* Laws.) and Jeffrey pine (*P. jeffreyi* Grev. and Balf.) in the eastside pine region of California. Ground scarification was used to simulate fresh logging disturbance on bare ground and to remove vegetation elsewhere.

The specific factors chosen for study were:

1. Germination and survival of seedlings as related to ground cover density on scarified seedbeds.

2. Comparative height growth of seedlings on areas of varying ground cover density.

The experiment was conducted on the Blacks Mountain Experimental Forest in northeastern California during the years 1948 to 1952.

### Selection of Study Areas

In 1948 six areas, each of varying ground cover density, were selected for scarification and rodent poisoning. These areas satisfied certain conditions. First, each represented a natural regeneration area

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1/ Formerly Forester, California Forest and Range Experiment Station; now with the Intermountain Forest and Range Experiment Station. Analyzed data for first three years and submitted thesis to the University of California in partial satisfaction of the requirements for the Degree of Master of Science.

2/ Forester (Silviculture). Aided in field work and continued the study through the fourth year.

as prescribed under the unit area control form of management[3] when applied to the eastside ponderosa pine type. Second, the areas had to be sufficiently large and properly shaped--generally larger than 0.2 acre and any shape except extremely long and narrow. Third, the trees bordering the areas had to be bearing a satisfactory cone crop during seedbed preparation so that seed would be supplied soon after.

## Scarification

The forest floor on the plots was scarified two weeks before seedfall with an offset disc-harrow pulled by a wheeled farm tractor. The disc-harrow had two sets of discs with 22-inch blades. By adjusting the rear set of discs to cut between the furrows made by the forward set, maximum disturbance was attained. This machine scarified strips four and one-half feet wide. It performed well on open bare areas and on areas with very light cover of low vegetation. However, it was not heavy enough to break through and tear up a duff layer or thick bunch-grass roots, and in slash the equipment hung up on limbs and chunks. A definite need exists for developing scarification equipment which can cope with these impediments as well as the stony soil surfaces of the eastside type.

## Rodent Poisoning

Poisoning was aimed at three seed-eating rodents: Ground-squirrels (Citellus spp.), chipmunks (Eutamias spp.) and white-footed mice (Peromyscus spp.). No attempt was made to control pine squirrels (Tamiasciurus spp.) and California gray squirrels (Sciurus griseus griseus Ord.) since activity of these animals in the study areas was negligible during the period of cone development. Rodent populations were not determined by trapping, but observations indicated that each of the three kinds of rodents toward which the poisoning was directed was present before seedfall in substantial numbers on all study areas.

The lethal bait consisted of oat groats treated with sodium fluoroacetate, also known as "1080". Three ounces of "1080" were added to every 100 pounds of groats. In all, 810 acres were treated at a cost of 26 cents per acre[4].

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3/ Hallin, William E. 1951. Unit area control in California forests. U. S. Forest Serv., Calif. Forest and Range Expt. Sta. Research Note 77, 6 pp.

4/ Cosens, Richard D. and David Tackle. 1950. Costs of rodent control in pine regeneration in California. U. S. Forest Serv., Calif. Forest and Range Expt. Sta. Research Note 73, 5 pp.

### Seedfall

An abundant seed crop occurred in 1948. Seedfall was not measured on the study areas, but 120 seedtraps on three comparable logged plots nearby caught sound pine seed at the rate of 130,000 seed per acre.

### Germination and Survival Counts

Seedling germination and survival were sampled on milacre quadrats arranged in transects. These transects ran through all degrees of ground-cover density present on the six locations.

Each milacre quadrat was classified by the type and visible surface density of ground cover. If the quadrat had one-tenth or less of its surface covered, it was classified as bare; if more than one-tenth but not greater than four-tenths, light; more than four-tenths but not over seven-tenths, medium; and if more than seven-tenths, heavy.

Germination, survival and height growth were analyzed by the original quadrat classifications. In 1951 each quadrat was reclassified to detect any changes in surface density. No appreciable change was found for either vegetation or duff. On some quadrats slash had settled nearer the ground but the overall density remained unchanged.

### Height Growth Measurements

If stocking is adequate, seedling vigor determines how soon, if ever, the desired reproduction will dominate competing vegetation and establish a forest cover. Therefore, seedling vigor, best measured by height growth, is another measure of regeneration success. To obtain comparisons, heights of all seedlings not damaged by deer, rodents, cattle, or other agents, were recorded for a randomly selected sample of quadrats from each of the four ground-cover density groups.

## Results

### Germination

The greatest number of seed per acre germinated on seedbeds described as bare. Here over 33,000 seed germinated per acre. As ground-cover density increased, germination declined, with greater disparity between germination on bare and light densities of cover than between germination on medium and heavy densities. Seedbeds with light, medium, and heavy ground cover had 11,420 seedlings, 3,816 seedlings, and 2,914 seedlings per acre, respectively. Roughly similar trends are indicated for the density range within each type of ground cover (Table 1). For example, 5,062 seed per acre germinated on quadrats with light squaw carpet cover, 3,091 seed per acre on medium squaw carpet, but only 1,774 seed per acre germinated on heavy squaw carpet.

Table 1.--Germination by type and density of ground cover

| Ground-cover density | Type of ground cover: Squaw carpet[1] | Grass | Woolly mules-ears[2] | Duff | Slash | All | Quadrat basis |
|---|---|---|---|---|---|---|---|
| | . . . . . number seeds germinating per acre . . . . | | | | | | number |
| Bare | -- | -- | -- | -- | -- | 33,329 | 164 |
| Light | 5,062 | 13,472 | -- | 5,643 | -- | 11,420 | 119 |
| Medium | 3,091 | 5,889 | 5,286 | 1,750 | 2,333 | 3,816 | 38 |
| Heavy | 1,774 | 5,944 | -- | 2,286 | 1,428 | 2,914 | 70 |
| Basis; number of quadrats | 58 | 116 | 7 | 36 | 10 | -- | -- |

1/ *Ceanothus prostratus* Benth.

2/ *Wyethia mollis* Gray.

Variable effects of ground-cover types on germination are also shown. The most marked example of this is the germination obtained on grassy quadrats[5]. On these, germination for any cover density class was much greater than for any other type of cover in the same density range.

First Year Survival

The effect of ground cover upon pine seedling survival was evident as early as the end of the first growing season. While 42 percent of the seedlings on bare areas survived, only 16 percent remained alive where the cover density was heavy (Table 2). The relatively low survival (26 percent on areas with only light cover shows that even a small amount of competition is unfavorable to seedling establishment.

5/ Species of bunch grasses and sedge distributed approximately as follows: Idaho fescue (*Festuca idahoensis*) - 71 percent, squirreltail (*Sitanion hystrix*) - 11 percent, western needlegrass (*Stipa occidentalis*) - 10 percent, little bluegrass (*Poa sandbergii*) - 4 percent, and sedge (*Carex rossii*) - 4 percent.

Table 2.--Percentages of seedling survival for the first and fourth years after germination by type and density of ground cover

FIRST YEAR

| Ground-cover density | Squaw carpet | Grass | Woolly mules-ears | Duff | Slash | All[1/] |
|---|---|---|---|---|---|---|
| | Type of ground cover | | | | | |
| | percent survival | | | | | |
| Bare | -- | -- | -- | -- | -- | 42 (41.9) |
| Light | 31 (4.1)[2/] | 26 (22.8) | -- | 27 (3.6) | -- | 26 (30.5) |
| Medium | 9 (2.8) | 19 (2.3) | 27 (1.8) | 14 (2.0) | 29 (0.8) | 19 (9.7) |
| Heavy | 11 (7.9) | 16 (4.6) | -- | 22 (3.6) | 20 (1.8) | 16 (17.9) |
| All[1/] | 20 (14.8) | 25 (29.7) | 27 (1.8) | 24 (9.2) | 24 (2.6) | 38[3/] (100.0) |

FOURTH YEAR

| Ground-cover density | Squaw carpet | Grass | Woolly mules-ears | Duff | Slash | All[1/] |
|---|---|---|---|---|---|---|
| Bare | -- | -- | -- | -- | -- | 33 |
| Light | 19 | 11 | -- | 7 | -- | 11 |
| Medium | 0 | 0 | 8 | 7 | 14 | 4 |
| Heavy | 0 | 4 | -- | 13 | 0 | 4 |
| All[1/] | 9 | 10 | 8 | 8 | 12 | 24[3/] |

1/ Weighted by number of quadrats sampled in each category. Data are presented in this form to indicate the natural regeneration which can be expected after scarification, rodent poisoning, and seedfall as described in this report.

2/ Numbers in parentheses show the percent of ground area in each category.

3/ Includes data for bare ground.

First year seedling survival on a stocked quadrat basis--one or more seedlings per milacre quadrat (Table 3)--further demonstrates the effect of the density of ground cover. Stocking after the first year under medium and heavy cover by either stocked quadrats or number of seedlings per acre (Table 4) was well below that presently considered necessary for producing a fully stocked stand at maturity.

Survival During Early Establishment

Seedling survival diminished each year after germination (Tables 4 and 5). Reduction in survival between the first and fourth years on bare areas was decidedly lower than the reduction on areas of denser ground cover, whether numbers of seedlings (Table 5) or numbers of stocked quadrats (Table 3) are considered. If numbers of seedlings are used, the reductions in survival between the first and fourth years are 9 percent for bare, 15 percent for light, 15 percent for medium, and 11 percent for heavy densities. Though these losses are about the same percentage-wise, the loss for the heavy ground cover is more significant because far fewer seedlings survived there the first season. Reductions in stocked milacre quadrats during the same period for bare, light, medium, and heavy ground-cover densities were 20 percent, 33 percent, 23 percent, and 9 percent, respectively.

Height Growth

The height growth of seedlings also showed pronounced effects of ground-cover density. These differences increased markedly in the fourth year, the average total heights for all seedlings on bare, light, medium, and heavy cover densities being 5.6, 2.3, 3.2, and 2.5 inches, respectively (Table 6). When only the tallest seedlings (one per quadrat) were used, the average heights became 6.7, 3.0, 3.1, and 2.4 inches (Table 7).

Differences in height growth through the fourth year were compared by t-tests and were found to be highly significant between bare and light density covers for all seedlings; and significant for the tallest seedlings. The seedling height differences between light and medium cover densities were significant for all seedlings[6/]. No other differences were statistically significant.

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6/ Height differences between seedlings growing on light and medium cover densities were not significant at the end of the third year. This discrepancy in statistical significance of height growth between the third and fourth growing seasons is a reflection of seedling mortality and field technique and not height growth per se. During the first three years heights were measured from cotyledon scars to tips of terminal buds. In the fourth growing season the cotyledon scars became indistinct on many seedlings so heights had to be measured from ground line to tips of terminal buds

Table 3.--Milacre quadrat stocking percentages for first and fourth years by ground-cover density.

| Ground-cover density | Stocked quadrats First year | Stocked quadrats Fourth year | Basis First year | Basis Fourth year[1] |
|---|---|---|---|---|
| | . . . percent | | . . . number . . . | |
| Bare | 90 | 70 | 164 | 115 |
| Light | 66 | 33 | 119 | 101 |
| Medium | 37 | 14 | 38 | 36 |
| Heavy | 17 | 8 | 70 | 63 |
| All | 65 | 39 | 391 | 315 |

1/ Sample size reduced by logging disturbance

Seedlings on bare areas were not only taller but were much more vigorous in appearance; they had greater needle complement, longer needles, and more robust stems, than seedlings on areas with greater cover density (Figures 1, 2, 3, 4, and 5)

Table 4.--Number of seedlings surviving per acre by type and density of ground cover, and year after germination

| Ground-cover density and year | | Squaw carpet | Grass | Woolly mules-ears | Duff | Slash | All |
|---|---|---|---|---|---|---|---|
| Bare | 1 year | -- | -- | -- | -- | -- | 14,043 |
| | 2 year | -- | -- | -- | -- | -- | 13,122 |
| | 3 year | -- | -- | -- | -- | -- | 12,035 |
| | 4 year | -- | -- | -- | -- | -- | 11,017 |
| Light | 1 year | 1,562 | 3,528 | -- | 1,500 | -- | 3,025 |
| | 2 year | 1,312 | 2,575 | -- | 917 | -- | 2,178 |
| | 3 year | 937 | 1,822 | -- | 417 | -- | 1,535 |
| | 4 year | 937 | 1,493 | -- | 417 | -- | 1,277 |
| Medium | 1 year | 273 | 1,111 | 1,428 | 250 | 667 | 710 |
| | 2 year | 0 | 571 | 1,000 | 250 | 333 | 389 |
| | 3 year | 0 | 286 | 571 | 125 | 333 | 222 |
| | 4 year | 0 | 0 | 429 | 125 | 333 | 139 |
| Heavy | 1 year | 194 | 944 | -- | 500 | 286 | 457 |
| | 2 year | 103 | 462 | -- | 357 | 286 | 254 |
| | 3 year | 34 | 231 | -- | 357 | 0 | 143 |
| | 4 year | 0 | 231 | -- | 286 | 0 | 127 |
| All | 1 year | 586 | 2,940 | 1,428 | 833 | 400 | 6,962 |
| | 2 year | 428 | 2,129 | 1,000 | 529 | 300 | 5,584 |
| | 3 year | 321 | 1,484 | 571 | 324 | 200 | 4,943 |
| | 4 year | 267 | 1,204 | 429 | 294 | 200 | 4,473 |

Table 5.--Seedling survival, by ground-cover density

| Ground-cover density | Years after seedfall: First | Second | Third | Fourth |
|---|---|---|---|---|
| | . . . . . . . . . percent survival | . . . . . . . . | | |
| Bare | 42 | 39 | 36 | 33 |
| Light | 26 | 19 | 13 | 11 |
| Medium | 19 | 10 | 6 | 4 |
| Heavy | 16 | 9 | 5 | 4 |
| All | 38 | 30 | 27 | 24 |

Table 6.--Average heights of seedlings, in third and fourth years, by ground-cover density

| Ground-cover density | Third year: Basis: Quadrats | Third year: Basis: Seedlings | Third year: Average height 1/ | Third year: Difference and significance 3/ | Fourth year: Basis: Quadrats | Fourth year: Basis: Seedlings | Fourth year: Average height 2/ | Fourth year: Difference and significance 3/ |
|---|---|---|---|---|---|---|---|---|
| | number | number | inches | inches | number | number | inches | inches |
| Bare | 10 | 73 | 2.8 | | 8 | 61 | 5.6 | |
| | | | | 1.5 HS | | | | 3.3 HS |
| Light | 10 | 38 | 1.3 | | 9 | 26 | 2.3 | |
| | | | | 0.1 N | | | | 0.9 S |
| Medium | 6 | 8 | 1.2 | | 4 | 5 | 3.2 | |
| | | | | 0.1 N | | | | 0.7 N |
| Heavy | 5 | 5 | 1.1 | | 3 | 4 | 2.5 | |

1/ Measured from cotyledons to tip of terminal bud.
2/ Measured from ground line to tip of terminal bud
3/ HS - highly significant
S - significant
N - not significant

Table 7.--Average heights of tallest seedlings (one per quadrat), in third and fourth years, by ground-cover density

| Ground-cover density | Third year: Seedlings measured | Third year: Average height 1/ | Third year: Difference and significance 3/ | Fourth year: Seedlings measured | Fourth year: Average height 2/ | Fourth year: Difference and significance 3/ |
|---|---|---|---|---|---|---|
| | number | inches | inches | number | inches | inches |
| Bare | 10 | 3.2 | | 8 | 6.7 | |
| | | | 1.7 S | | | 3.7 S |
| Light | 10 | 1.5 | | 9 | 3.0 | |
| | | | 0.2 N | | | 0.1 N |
| Medium | 6 | 1.3 | | 4 | 3.1 | |
| | | | 0.2 N | | | 0.7 N |
| Heavy | 5 | 1.1 | | 3 | 2.4 | |

1/ Measured from cotyledons to tip of terminal bud.
2/ Measured from ground line to tip of terminal bud.
3/ HS - highly significant
S - significant
N - not significant

## Discussion

Comparison of results for various ground-cover densities shows that ponderosa pine seedbed preparation should be aimed at eliminating all competing ground cover and exposing loose mineral soil, not necessarily over the whole ground surface but in enough evenly distributed spots for sufficient germination and early seedling survival to insure adequate future stocking. A search for reproduction on bare but unscarified ground within the poisoned area indicated that scarification is desirable even on bare ground. Seedbeds should be prepared in the same year as the seedfall to obtain the maximum benefit of loose mineral soil before it again becomes compacted.

Besides hindering germination and survival, small amounts of competing vegetation are detrimental to pine seedling development. Four years after seedfall, live seedlings on the bare soil averaged 1.8 to 2.4 times as tall as seedlings growing where ground cover was present. The dominant seedlings growing on bare soil were 2.2 to 2.9 times taller than dominant seedlings growing elsewhere. These differences are statistically significant. Visible surface cover density, therefore, appears to be a fairly good indicator of poor seedling height growth, at least for the first four years.

Some might argue that areas with light cover density have adequate stocking (1,277 seedlings per acre) three years after seedfall. However, the number of seedlings per acre becomes less impressive when we see that only 33 percent of the milacre quadrats are stocked, and when the poor height growth (Tables 6 and 7) is considered. The chance for seedlings to attain full growth potential in early life has been thwarted by only a small amount of competition or ground cover. Bare soil seems the only suitable condition for early maximum stand development.

## Conclusions

Results of the study allow the following conclusions:

1. Duff, slash, and competing vegetation are all detrimental to establishment and development of seedlings in the eastside pine type of California.

2. Detrimental effects of ground cover become increasingly greater with time, at least for the first four years.

3. Proper site preparation aids seed germination and seedling survival, and minimizes the period needed by seedlings to dominate the ground and assure a new stand of trees.

Figure 1.--Bare soil quadrat. Five-year-old seedlings. Average height of 27 undamaged seedlings: 9.8 inches. Range of heights: 15.2 to 4.0 inches. Two seedlings damaged.

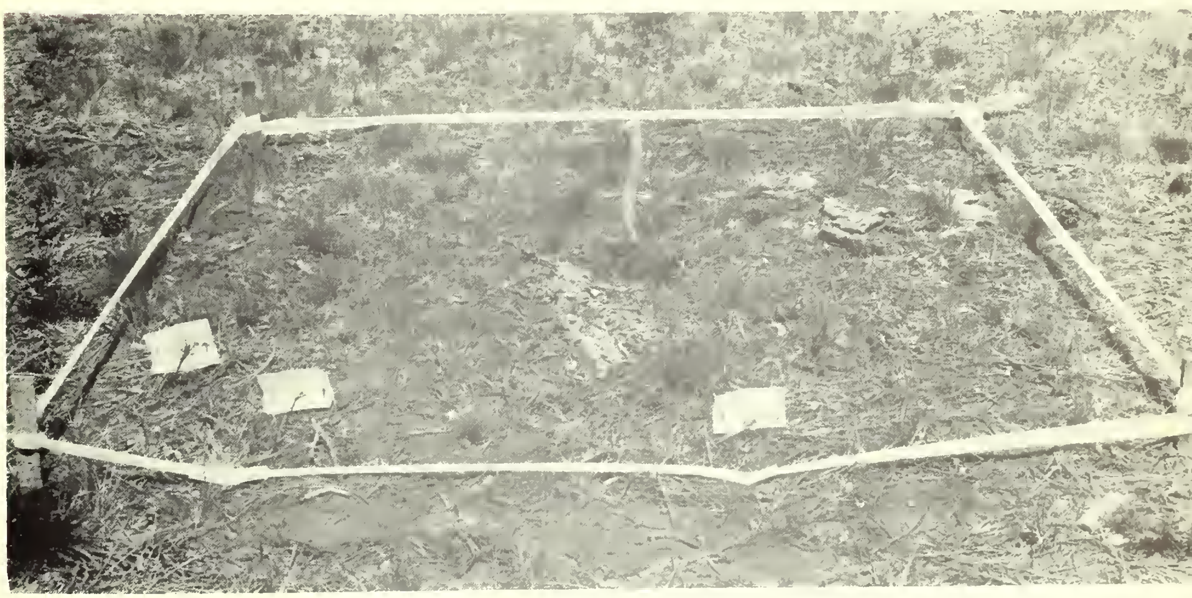

Figure 2.--Heavy grass quadrat. Five-year-old seedlings. Average height of 3 seedlings: 3.1 inches. Range of heights: 2.4 to 4.3 inches.

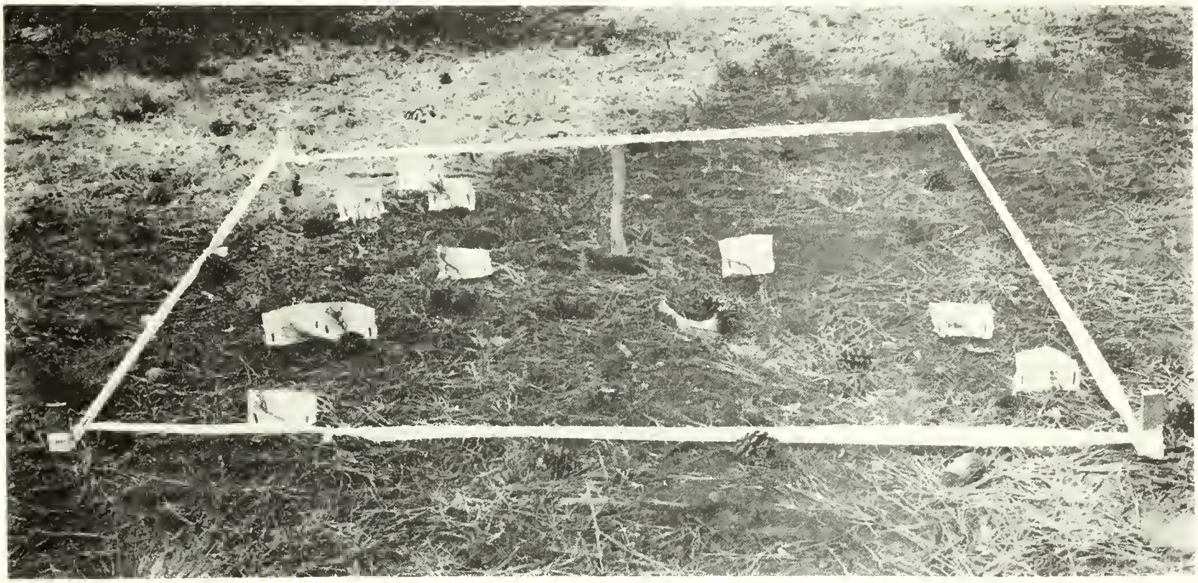

Figure 3.--Light duff quadrat. Five-year-old seedlings. Average height of 10 seedlings: 3.7 inches. Range of heights: 3.0 to 4.6 inches.

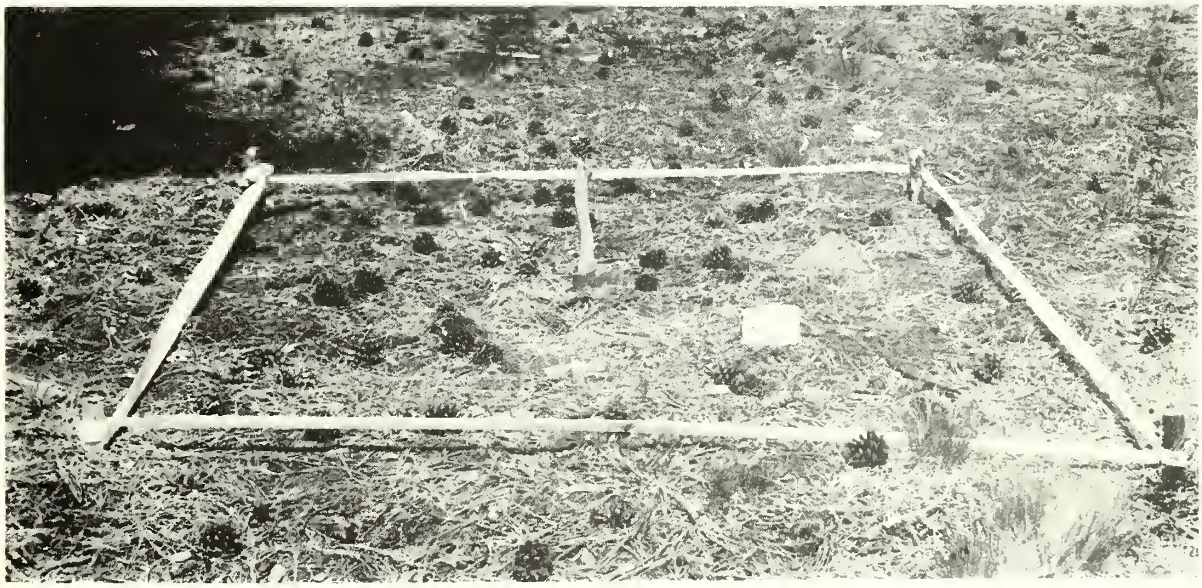

Figure 4.--Heavy duff quadrat. Five-year-old seedling. Height: 1.8 inches.

# SEASONING CALIFORNIA HARDWOODS

H. H. SMITH

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FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M. JEMISON, DIRECTOR

# SEASONING CALIFORNIA HARDWOODS

H. H. Smith

Utilization of the several hardwood timber species native to California has not kept pace with softwood lumber production. Difficulties encountered in seasoning hardwood lumber have largely accounted for its limited use. Some hardwood lumber has been successfully cut and remanufactured into flooring, but the results were not sufficiently encouraging to establish a going hardwood lumber industry. Results of several seasoning experiments, however, are now available[1]. They indicate that past difficulties in the seasoning of western hardwood lumber can be overcome. This paper describes the drying procedure and results obtained in cooperative studies conducted at two mills in the redwood region of California--the Union Lumber Company at Fort Bragg and the Pacific Lumber Company at Scotia. Results of this work, though not productive of a final answer, add to the growing store of information that eventually may lead to more complete utilization of California's hardwood timber.

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1/ Espenas, Leif D. 1953. The seasoning of one-inch tanoak lumber. Oregon Forest Products Laboratory Bul. 3. 46 pp. Corvallis, Oregon.

Espenas, Leif D. 1951. The seasoning of Oregon hardwoods. Oregon Forest Products Laboratory, Inform. Cir. 6. 35 pp. Corvallis, Oregon.

Smith, Harvey H. 1949. Seasoning California black oak. California Forest and Range Experiment Station, Res. Note No. 62. 8 pp. Berkeley, Calif.

Smith, H. H. 1950. Further experiments in seasoning California black oak. California Forest and Range Experiment Station, Res. Note No. 75. 11 pp. Berkeley, Calif.

Torgeson, O. W. 1950. Kiln-drying schedules for 1-inch laurel, madrone, tanoak and chinquapin. Forest Products Laboratory No. R1684. 24 pp. Madison, Wisconsin.

Voorhees, Glenn. 1944. The essentials of kiln drying Oregon hardwood lumber. Oregon Forest Products Laboratory, Res. Leaflet No. 2. 17 pp. Corvallis, Oregon. (Mimeographed)

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The California Forest and Range Experiment Station is maintained in cooperation with the University of California at Berkeley, California.

Agriculture--Berkeley

At Fort Bragg, tanoak (Lithocarpus densiflorus (Hook. & Arn.) Rehd), madrone (Arbutus menziesii Pursh), golden chinkapin (Castanops: chrysophylla (Dougl.) A. DC.), and California-laurel (Umbellularia californica (Hook. & Arn.) Nutt.) were included in the test; at Scotia, tanoak and madrone.

The procedure used in seasoning these hardwoods was to first dr) the lumber in unit packages on the air-drying yard, then move the lumbe: into kilns for drying to the desired final moisture content. This procedu: is similar to the method of drying used extensively in Eastern hardwood-producing regions.

## Experimental Drying of Hardwoods at Fort Bragg

At Fort Bragg thirteen logs were sawed into 1-inch and 1-1/2-inch lumber. Log sizes and volumes were as follows:

| Species | Log diameter (inches) | Log length (feet) | Volume, Scribner rule (bd. ft. log scale) | |
|---|---|---|---|---|
| Tanoak | 18 | 14 | 190 | |
| | 18 | 29 | 300 | |
| | 23 | 20 | 470 | |
| Total tanoak volume: | | | | 960 |
| Madrone | 16 | 20 | 200 | |
| | 21 | 20 | 380 | |
| Total madrone volume: | | | | 580 |
| Golden chinkapin | 14 | 14 | 100 | |
| | 14 | 16 | 110 | |
| | 16 | 20 | 200 | |
| | 18 | 20 | 270 | |
| Total chinkapin volume: | | | | 680 |
| California-laurel | 18 | 16 | 210 | |
| | 19 | 14 | 210 | |
| | 20 | 20 | 350 | |
| | 21 | 20 | 380 | |
| Total California-laurel volume: | | | | 1,150 |
| Total volume, all species: | | | | 3,370 |

## Air Drying

The lumber was segregated by thickness, but not by species, and piled in unit packages 4 feet by 4 feet by 16 to 20 feet for air drying. Two-inch Douglas-fir lumber was used for the bottom boards of each unit package. One-inch by 2-inch stickers were spaced 18 inches apart. Eighteen samples were prepared from representative material and placed in pockets within the units of lumber to follow the progress of the air drying.

In the redwood region along the coast, seasonal changes of temperature and humidity are small. Here there is no season favorable to fast drying. On this drying yard, the average monthly temperatures varied from 45.5$^{o}$in January to 57$^{o}$ in September. The average monthly relative humidity in this area remains high throughout the whole year, varying only from a low of 77 percent in February to a high of 88 percent in August. The most important factors that influenced the rate of air drying were precipitation and the effectiveness of the pile-roofs or cover boards. The test piles were not covered to protect the lumber during rainy weather, and during rain storms considerable water entered the piles, causing the lumber to regain moisture.

The four hardwoods dried differently on the air-drying yard (fig. 1). California-laurel dried to the lowest moisture content and showed the least amount of drying degrade. Much of the laurel came from one large, very gnarled, irregularly shaped log. The lumber was beautifully figured due to the irregular grain. Even this highly figured, cross-grained lumber remained surprisingly flat during air drying. Surface checking was not serious, though some checking developed, particularly in the extremely cross-grained pieces.

Tanoak showed a tendency to surface check during air drying, but remained relatively flat. The greatest amount of checking, and some excessive shrinkage that could almost be classed as collapse, developed in dark areas of the heartwood. These dark areas appeared to be similar to the mineral streak of hard maple lumber. The amount of dark heartwood varied considerably from log to log and in lumber from the same log. An estimated 10 percent of the tanoak lumber contained this type of defect.

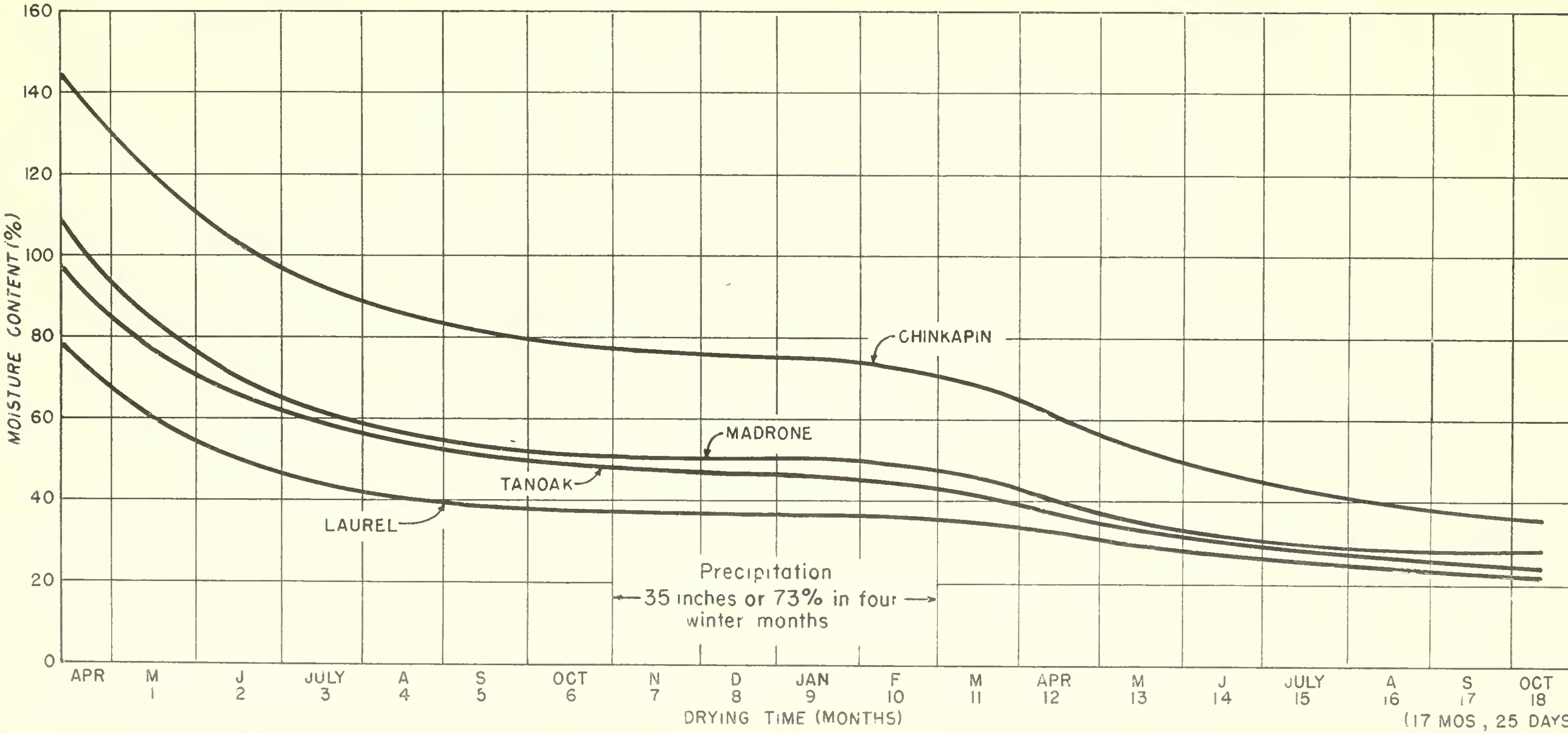


FIGURE 1
AIR DRYING OF CALIFORNIA HARDWOODS AT FORT BRAGG
(1-1/2 - INCHES THICK)

The madrone lumber showed less tendency to check than did the tanoak, but warped excessively. The principal warp was in the form of cupping toward the bark side of flat-sawed pieces. The shrinkage values for madrone as listed in the U. S. D. A. Technical Bulletin 479, "Strength and Related Properties of Woods Grown in the United States," are 11.9 percent in the tangential direction, but only 5.4 percent in the radial direction. The figure for volumetric shrinkage is 17.4 percent. Few other hardwoods have so high a ratio of tangential to radial shrinkage or so high a volumetric shrinkage. Thus madrone, because of its inherent shrinkage characteristics, can be classed as a wood that is prone to warp during seasoning.

Golden chinkapin showed the greatest tendency to develop checking and collapse of the four woods dried. Collapse developed during drying on the air yard under very mild drying conditions. The chinkapin also required longer to air dry to a moisture content suitable for final kiln drying.

## Kiln Drying

The kiln drying of thoroughly air-dried hardwoods is usually relatively easy. Checking and honeycombing of the wood are associated with the loss of free water. Hence, air-dried hardwood lumber at an average moisture content of 20 percent or less can be kiln dried with little danger of new checks or honeycomb developing. Shrinking, however, will continue during kiln drying, and warping will become more pronounced.

Two kiln runs of one-inch hardwoods were made, the first using a relatively mild schedule for air-dried lumber and the second using a more severe schedule (figs. 2 and 3).

California-laurel was the only species of the four that dried with little or no difficulty. Cupping of flat-sawed lumber, owing to the high ratio of tangential to radial shrinkage, was the most objectionable dry defect encountered with the other three woods. This type of defect was serious in madrone and developed to a lesser degree in tanoak and chinkapin. In the chinkapin, excessive shrinkage or collapse also was serious. Old checks that opened during the early stages of kiln drying soon reclosed and remained closed as the moisture gradient flattened out.

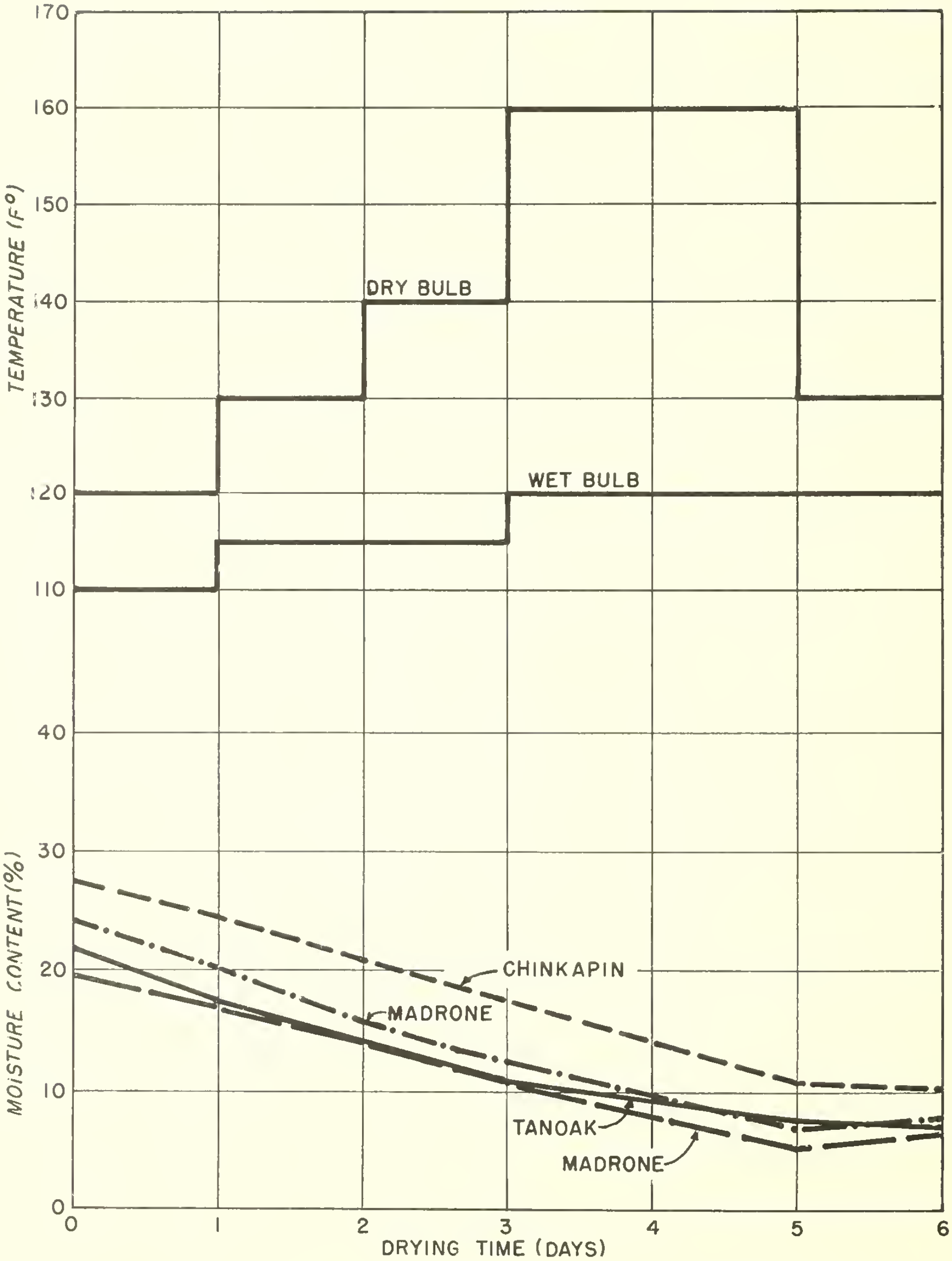


FIGURE 2
KILN RUN No. 1, FORT BRAGG, CALIFORNIA
1-INCH CALIFORNIA HARDWOODS

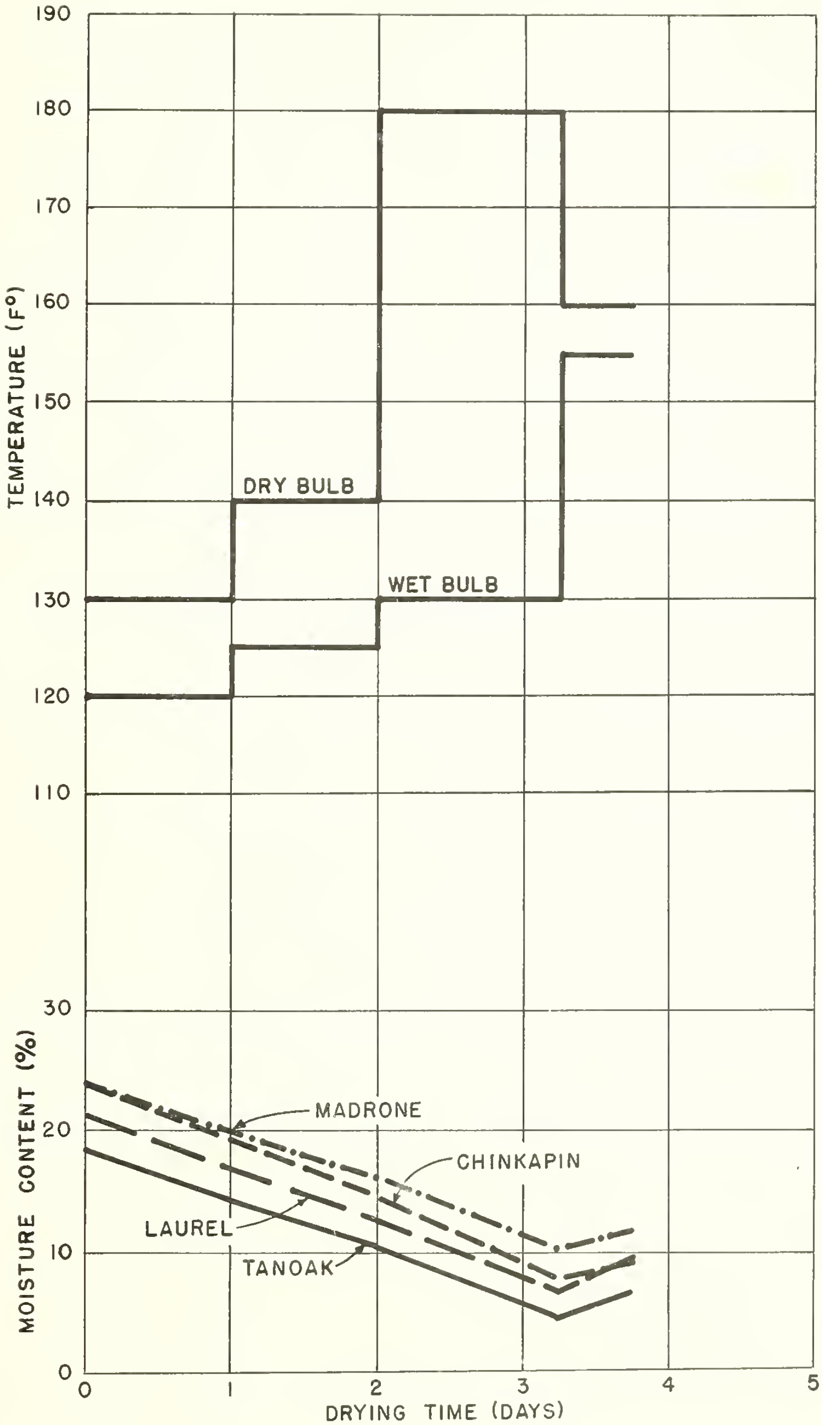


FIGURE 3
KILN RUN No. 2, FORT BRAGG, CALIFORNIA
I-INCH CALIFORNIA HARDWOODS

The stresses that developed during the kiln drying were only partially relieved by the mild stress relief used after run No. 1. This lumber was later reconditioned during the final conditioning of run No. 2. Samples from kiln run No. 2 increased in moisture content an average of 2.1 percent during 12 hours of conditioning at 160-155° F. Good relief of drying stresses in lumber of both kiln runs was accomplished.

Kiln drying the 1-1/2-inch hardwood was delayed to permit 2 additional months of air drying. By the middle of October (18 months, including 2 summers) the laurel had dried to a moisture content of 22 percent, tanoak 24 percent, madrone 28 percent, and chinkapin 35 percent. Continued air drying after this date would be of doubtful value; therefore, the lumber was kiln dried even though the moisture content was not as low as desired. The kiln drying time for the 1-1/2-inch lumber was 192 hours or 8 days (fig. 4); more than twice the time required for drying the 1-inch lumber in kiln run No. 2. The severity of the drying schedule used was similar to run No. 2.

The results obtained in drying the 1-1/2-inch hardwood were less favorable than those obtained in drying the 1-inch lumber. Checking was most serious in the flat-sawed boards of tanoak and chinkapin. Flat-sawed boards with a sharp curvature of the growth rings also cupped severely. Other forms of warping, such as twisting and bowing, indicated the need for careful piling for drying. Collapse was most serious in chinkapin, though some did occur in the madrone, usually adjacent to knots and similar defects.

## Experimental Drying of Hardwoods at Scotia

At Scotia 6 logs of tanoak and madrone were sawed into 3/4-inch and 1-1/4-inch lumber. Three logs of Hinds walnut (Juglans hindsii Jeps.), not included in the original plan were sawed into 1- and 2-inch lumber and dried along with the other hardwoods. Log sizes and volumes were as follows:

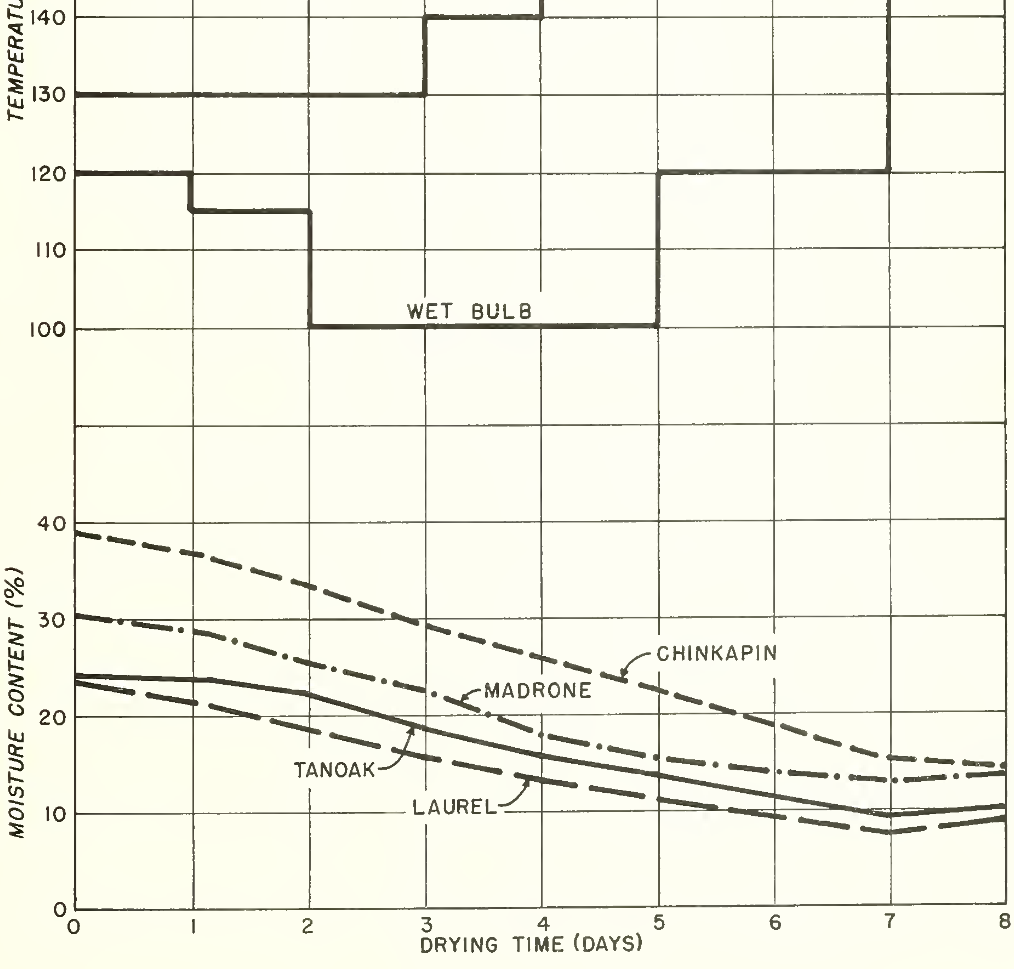


FIGURE 4
KILN RUN No. 3, FORT BRAGG, CALIFORNIA
1-1/2-INCH CALIFORNIA HARDWOODS

| Species | Log diameter (inches) | Log length (feet) | Volume, Scribner rule (bd.ft. log scale) | |
|---|---|---|---|---|
| Tanoak | 13 | 18 | 110 | |
| | 16 | 20 | 230 | |
| | 22 | 25 | 540 | |
| | 25 | 20 | 570 | |
| | 29 | 27 | 1,060 | |
| Total tanoak volume: | | | | 2,510 |
| Madrone | 32 | 26 | 1,200 | |
| Total madrone volume: | | | | 1,200 |
| Walnut | 21 | 12 | 120 | |
| | 33 | 12 | 590 | |
| | 48 | 10 | 1,080 | |
| Total walnut volume: | | | | 1,790 |
| Total volume, all species: | | | | 5,500 |

The Hinds walnut dried easily without defects. Since the walnut presented no special problems and was not included in the original plan, no further reference will be made to this species.

The lumber was segregated by thickness and species and piled in unit packages 4 feet by 4 feet by 16 feet and 20 feet. Two-inch Douglas-fir bottom boards were again used in the first course as a foundation for each package. There was sufficient tanoak to make one package of 3/4-inch and one of 1-1/4-inch lumber. Similar packages of madrone were filled out with some tanoak and some Hinds walnut lumber. Two other packages were made up, one of 2-inch walnut and one of walnut and tanoak of all sizes.

Air Drying

Twenty-one samples were prepared from representative material and placed in pockets within the packages of lumber for determining the moisture loss on the yard. The packages were piled on the yard for air drying. The test lumber was piled three units high, with three units of redwood on top, making piles six units high.

The hardwood lumber dried rapidly on the yard, particularly after March, when the rainy winter weather ended (fig. 5). The unit packages were repiled during the air drying, thus changing the drying rates of different samples. Also, some samples were not accessible during part of the air-drying period. Consequently, the average moisture content indicated for each thickness of each species is not always an average for identical samples. However, the figures do indicate that 1-inch lumber of both tanoak and madrone can be air dried to a moisture content suitable for final kiln drying in less than one year in this area when piled during the winter or early spring so as to take full advantage of the summer months when there is little or no rain.

The amount of defects that developed in the tanoak and madrone during air drying was relatively small. This is somewhat in contrast to the results obtained at Fort Bragg where the tanoak showed a tendency to check and the madrone to warp. The more favorable drying results at Scotia were apparently due to three factors: (1) thinner, narrower lumber, (2) a very high percentage of quarter-sawed lumber, and (3) uniform thickness of lumber that permitted better piling.

These results indicate that perhaps faster drying by opening the yard (wider spacing of the piles) can be tried with little or no increase in the amount of drying defects.

Kiln Drying

Half of the 1-1/4-inch tanoak and madrone was dried along with vertical grain Douglas-fir flooring strips in a commercial kiln (Table 1). Both hardwoods dried from a moisture content slightly higher than 20 percent to a final moisture content of 6 percent in 6-1/2 days. The final conditioning for 3 hours at 170° F. dry bulb and 164° F. wet bulb temperature did not completely relieve the drying stresses. Actually, the 6° F. depression was not reached until the end of the conditioning period.

The remainder of the 1-1/4-inch tanoak and madrone was dried along with 1-1/4-inch redwood in a commercial kiln (Table 2). The hardwood dried from a moisture content slightly higher than 20 percent to a moisture content of 4.4 percent in 9 days. After two days of equalizing and one day of conditioning the moisture content was increased to 6.5 and drying stresses were completely relieved.

The commercial operator who dried these two units of tanoak and madrone felt the second, longer and milder schedule was the better. No hardwood lumber grader was available for determining the grade before and after kiln drying. The results of the two runs were judged by comparing the quality of the lumber as it was repiled into solid units.

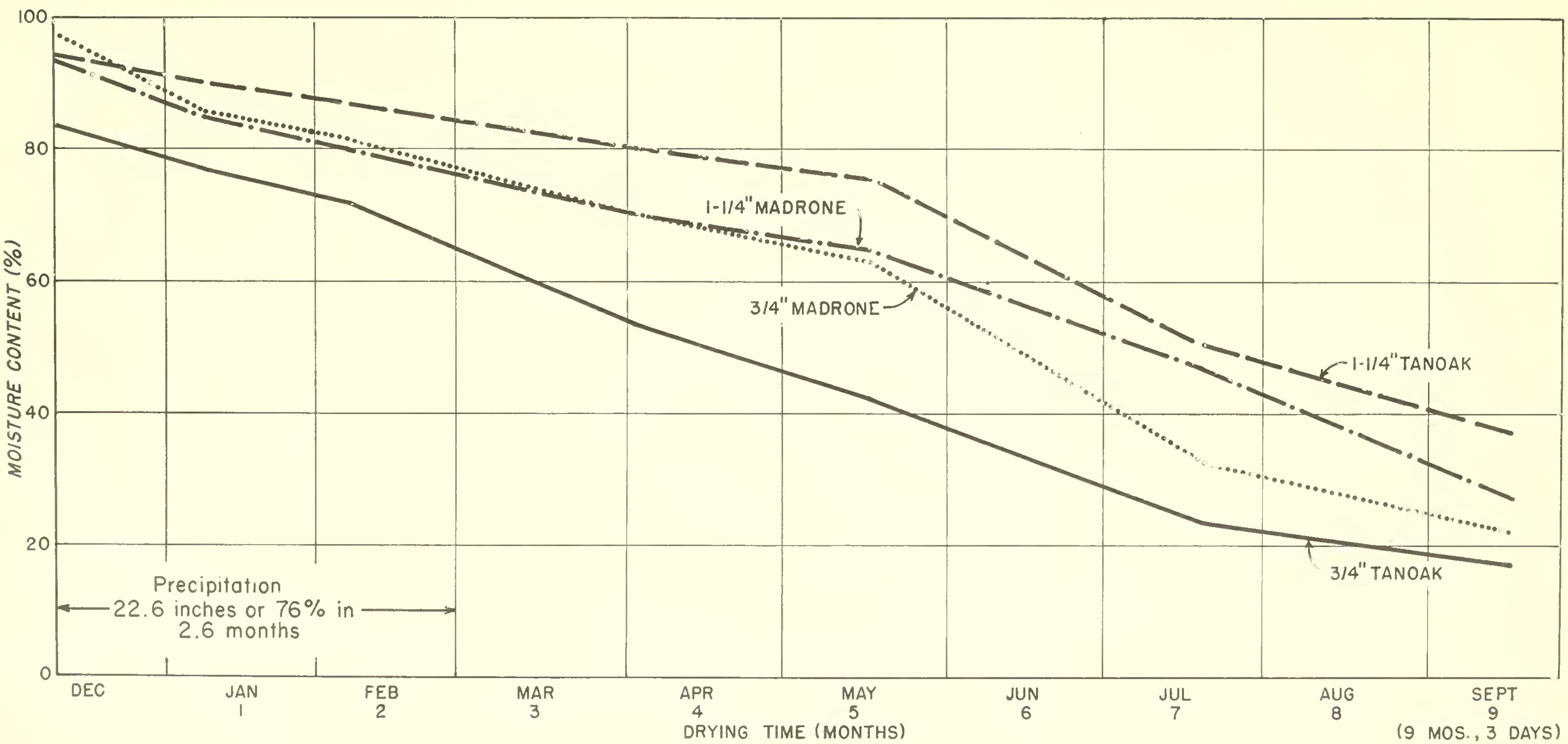


FIGURE 5
AIR DRYING OF CALIFORNIA HARDWOODS AT SCOTIA

Table 1. --Commercial kiln schedule for 1-inch vertical grain Douglas-fir flooring strips

| Time, days | Temperature | | Equilibrium moisture content |
|---|---|---|---|
| | Dry bulb | Wet bulb | |
| | (° F.) | (° F.) | (percent) |
| 1 | 130 | 120 | 12.1 |
| 1 | 135 | 120 | 9.7 |
| 1 | 140 | 125 | 9.6 |
| 1/2 | 150 | 130 | 8.0 |
| 1/2 | 160 | 135 | 6.8 |
| 1/2 | 160 | 130 | 5.8 |
| 1/2 | 165 | 130 | 5.0 |
| 1-1/2 | 170 | 120 | 3.2 |
| Condition (for 3 hrs.) | 170 | 164 | 14.0 |

Table 2. --Commercial kiln schedule for 1-1/4-inch redwood lumber

| Time, days | Temperature | | Equilibrium moisture content |
|---|---|---|---|
| | Dry bulb | Wet bulb | |
| | (° F.) | (° F.) | (percent) |
| Drying: | | | |
| 3 | 110 | 90 | 7.7 |
| 1 | 120 | 94 | 6.3 |
| 1 | 120 | 92 | 5.8 |
| 1 | 130 | 99 | 5.4 |
| 1 | 140 | 106 | 5.0 |
| 1 | 150 | 113 | 4.6 |
| 1 | 160 | 120 | 4.3 |
| Equalizing: | | | |
| 1 | 160 | 140 | 7.9 |
| 1 | 160 | 150 | 11.5 |
| Conditioning: | | | |
| 1 | 165 | 160 | 15.0 |

Experimental kiln drying of lumber in a commercial kiln along with a large charge of other wood has definite limitations. The drying temperatures and humidities and the length of the drying period all must be acceptable for the large charge of lumber being dried. Seldom are these drying conditions optimum for the test material.

About the time the 1-1/4-inch lumber was dried, plans were completed for building a small one-unit capacity, experimental kiln at this plant. The drying of the 3/4-inch lumber was therefore delayed until the experimental kiln was available. There would then be no limitations on the drying conditions used and schedules considered most suitable for drying the 3/4-inch tanoak and madrone could be used. During this delay of approximately three months, the air-dried lumber was again moved on the yard and piled unprotected from the winter rains. A moisture pick-up of more than 35 percent occurred.

The two kiln runs then were made in the small experimental kiln (figs. 6 and 7). In run No. 4 an estimated 25 percent of the tanoak was clear. In this clear wood no drying defects developed. In run No. 5 more than 75 percent of the madrone was clear, and no drying defects developed. Most of the degrade in tanoak resulted from the greater number of knots and the dark-colored heartwood (mineral streak).

The successful air drying and kiln drying of the tanoak and madrone at Scotia was apparently the result of better piling and the thinner sizes. This test material was more accurately sawed to a uniform thickness and could be piled on stickers for drying so that the lumber was held flat. A high percentage of the lumber was quartersawed, and did not cup as did the flat-sawed material; thus the finished kiln-dried product was of good quality.

## Conclusion

The results obtained in the air drying and kiln drying of tanoak, madrone, California-laurel, and chinkapin make us hopeful of developing suitable drying procedures for the first three of these four species. The results lead to the following conclusions:

(1) One and two-inch laurel is relatively easy to dry, and seasoning need not limit utilization of this species.

(2) One-inch lumber of tanoak and madrone can be seasoned by a combination of careful air drying followed by kiln drying to the desired final moisture content. Tanoak and madrone lumber in thicknesses greater than one-inch will be difficult to dry satisfactorily even under carefully controlled conditions.

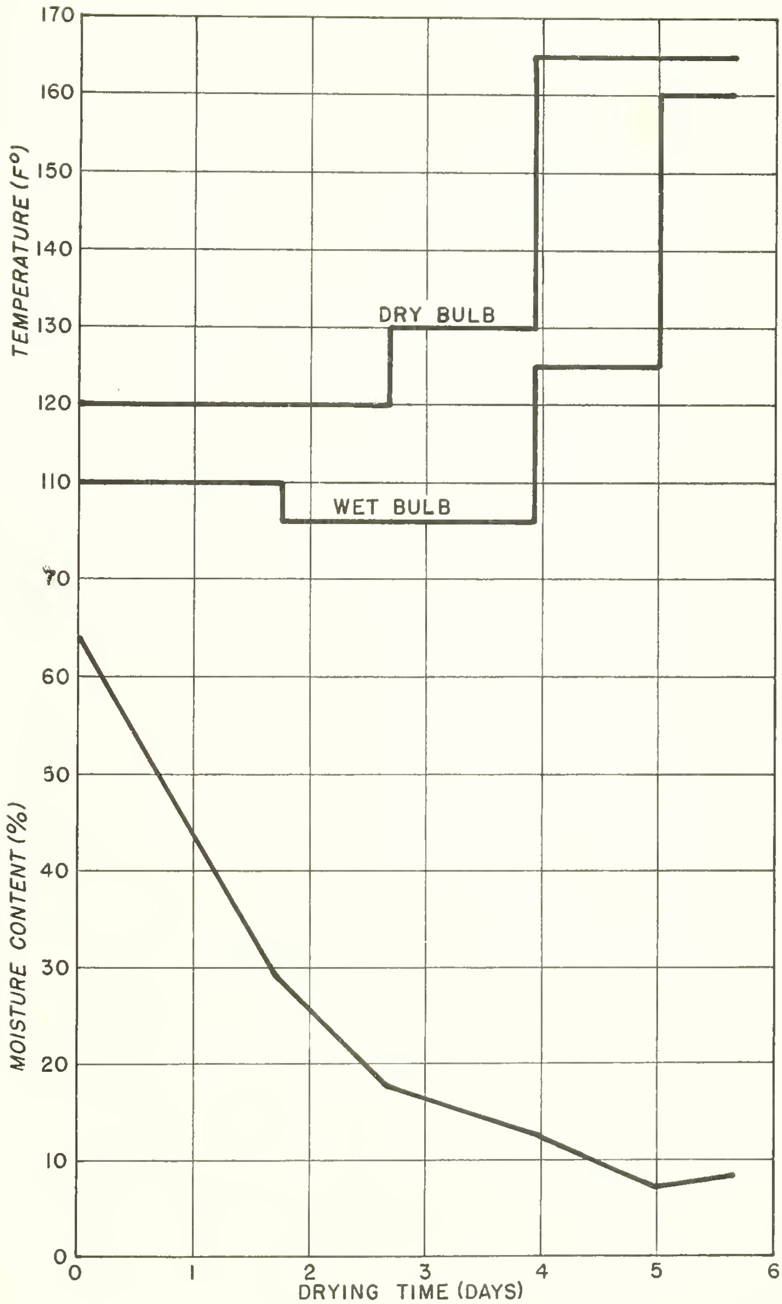


FIGURE 6
KILN RUN No. 4, SCOTIA, CALIFORNIA
3/4-INCH TANOAK
(RAIN-WET, WAS PREVIOUSLY THOROUGHLY AIR-DRIED)

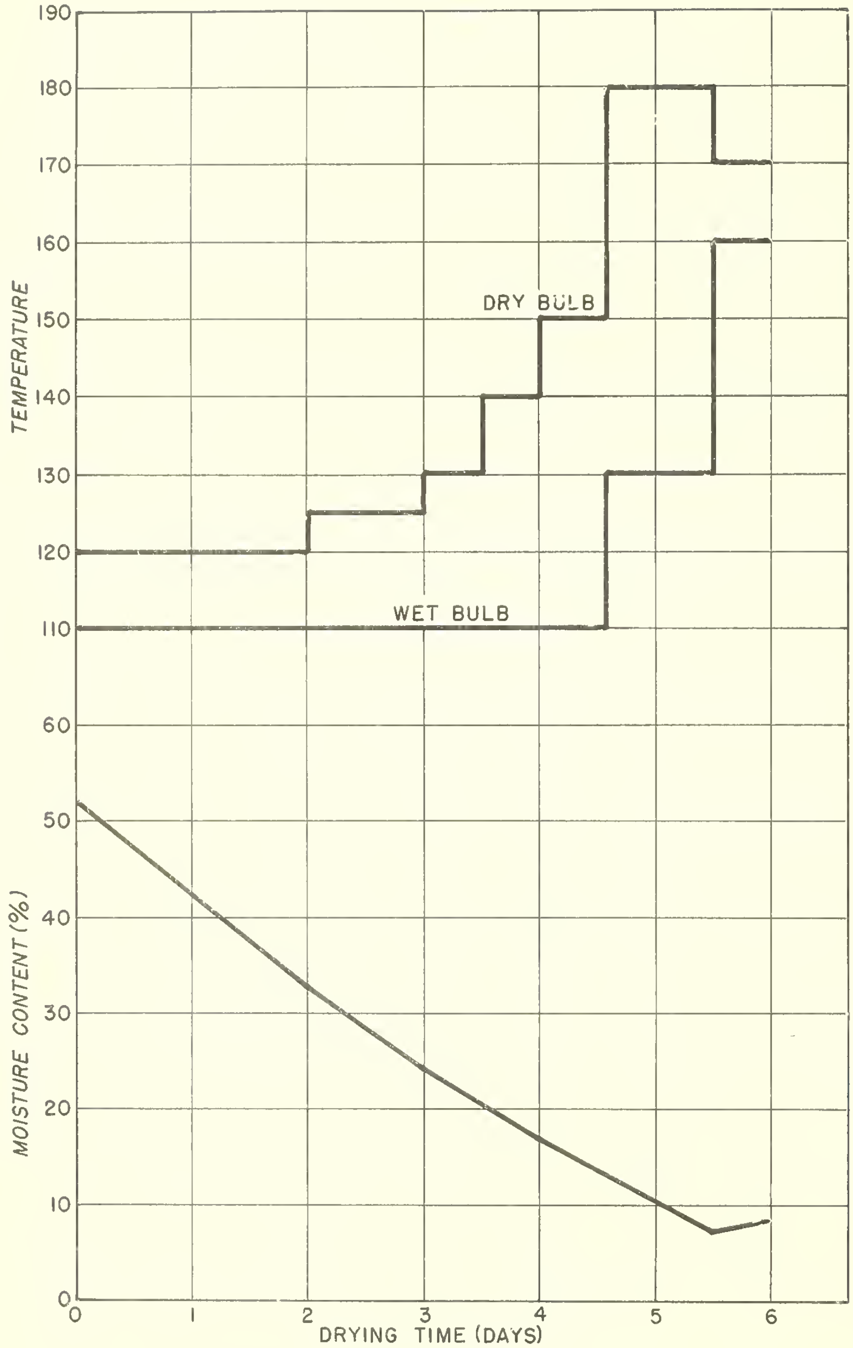


FIGURE 7
KILN RUN No 5, SCOTIA, CALIFORNIA
3/4-INCH MADRONE
(RAIN-WET, WAS PREVIOUSLY THOROUGHLY AIR-DRIED)

(3) This experiment indicates chinkapin lumber is the most difficult to dry of the four hardwoods dried. Excessive degrade developed during the drying of this species.

(4) Warping was the most serious difficulty encountered in the seasoning of these woods. Measures to minimize warping during drying, such as good piling practices, are therefore important. Accurate sawing of the lumber is essential to facilitate good piling.

Suggested Schedule for Kiln Drying

The U. S. Forest Products Laboratory at Madison, Wisconsin, has suggested schedules for all four species of California hardwoods included in the experiment[2/]. This California study indicates that somewhat milder drying conditions than those suggested by the Forest Products Laboratory might be advisable. Such schedules are listed below for air-dried one-inch tanoak, madrone, and California laurel. The results of the experimental drying of chinkapin were not satisfactory, and further work will be required before a schedule can be suggested for this species.

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2/ Torgeson, O. W. 1951. Schedules for the kiln drying of wood. Forest Products Laboratory No. D1791. 15 pp. Madison, Wisconsin.

Suggested kiln schedule for thoroughly air-dried, 1-inch tanoak and madrone

| Moisture content from (percent) | Moisture content to (percent) | Dry bulb temp. (° F.) | Wet bulb temp. (° F.) |
|---|---|---|---|
| Above | 25 | 120 | 110 |
| 25 | 20 | 130 | 115 |
| 20 | 15 | 140 | 115 |
| 15 | Final | 180 | 130 |

Suggested kiln schedule for thoroughly air-dried, 1-inch California-laurel

| Moisture content from (percent) | Moisture content to (percent) | Dry bulb temp. (° F.) | Wet bulb temp. (° F.) |
|---|---|---|---|
| Above | 25 | 130 | 120 |
| 25 | 21 | 140 | 125 |
| 20 | 15 | 150 | 125 |
| 15 | Final | 180 | 130 |

For relieving the drying stresses, a final equilibrium moisture content of at least 4 percent above the moisture content of the kiln-dried lumber should be maintained for 8 to 12 hours, or until the lumber has increased in moisture content approximately 2 percent.

# OWNERSHIP AND USE OF FOREST LAND IN THE REDWOOD – DOUGLAS-FIR SUBREGION OF CALIFORNIA

ADON POLI and
HAROLD L. BAKER

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FOREST SERVICE
in cooperation with
PRODUCTION ECONOMICS RESEARCH BRANCH
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U. S. DEPARTMENT OF AGRICULTURE

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The California Forest and Range Experiment Station is maintained by the Forest Service at Berkeley in cooperation with the University of California

Agriculture--Berkeley

# OWNERSHIP AND USE OF FOREST LAND

# IN THE REDWOOD--DOUGLAS-FIR SUBREGION OF CALIFORNIA


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U. S. DEPARTMENT OF AGRICULTURE

Forest Service, California Forest and Range Experiment Station

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Agricultural Research Service

Production Economics Research Branch

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California Forest and Range Experiment Station
George M. Jemison, Director
Berkeley, California

## FOREWORD

Ownership as it relates to the use of forest land is still a relatively new field of research. But it is generally recognized that knowledge of the type and size of forest land holdings and of the owners of this land is essential to persons or agencies concerned with decisions as to forest policy and management. This report presents detailed information on ownership of forest land in the Redwood--Douglas-fir subregion of California.

This information was obtained from a cooperative ownership study established by the Forest Service and Production Economics Research Branch, Agricultural Research Service (formerly part of the Bureau of Agricultural Economics). The major purpose of this cooperative arrangement was to obtain in detail information pertaining to ownership of forest land and to integrate this information with timber resource data obtained by the Forest Service under its National Forest Survey. Combination of these data with other economic facts will provide a sound basis for formulating policies and plans for the management and use of forest lands.

Detailed analysis of the correlation of these ownership facts with forest management practices actually found on the various ownership holdings in this study is the logical next step in this field of research. Such an analysis would include a detailed evaluation of protection from fire, insects, and disease, cutting practices, stand improvement, restocking, and other measures associated with management of forest land.

Some of the information concerning ownership in this release was published in separate Forest Survey statistical reports for several counties in this subregion. These counties are Del Norte, Humboldt, Mendocino, Sonoma, Santa Cruz, and San Mateo. A report similar to this was published for the Coast Range Pine subregion.

CONTENTS

# OWNERSHIP AND USE OF FOREST LAND IN THE REDWOOD--DOUGLAS-FIR SUBREGION OF CALIFORNIA

## SUMMARY AND CONCLUSIONS


The area covered by this study consists of 7,048,000 acres of forest, range, and farm-forest land in a long narrow strip along the northern California coast. Three-fifths of this is commercial forest land, which carries a net saw-timber volume of 137.6 billion board feet, principally Douglas-fir and redwood.

About three-fourths of the land is privately owned. The other fourth is public land, mainly national forest.

The bulk of the commercial forest land is in the northern part of the area, extending from about Sonoma County northward to the Oregon border. Most of the large-scale timber operations are centered in Humboldt and Mendocino Counties, the leading lumber-producing counties in California in 1951. These large-scale operations are primarily in the redwood timber zone near the coast where the land is used almost exclusively for commercial timber production. Forest land in this redwood zone is generally in large, reasonably well-blocked private ownerships. These large holdings possess the timber stands necessary for good forest land management.

Along the fringes of the redwood timber zone and in various localities within it are numerous small scattered holdings with timber on them. Some of these are used primarily for farming, recreation, and residence; but most are left unused and unattended by their owners. In the strictly commercial timberland areas of this zone, the presence of many small holdings interspersed among larger holdings generally complicates management of forest land for timber production. Many diversified ownerships, scattered settlement, and increased fire hazard are some of the factors that affect management. Furthermore, owners of small timber tracts are usually unfamiliar with timber management techniques, and many are nonresidents who live too far from their properties to give them proper attention.

Only a relatively small acreage of redwood forest is in Federal ownership. The unusual scenic values of the redwood groves as tourist attractions and their desirability for recreation have resulted in the establishment, from former private timber holdings, of a number of State-owned redwood parks. These parks provide much needed public recreation grounds for the constantly expanding urban population of this State. Future acquisition of additional redwood groves for State parks is anticipated. Recreational use of redwood forest land in these parks and in some of the private holdings along the main highways is a highly desirable use.

East of the redwood timber zone much commercial forest land in private ownership lies intermingled with grass and woodland-grass areas. Some large blocks of commercial forest land are in national forests.

Commercial forest land in this eastern timber zone grows mainly Douglas-fir. Ranching and farming are major uses of the privately owned land. The land in public ownership is used principally for timber production. Timber operations here are generally on a smaller scale than in the redwood zone, and some are conducted as enterprises secondary to ranching, farming, and other land uses. On the average, ownerships here are smaller and the patterns of land ownership and land use more complex than in the northwestern redwood timber zone. These ownerships have been acquired and are used for many different purposes, and the owners' interests are principally in nontimber uses of the land. Consequently, a large percentage of the timberland acreage is not managed for timber production. Clearing timberland for grazing purposes is a common practice on the ranch holdings. These clearing operations, however, are not always successful in producing grass because some of the soils in the cleared areas are better adapted to producing timber. In recent years the increased demand and resulting high prices for Douglas-fir have slowed down the clearing of timberland for grazing.

In the southern part of the study area, from about Mendocino County southward to Monterey County, commercial forest land tracts are interspersed with areas of grass, woodland-grass, and farm land. Recreation, residence, and farming are major uses of the land. Timber operations are usually on a small scale, and many are conducted as enterprises secondary to farming, recreation, residence, and other land uses. Patterns of ownership and land-use are complex here. From 80 to 90 percent of the land owners have holdings smaller than 180 acres. These small holdings average about 54 acres. About half their land is commercial forest land. Redwood and Douglas-fir are principal timber types.

The large urban population of the San Francisco Bay area exerts a strong pressure on the nearby forest land for small recreational and residential holdings. This persistent demand has established recreation and residence as major uses for much of this land. There is evidence that more and more rural land (agricultural as well as forest) will go into these types of land use. The ownership pattern of small forest-land holdings is appropriate for this southern area because the main objective of management is to hold the trees for their aesthetic values rather than to produce timber.

For the study area as a whole, there are several ways in which the overall pattern of land ownership and use might be improved. Complex patterns of small scattered holdings in strictly timber-producing areas, as in certain parts of the redwood timber zone, might be simplified by consolidating some small holdings in such a way that ownership will not be an obstacle to efficient timber management. Continued sale of some of these small properties will help this consolidation. Voluntary exchange of land is another possibility. The feasibility of handling some of these tracts on a cooperative basis, either as a private undertaking or as a public service, might also be explored. Acquisition of forest land for agriculture in commercial forest areas should be discouraged by agencies and individuals concerned with farm programs, especially when production of timber has been established as the best use of the land.

In forest areas where ranching and farming have been established as the principal use of the land, as in the Douglas-fir timber zone on the eastern slopes of the Coast Range Mountains, farm-forestry programs might be expanded to better integrate small-scale timber enterprises with the agricultural activities of the ranch and farm ownerships. Educational programs to point out the economic benefits of good forest-land management on ranches and farms might be sponsored by both public agencies and private groups.

Where recreation and residence have been established as major uses of forest land, as in the southern part of this study area, it would be desirable to provide for the orderly and planned development of future recreational and residential sites. One way to accomplish this is through the active use of local planning boards or similar organizations. Zoning is also useful in preventing undesirable patterns of settlement.

## PHYSICAL AND ECONOMIC SETTING

The Redwood--Douglas-fir subregion of California lies on the Pacific Coast in the northwestern part of the State. It is a long narrow strip of land, ranging from 20 to 50 miles in width from the coast to its eastern boundary and extending from the Oregon-California State line southward to Monterey County. As defined by the Forest Survey, this subregion incorporates a total land area of 7,578,000 acres and includes all of Del Norte, Humboldt, Sonoma, Marin, San Francisco, San Mateo, and Santa Cruz Counties plus parts of Siskiyou, Mendocino, and Santa Clara Counties. Forest, range, and farm-forest land amounts to 7,048,000 acres. All figures and comments in this report relate to this acreage only (fig. 1). The 530,000 acres excluded are agricultural, urban, industrial, and other intensively developed lands outside the study area.

Its redwood forests have brought the subregion international fame. Almost half the timber-producing land is occupied by redwood stands. Only here do coast redwood trees1/ grow in their natural state. These trees are unequaled for their great size, height, and age. The average redwood tree is about 6 feet in diameter, and some trees have been found to exceed 20 feet in diameter, 350 feet in height, and 2,000 years in age. An unusually favorable combination of species, soils, topography, and climate has resulted in heavier stands of timber in the redwood forests than are found anywhere else in the world.2/ The majestic beauty of the virgin

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1/ Redwood (Sequoia sempervirens [D. Don] Endl.) is here distinguished from giant sequoia (Sequoia gigantea [Lindl.] Decne).

2/ Fritz, E. Redwood, the Extraordinary. The Timberman, 30(7): 38. May 1929. Fritz says: "Acres have been found on river flats that ran as high as one million board feet, and this figure was exceeded in scaling the logs cut on a sample acre on the Larabee Flat cut within the present decade, and doubtless can be exceeded on other selected areas still standing. The average of course is much less, but is still as high as 90,000 to over 100,000 board feet per acre over considerable areas, even on the slopes."

stands, the enormous volumes of timber, the great size and age of the individual trees, and other unusual characteristics of the redwood all contribute to its world-wide renown.3/

Douglas-fir trees are found throughout the entire subregion. They grow in pure stands and mixed with redwood, pine, and other species. In recent years, Douglas-fir--like some other "white woods"--has become an important source of commercial timber in this forest area.

Most of the subregion is generally hilly and mountainous, but in the central and southern portions are several fairly large interior valleys. The Coast Range Mountains extend north and south over practically the entire length of the area. This range is not a single continuous chain of mountains but is made up of several irregular ridges oriented northwest to southeast, with deep narrow valleys between. Some mountain peaks rise to altitudes of about 7,500 feet.

Several large streams drain westward into the Pacific Ocean. The largest of these are the Klamath and Eel Rivers in the north, and the Russian River in the south. Other rivers of import in the study area are the Smith, Trinity, Mad, and Mattole.

The climate for much of the subregion is characterized by mild temperatures during most of the year; heavy winter rainfall; and dense coastal fogs in spring, summer, and early fall. Extremes of temperatures in the greater part of the subregion range from about 20 degrees in winter to about 90 degrees in summer. Rainfall varies considerably throughout the subregion with differences in elevation and distance from the coast. The average annual precipitation ranges from about 20 inches in the south near Monterey County to about 100 inches in the north near the Oregon border. Precipitation is principally in the form of rain but some snow occasionally falls on the higher mountain ridges.

Although precipitation occurs mainly from November through April, the coastal redwood belt is kept humid during the rest of the year by frequent dense low coastal fogs which penetrate deep into the redwood forest at night and in early morning. These heavy nocturnal fogs apparently are a requisite for redwood growth, because few redwood timber stands are found beyond the reaches of the coastal fog belt.

The natural resources of the subregion include timber, grass, farm land, minerals, fish, game, and water. Richest of these are the heavy stands of timber, principally redwood and Douglas-fir. For many years these stands have supported an active lumber industry which provides employment for a large segment of the subregion's populace. They also furnish the raw material from which numerous items are manufactured for the benefit of users everywhere. In addition, the aesthetic values of the redwood forests attract a large tourist trade and thus indirectly contribute substantially to the employment and income of the local people.

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3/ Shirley, James C. The Redwoods of Coast and Sierra. 1-84. Univ. of Calif. Press. Berkeley 1942.

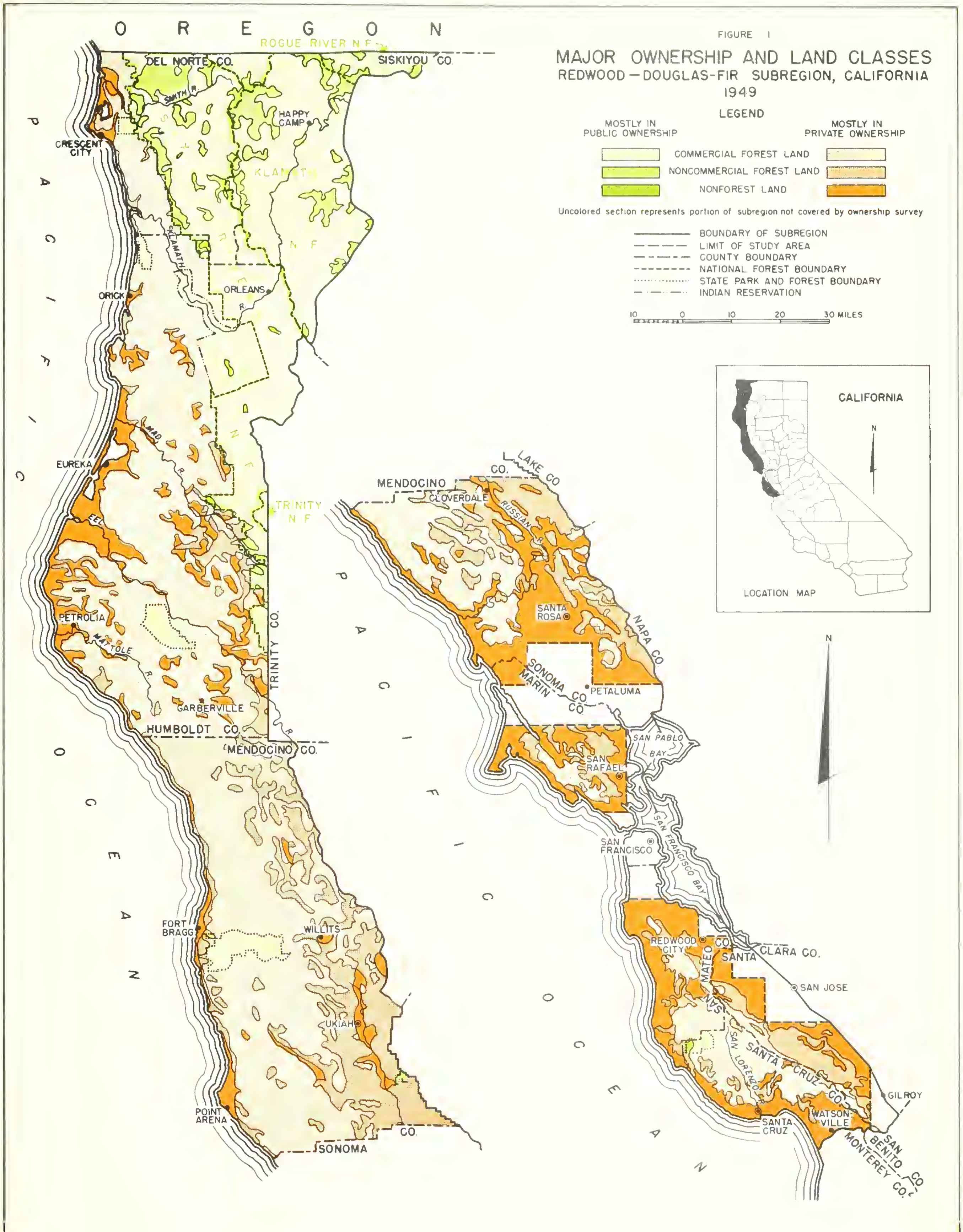
FIGURE I
MAJOR OWNERSHIP AND LAND CLASSES
REDWOOD—DOUGLAS-FIR SUBREGION, CALIFORNIA
1949
LEGEND
MOSTLY IN PUBLIC OWNERSHIP
MOSTLY IN PRIVATE OWNERSHIP
COMMERCIAL FOREST LAND
NONCOMMERCIAL FOREST LAND
NONFOREST LAND
Uncolored section represents portion of subregion not covered by ownership survey
BOUNDARY OF SUBREGION
LIMIT OF STUDY AREA
COUNTY BOUNDARY
NATIONAL FOREST BOUNDARY
STATE PARK AND FOREST BOUNDARY
INDIAN RESERVATION
10 0 10 20 30 MILES
CALIFORNIA
LOCATION MAP
N
O R E G O N
ROGUE RIVER N.F.
DEL NORTE CO.
SISKIYOU CO.
CRESCENT CITY
HAPPY CAMP
KLAMATH N.F.
ORLEANS
ORICK
EUREKA
TRINITY N.F.
TRINITY CO.
PETROLIA
GARBERVILLE
HUMBOLDT CO.
MENDOCINO CO.
FORT BRAGG
WILLITS
UKIAH
POINT ARENA
SONOMA CO.
PACIFIC OCEAN
MENDOCINO CO.
LAKE CO.
CLOVERDALE
SANTA ROSA
NAPA CO.
SONOMA CO.
MARIN CO.
PETALUMA
SAN PABLO BAY
SAN RAFAEL
SAN FRANCISCO
SAN FRANCISCO BAY
REDWOOD CITY
SAN MATEO CO.
SANTA CLARA CO.
SAN JOSE
SANTA CRUZ CO.
SANTA CRUZ
WATSONVILLE
GILROY
SAN BENITO CO.
MONTEREY CO.

Commercial forest land[4] comprises 60 percent (4,238,000 acres) of the 7,048,000 acres in the study area. The rest consists of 1,522,000 acres of noncommercial forest land, and 1,288,000 acres of nonforest land (table 7). The productive forest land (commercial forest land) is composed primarily of two broad forest types. The redwood type, containing the heaviest timber-producing stands, extends eastward from the coast in an irregular belt, 5 to 30 miles wide. Douglas-fir grows as the principal associate of redwood throughout this area. The eastern limits of the redwood type coincide more or less with the crests of the Coast Range mountains, where conditions become unfavorable for growth of redwood trees. The Douglas-fir type is located to the east of these ridges.

Most of the noncommercial forest land lies intermingled with and east of the Douglas-fir type. The principal cover is a mixed hardwood and grass type. Although this land is not considered suitable for production of commercial timber, it is used extensively for grazing livestock and as a wildlife hunting grounds.

Nonforest land is mainly of two types: land that has never supported forest growth or land from which forests have been removed and which has been developed for uses other than timber production, such as grazing, cultivated agriculture, and residential or industrial developments.

The 1948 inventory of the forest resource[5] shows that almost two-thirds of the timber-producing land is concentrated in Humboldt and Mendocino Counties. Humboldt County alone contains 41 percent. The Coast Range Pine subregion also has a concentration of commercial forest land in northern counties.[6] More lumber was produced in Humboldt County in 1951 than in any other county in California. Mendocino County was second.

Although logging operations have been underway in the subregion for more than 100 years, 83 percent of the commercial forest land is still occupied by sawtimber stands (table 1). These stands, growing on lands rated mostly good or better in timber-producing capacity, contain much high-quality harvestable material. A great deal of this volume is in timber stands which are inaccessible because of inadequate roads. About 12 percent of the timberland is nonstocked with commercial timber species. This land is occupied primarily by hardwoods and brush.

Estimates of volume made in 1948 showed a standing saw-timber volume on the commercial forest land of 137.6 billion board feet.[7] Fifty-seven

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4/ For explanation of terms used in this report see section entitled: Definition of Terms, page 49.

5/ For detailed statistics from this inventory, forest survey procedure, and definition of terms, see: Forest Statistics for the Redwood--Douglas-fir Subregion in California. Forest Survey Release No. 19: 1-54. Calif. Forest and Range Expt. Sta. Berkeley, January 1953.

6/ Forest Statistics for the Coast Range Pine Subregion in California. Forest Survey Release No. 12: 1-48. Calif. Forest and Range Expt. Sta. Berkeley, April 1952.

7/ Measured by International 1/4-inch log rule.

Table 1.- Commercial forest land by timber type and by stand-size class, Redwood--Douglas-fir Subregion, California, 1948

| Timber type | Total | | Old-growth saw-timber stands | Young-growth saw-timber stands | Pole-timber stands | Non-stocked |
|---|---|---|---|---|---|---|
| | Thousand acres | Pct. | Thousand acres | | | |
| Douglas-fir | 2,005 | 47.3 | 934 | 743 | 47 | 281 |
| Redwood | 1,918 | 45.3 | 727 | 858 | 164 | 169 |
| Pine--Douglas-fir--Fir | 266 | 6.3 | 140 | 81 | 8 | 37 |
| Fir | 39 | 0.9 | 17 | 13 | 3 | 6 |
| Pine | 10 | 0.2 | 3 | 7 | - | (1/) |
| All types | 4,238 | 100.0 | 1,821 | 1,702 | 222 | 493 |
| Percent | | 100.0 | 43.0 | 40.2 | 5.2 | 11.6 |

1/ Less than 500 acres.

Table 2.- Net volume of live saw timber on commercial forest land by species and by stand-size class, Redwood--Douglas-fir Subregion, California, 1948

| Species | Total | | Old-growth saw-timber stands | Young-growth saw-timber stands | Pole-timber stands | Non-stocked |
|---|---|---|---|---|---|---|
| | Million bd. ft. | Pct. | Million bd. ft. | | | |
| Douglas-fir | 78,968 | 57.4 | 49,985 | 28,201 | 214 | 568 |
| Redwood | 38,778 | 28.2 | 29,100 | 9,198 | 240 | 240 |
| White fir | 5,030 | 3.7 | 2,146 | 2,882 | 2 | - |
| Sugar pine | 4,694 | 3.4 | 3,490 | 829 | 372 | 3 |
| Ponderosa and Jeffrey pines | 2,582 | 1.9 | 1,603 | 979 | - | - |
| Grand fir | 1,291 | 0.9 | 301 | 990 | - | - |
| Other softwoods1/ | 2,668 | 1.9 | 1,827 | 728 | 113 | - |
| Hardwoods2/ | 3,542 | 2.6 | 1,915 | 1,314 | 8 | 305 |
| Total all species | 137,553 | 100.0 | 90,367 | 45,121 | 949 | 1,116 |
| Percent | | 100.0 | 65.7 | 32.8 | 0.7 | 0.8 |
| Average volume per acre (bd.ft.) | 32,457 | - | 49,625 | 26,511 | 4,275 | 2,264 |

1/ Includes California red fir, incense-cedar, western hemlock, mountain hemlock, Sitka spruce, western white pine, Port-Orford-cedar, western red cedar, Bishop pine, California torreya, knobcone pine, Brewer spruce, and Pacific yew.

2/ Includes tanoak, madrone, California black oak, canyon live oak, alder, chinquapin, Garry oak, ash, coast live oak, interior live oak, laurel, and maple.

percent of this was in Doublas-fir (table 2) and 28 percent in redwood. Most of the remaining volume was white fir and sugar pine. Most of the total volume was in trees 41.0 inches in diameter and larger. Two-thirds of the redwood saw-timber volume was in this largest diameter class.

The timber resource situation is always changing. Saw-timber volume is constantly being added through growth and removed through logging and natural mortality. In 1948, 39 percent (679 million board feet) more saw timber was removed than was grown. Average annual growth for that year was 1.1 billion board feet, while the output of timber products plus saw timber destroyed or left in the woods amounted to 1.7 billion board feet. The difference between the rate of timber growth and removal is expected to increase in the next few years because of increased cutting of Douglas-fir. A cut in excess of growth is desirable for some time in this subregion because about two-thirds of the saw-timber volume is in uncut old-growth stands. Old-growth stands generally have high mortality losses and consequently show only little net growth. But the rate of growth should increase after cutting, provided the areas cut are adequately stocked and protected.

Other natural resources are of considerable value. Large areas of grass and woodland-grass throughout the subregion support numerous beef, sheep, and dairy ranch enterprises (fig. 2). Rich farm land in the interior valleys and on the coast grows many valuable crops and supports a large farm population.

Of increasing significance are the recreational values of the forest areas, mountain streams, picturesque and rugged coast line, abundance of fish and other wildlife, and the mild pleasant climate (fig. 2). These recreational features furnish employment, income, and pleasure to many local people as well as pleasure to thousands of outsiders who visit the subregion.

About 0.6 million people actually live in the area of study, but the ownership and use of the forest land are influenced by a much larger number of people who live in adjacent urban areas of the San Francisco Bay region. These people rely on the wood products manufactured in the study area, and visit the forests for recreation. They also depend upon the forests for part of their water supply. The total number of people within this sphere of influence is estimated at about 2.5 million.

Many of the residents of the northern part of the study area are original settlers or descendants of original settlers who were attracted to the region by early lumbering, agriculture, mining, and related activities. A few descendants of original California Indians live on reservations and individual allotments, principally in the central and northern parts of the subregion. The major part of the population of the southern portion is of more recent origin. Increased industrial activity during the war and post-war years has attracted many people from other States.

Transportation facilities for inter- and intra-subregional shipment of freight include truck, rail, ship, and air. Most important of these to the movement of forest products is truck transport. All the counties in

Figure 2.- Large areas of grass and woodland-grass are intermingled with the timber areas and support many live-stock ranches throughout the Redwood--Douglas-fir subregion. Richest of natural resources are the heavy stands of timber. They support an active timber industry and provide valuable watersheds. Recreational and watershed values of forest lands are becoming increasingly important to the economy of the subregion.

the area have at least one well-developed public highway--supplemented with many miles of good, locally maintained roads. But there are too few timber access roads. Railroad facilities are most extensive around the San Francisco Bay area. Several railroads--including transcontinental lines--converge on San Francisco from the south and east. Only one railroad operates north of San Francisco and this only into Humboldt County. Del Norte County has no rail transportation. Waterborne freight shipments are handled at several major ports: San Francisco Bay, Humboldt Bay, and Crescent City. San Francisco Bay is one of the world's largest landlocked harbors. Air freight has as yet no specific importance in the shipment of forest products.

Lumbering, livestock ranching, and recreation are the leading industries. Cultivated agriculture, commercial fishing, and manufacturing are important, too, in certain localities.

Lumbering as a major industry began in the area in the 1850's. The first power sawmill was operated in the redwood forests of Santa Cruz County in 1842.[8/] This and other early sawmills were driven by water power. Logs were hauled to the mills by oxen, or floated downstream in winter. Later, when lumbering began to develop into a major industry, steam furnished power in logging and milling of timber. Today, after a century of lumbering history, the industry has developed to almost 400 sawmills of a wide variety of types and sizes and capable of producing more than 2 billion board feet of lumber annually (figs. 3-5).

During 1948, the year of inventory of the forest resource, 393 mills produced 1.4 billion board feet of lumber. The 5 largest mills--annual output 50 million board feet or more--produced 22 percent of the lumber output. In contrast, the 140 smallest mills, with annual outputs of less than 0.5 million board feet, produced only 2 percent.

Although the number of active sawmills has changed little since 1948, there has been a marked shift between the production size classes. The number of mills in the medium size classes has increased while the number of very large and very small mills has decreased. In 1948, 38 percent of the active mills had outputs of 1 to 10 million board feet annually. Four years later, 53 percent of the active mills in the study area had annual productions within these limits.

Timber operators manufacturing products other than lumber make a substantial demand on the forests for wood material. The principal products are plywood and veneer, cooperage, posts, shingles, shakes, hewn ties, and other split products. For the most part, these products require a special kind and quality of material. Production of veneer in particular requires logs of the largest size and highest quality. In 1951, 13 plywood and veneer, 3 veneer, and 5 plywood plants in the area converted about 164

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8/ May, Richard H. A Century of Lumber Production in California and Nevada. Forest Survey Release No. 20, p. 1. Calif. Forest and Range Expt. Sta. Berkeley, June 1953.

Figure 3.- This is a large sawmill typical of those found on the large timber holdings on the coast. These large mills generally saw 25 or more million board feet of lumber per year. They use principally redwood and Douglas-fir timber. The first sawmill on this site was constructed in 1860 but it burned in 1889. The present mill was built on this same site in 1890. It has operated almost continuously ever since.

Figure 4. This is a small sawmill typical of some recently constructed by forest industries in this area. These mills produce from 1 to 10 million board feet of lumber per year. They saw redwood and Douglas-fir timber mostly.

Figure 5.- This is a small sawmill typical of some of those found on farms, ranches, and small timber holdings. These small mills produce less than one million board feet of lumber per year. Lumber from these small mills is not generally of the highest quality. Much of the lumber is for local use.

million board feet of peeler logs[9] into veneer and plywood. Some logs of poor quality or small size--generally undesirable for other uses--are converted to hardboard at a large pressed board plant located in the subregion.

The timber industry contributes much to the economy of the area, both in jobs and wages for the woods and mill workers and in value of forest products. Using 1951 production as a base, the estimated number of wage earners engaged in logging and milling operations in the study area is about 21,000. Including the families of these workers, that part of the population directly dependent upon the timber industry is about 89,000 persons. This is about 15 percent of the estimated total population of the study area.

Many others provide the timber industry workers and families with goods and services. These persons operate local independent enterprises. They are supported either partially or totally by persons engaged in lumbering and related industries and are therefore economically dependent upon the timber industry. This service population--including both workers and their families--is estimated at nearly 180,000 persons.

Either directly or indirectly, 269,000 persons are dependent on the timber industry. This is about 45 percent of the estimated total population of the study area.

The 1951 payroll of wage earners in the timber industry is estimated at $95,000,000. This figure does not include the service populace income for the same period. The value of products produced is difficult to determine because prices vary so much by species and by kind and quality of product. At average prices, the total value of forest products (f.o.b. mill) for 1951 has been estimated at about $200,000,000.

Changes within the timber industry--such as the increase or decrease in the number and size of mills--and changes in management policies of the members of this industry will affect the type and size patterns of land ownership in the study area. Forest land will be bought and consolidated into large holdings to provide for continuous or expanded operations. Or, large holdings will be broken up and sold as a consequence of inheritance provisions, speculation, or for other reasons. Part of the land acquired for new operations will be owned and operated by nonresident owners who seek timber supplies for current operations located elsewhere, or for new supplementary mills in the study area.

Ranching and farming are important activities of the subregion's economy. Predominant types of farming are livestock ranching, dairying, poultry raising, and growing deciduous fruits, nuts, and grapes.

The livestock ranches, mainly cattle and sheep, were established when the land was originally patented by the first settlers. Most of them

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9/ A peeler log is a log suitable for the manufacture of rotary cut veneer.

Figure 6.- Apples, grapes, and other fruits are grown successfully in small valleys, natural openings, and on certain cut-over land in the forest area. Dairy farms are mostly on or near the coast.

are in Mendocino, Humboldt, and Sonoma Counties. In contrast to livestock ranches elsewhere in the State, most of the herds are nonmigratory. The ranch units generally provide yearlong feeding, with some supplementary feed from outside sources in years when local feed conditions are poor.

Dairy farms are located mainly on and near the coast in Humboldt, Del Norte, Sonoma, Marin, and Mendocino Counties. Dairy herds utilize the natural grassland pasture supplemented chiefly by feed grown on the farm. Dairy farms in the southern part of the subregion usually have larger acreages of range land than do those in the northern part, principally because soils and climate in the southern coastal area generally favor the growth of grass over other competing types of vegetation.

Principal fruit crops of the subregion are prunes, grapes, apples, and pears (fig. 6). These fruits are grown on small intensively developed areas located mainly in the interior valleys of the central and southern parts of the subregion. The grapes are used principally for the manufacture of wines.

Poultry farms are found throughout the subregion, but most are concentrated in the Petaluma commercial poultry district of Sonoma County. Hens are raised chiefly for the eggs they produce.

The recent rapid increase in population in this State, shorter working hours, improved transportation facilities, and increased tourist trade have stimulated demand for use of forest and other rural land for recreation. Recreation, as a dominant use of forest land, has become particularly significant in counties near the San Francisco Bay area. This recreational demand is indicated partly by the rather large number (almost 3,000) of owners who have acquired wooded land specifically for this purpose. Recreational activities contribute materially to the local economy and to the general welfare of many people.

## OWNERSHIP IN RELATION TO USE OF LAND

Before the Spaniards came to California, Indians used the land for hunting and fishing and for growing the few native crops necessary for their sustenance. These people had few or no direct ties to the land but moved about in search of game and other food. Private ownership of land by individuals was unknown to them.

During the Spanish era, which began in the latter part of the 18th century, private ownership generally took the form of large tracts of land granted to Spanish settlers by the Spanish and Mexican Governments. These Spanish grants were made in the southern and central parts of the subregion as far north as Mendocino County. Although the Spanish settlers acquired land principally for grazing livestock, some of the grants in this area contained timberland as well as some good farm land. Most of the agricultural land in the grants was later subdivided into smaller tracts and sold to new settlers. But some of the timberland remained in fairly large holdings even after the land grants were broken up. The metes and bounds pattern of ownership formed by these Spanish "ranchos" is still a peculiarity of land records of several counties in this area.

When the United States acquired California from Mexico in 1848, all the land in the State, except for certain private claims such as pre-existing Spanish land grants, became part of the federal public domain. This land then became subject to disposal under the federal land laws. From that time on, individuals obtained land in this forest region primarily by filing entries with the Federal Land Office as provided by the Preemption, Homestead, and Timber and Stone Acts (enacted from 1841 to 1878).

These general land laws operated under the principle that forest land could best and most economically be developed under individual private ownership and in small units similar to those acquired for agriculture. Thus, the forest land obtained by individuals under these laws was generally limited to 160 acres. Many individuals who obtained land in this forest area sold their timberland shortly after acquisition to lumber companies, promoters, and speculators who consolidated the small tracts into much larger timber holdings. While this practice of circumventing the original land laws led to fraudulent transactions and much speculation,10/ it helped to establish an ownership pattern much more adaptable to forest land management than would have been possible by strict adherence to the provisions of the land laws.

Considerable land in this area was granted to the State by the Federal government. This usually consisted of the 16th and 36th section in each township as well as other land designated by congressional action. Nearly all of this State land was sold subsequently, as provided by law, to individuals, usually in 320 and 640-acre tracts. Funds obtained through the sale of this land were used to finance the development and maintenance of schools and colleges by the State. A few isolated sections remain in State ownership.

The desirability of redwood forests as commercial timber-producing land quickly placed nearly all of the redwood timber acreage in private ownership. Much of the nonredwood timberland in the eastern part of the subregion which remained unappropriated was placed in national forests by presidential proclamations issued since 1905. Some land was set aside for Indian reservations and allotments, and some of the less productive land (about 196,000 acres) still remains as unappropriated and unreserved public domain.

In recent years, a limited acreage of redwood timber land has shifted from private to public ownership through gift and purchase. This land

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10/ Wattenburger, Ralph T. The Redwood Lumbering Industry on the Northern California Coast, 1850-1900. M. A. Thesis. Typewritten. pp. 63-79. Univ. of California 1931.

Also - Hibbard, Benjamin H. A History of the Public Land Policies, pp. 466-7. Peter Smith. New York. 1939.

consists chiefly of State parks and the recently acquired State Forest in Mendocino County. The parks were established to preserve in their natural state some of the remaining spectacular stands of redwood timber.

## Public Ownership

This subregion has the smallest acreage of land in public ownership of any major forest region in the State. Public ownership comprises slightly more than one-fourth of the 7,048,000 acres of all land covered by this survey in the study area. This public area includes about one-third of all the timber-producing lands of the subregion (table 7, and figs. 7-9). In the other subregions of the State public agencies control from half to two-thirds of the commercial forest land.11/

The most productive timberlands, that is, lands supporting redwood stands, are primarily in private rather than public ownership.

### National Forests

Most of the public forest land is in national forests, principally the Six Rivers and Klamath National Forests. Other national forests represented are Trinity and Rogue River. All together, these forests contain about 73 percent of the total publicly owned land of the subregion and 76 percent of the publicly owned commercial forest land. About three-fourths of this timber-producing land supports stands predominantly of Douglas-fir. Less than 1.0 percent grows redwood timber (fig. 8 and table 8).

Most of the saw-timber volume on the public forest land is in "white woods," principally Douglas-fir. These woods, formerly considered of low value in the redwood area, now compose a leading part of the forest product output of the subregion. Much of the national forest saw-timber volume is in inaccessible areas and in timber stands of lower quality than those in private ownership. Most of the best and most accessible timber had passed into private ownership before the national forests were established. Recently, allowable cuts of national forest timber have been increased and access roads built to permit expanded use of national forest timber. A measure of this expanded use is the increase in receipts from sales of timber between 1948 and 1951. In 1948, sales in the national forests of this subregion totaled $68,000. By 1951, the value of sales increased to $373,000. Although some of this difference can be attributed to increase in prices, most of the change is due to an increase in the volume of timber cut. Increased use of national forest timber will provide a new timber supply for some private operators. These operators may thus establish continuous operations although they lack an adequate supply of timber of their own. Further, proper marking of timber for the increased cut will increase production on the national forest lands by improving the residual stands. Much of the timber on the national forests is overmature and hence subject to high mortality losses if not used. Consequently, net growth on these

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11/ Wieslander, A. E. and H. A. Jensen. Forest Areas, Timber Volumes and Vegetation Types in California. Forest Survey Release No. 4, p. 29. Calif. Forest and Range Expt. Sta. Berkeley, March 1, 1946.

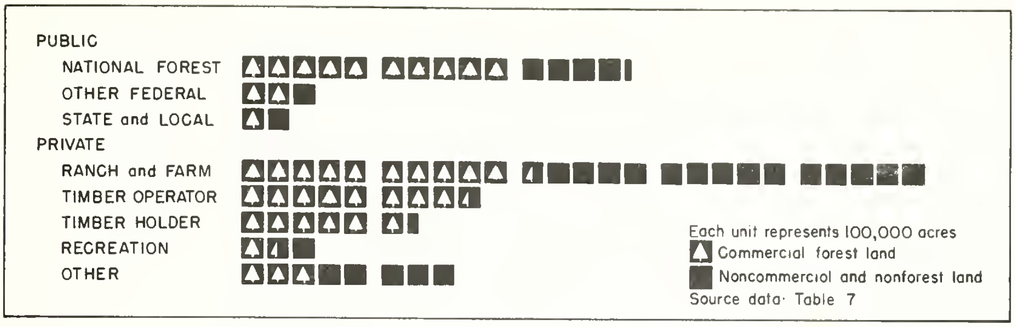


Figure 7.- Total acreage of land, by type of owner.

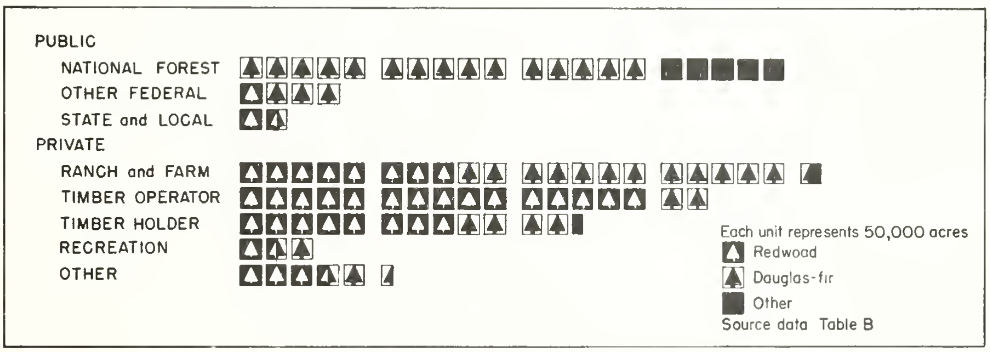


Figure 8.- Acreage of commercial forest land, by type of owner and by major timber types.

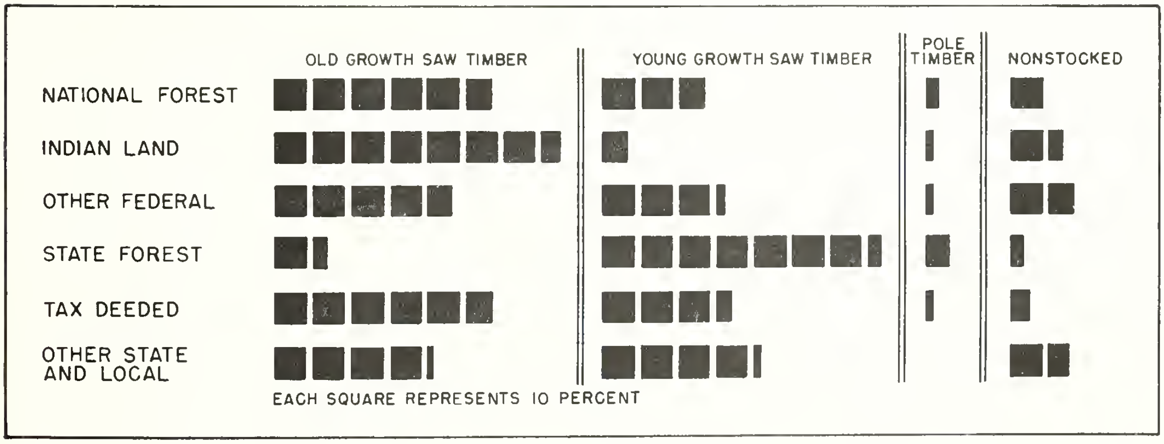


Figure 9.- Percentage of acreage of timberland held by public agencies, by stand-size class.

stands is low. After cutting, the rate of growth should increase, provided the cut-over areas are adequately restocked and protected. Construction of access roads while logging national forest timber will also provide a means for better fire protection of both the cut-over and virgin stands, although fire hazard is considerably greater for a period of years after cutting.

Some of the problems of sustained-yield[12/] management of forest land generally associated with ownership are absent or relatively unimportant in the national forests. In the administration of a national forest by the Forest Service, a large block of timberland is usually operated as a continuous single ownership. This permits establishment and maintenance of the long-run management plan required in growing timber as a crop. The element of size of ownership does not limit management, except on the relatively few small scattered or separated segments of any national forest. Under private ownership, size may be a limiting factor of management because of the existence of many small and scattered holdings. Furthermore, in the process of growing timber crops there may be periods of high costs of protection and improvement but little or no income. Public ownerships are generally better able to sustain these periods financially and to continue good forest management than are some types of private owners.

National forests have other uses besides production of timber. The forests are a source of water supplies. They provide forage for livestock production, supply food and cover for wildlife, and offer opportunities for recreation. Potential returns, and losses, from these uses must be considered in national forest-management plans. The national forests control cutting practices more than do many private operators, and there is usually less economic pressure on the Government to cut excessively.

Other Federal Agencies

Other Federal agencies administer about 16 percent of the publicly owned land. Nearly all of this land is vacant, unappropriated, and unreserved public domain, and land in Indian Reservations and Indian allotments. Almost two-thirds of this is commercial forest land. Except for the Indian Reservations, much of this land is in scattered isolated tracts and in locations which are not readily accessible. Consequently, these tracts are difficult to manage for timber production. Consolidation of some of these scattered holdings of public land by exchange or sale would improve the ownership pattern in the areas in which much of this land is situated.

State Ownership

State-owned land consists mainly of State parks, State forests, and tax-deeded land reverted to the State for nonpayment of taxes. State parks are mainly old-growth timber stands, situated along the Redwood highway and other main roads. A few are coastal parks. This land has gone from private into State ownership within the past 30 years through purchase and gifts

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12/ Sustained-yield forestry is defined as the continuous production of annual or periodic forest crops in approximately equal or increasing amounts on a given area of forest land.

Figure 10.- The public forests and parks offer the best opportunity for people who own no rural land to enjoy outdoor recreation. The scenes above and at lower right are in a county redwood park in San Mateo County. The scene at lower left is in a State redwood park in Santa Cruz County. Both of these parks are readily accessible to a large urban population.

from various individuals and organizations like the Save-the-Redwoods League. The parks, which contain some of the finest redwood timber stands remaining in the subregion, have been withdrawn from timber utilization to provide much needed public recreation areas. Preservation of these famed redwood groves in their natural state affords pleasure to thousands of people from all parts of the country and from many foreign countries. Because these recreational tracts are used and enjoyed by so many people, their economic value for recreation undoubtedly exceeds the value of the lumber that could be cut from the timber stands involved. Furthermore, as population expands in the State, the value of these areas for recreation can be expected to increase. Public forests and parks offer the best opportunity for nonowners of rural land to enjoy reasonably unrestricted outdoor recreation (fig. 10). These parks are particularly desirable because of the relatively small acreage of redwood timberland in public ownership. Future plans of the State Division of Beaches and Parks contemplate the acquisition of additional acreages of selected redwood groves in this forest area.

The largest State forest is the Jackson State Forest in Mendocino County. The land in this forest is principally cut-over redwood timberland, but most of it is rather well stocked with young-growth saw timber. Most of this land was bought by the State in recent years from a pioneer timber operating company. Part of it was acquired from the National Park Service. This land is managed by the State Division of Forestry primarily for demonstrational and experimental purposes. It is considered ideal for demonstrating good forestry because it has sufficient acreages of timber stands in the various age classes to permit management on a sustained-yield basis. Use of this land in this way fulfills a special need in this area, because much commercial forest land here is owned by persons who are not in the business of producing timber. Demonstration areas like this forest may stimulate interest in improving the management of the timberland on some of these private holdings.

About 3 percent of the public land reverted to State ownership for nonpayment of taxes. Nearly all of this is commercial forest land which grows redwood and Douglas-fir timber. Because most of this is good timberland, it will undoubtedly return to private ownership under existing State and local policies of disposing of tax-deeded land. If allowed to remain in State ownership, this land could not be managed effectively for timber production because most of it is in relatively small scattered tracts. It could probably be managed best if consolidated with some of the adjoining larger private holdings.

Land in other State, county, and municipal ownerships amounts to about 3 percent of the total acreage of public land. About a fourth of this is timber-producing land. Most of it is in watershed holdings of municipal water organizations. Very little of this land is managed for timber production. Some of it is leased for livestock grazing.

Some timberland is in State holdings which are remnants of federal land grants to the State for the establishment and maintenance of schools. Some of this land has redwood and Douglas-fir timber on it, but it is in scattered inaccessible tracts.

## Private Ownership

Private holdings have been classified into 9 ownership types and 11 size classes (tables 3 and 14). The ownership classification differentiates particularly between (a) corporations and individuals, (b) operating and nonoperating owners, (c) farmers and nonfarmers, and (d) recreational and other classes of owners. Although absolute figures are given to designate the number of land holdings and of owners in the various statistical tabulations in this report, these figures are estimates derived by line sampling procedure employed in this survey and described in detail elsewhere.13/ Area figures have also been derived by the same statistical procedure but rounded off to the nearest 1,000 acres. The area covered by this ownership survey is sufficiently large to permit a reasonably accurate estimate of the true situation from line sampling.

This analysis indicates that individuals and private agencies owned 5,089,000 acres of land in the study area in 1949. The privately owned commercial forest land included in these private holdings amounted to more than two thirds of the total commercial forest land area.

In comparison with the publicly owned land, the privately owned commercial forest land has much more redwood timber, but it has a smaller proportion remaining as old-growth saw timber (tables 8, 9, and figs. 8, 11).

Adoption of sustained-yield management by private owners of commercial forest land is complicated by variations in length of tenure and type and size of ownership. Private ownership is often short-lived and is diversified as to type and size rather than continuous and long-run and in large single ownerships. Successful management of forest land demands a continuity of tenure and management policy not found under some forms of private ownership. Furthermore, greatest immediate financial return to the owner rather than maximum production of quality wood often determines the owner's willingness to adopt long-range forestry practices. Some private corporations and individuals have overcome these difficulties and established successful continuous operations.

On ranch, farm, and recreation holdings, production of timber is not a major source of income. And, although timber-producing lands do not comprise the major part of some of these ownerships, the possibility of a forest enterprise should be considered in deciding upon the most economic use or the best combination of uses. Timber operations, under restricted harvesting practices, may well be possible on ranch, farm, and some recreation holdings without subsequent reduction in the value of the land for other uses.

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13/ Hasel, A. A., and Adon Poli. A New Approach to Forest Ownership Surveys. Land Economics, 25(1): 1-10. February 1949.
Poli, Adon. Conducting a Survey of Ownership of Forest Land in California. Agricultural Economics Research. 4(1): 8 12. January 1952.

Table 3.- Percentage distribution of number of holdings, privately owned land, and privately owned commercial forest land by type of owner, Redwood--Douglas-fir Subregion, California 1949

| Type of owner | Holdings | | | Total land area | | Commercial forest land |
|---|---|---|---|---|---|---|
| | Number | Pct. | Av. size acres | Thousand acres | Pct. | Pct. |
| Timber operating company | 116 | 0.6 | 6,595 | 765 | 15.9 | 25.4 |
| Timber holding company | 141 | 0.8 | 1,277 | 180 | 3.7 | 5.9 |
| Timber operating individual | 220 | 1.2 | 541 | 119 | 2.5 | 3.7 |
| Timber holding individual | 1,236 | 6.9 | 382 | 472 | 9.8 | 14.7 |
| Range livestock farming company | 17 | 0.1 | 5,941 | 101 | 2.1 | 1.9 |
| Range livestock farming individual | 1,121 | 6.3 | 1,471 | 1,649 | 34.3 | 27.0 |
| Other farmers | 6,393 | 35.6 | 120 | 767 | 15.9 | 7.6 |
| Recreational property owners | 2,983 | 16.6 | 98 | 291 | 6.0 | 5.3 |
| Other classified owners | 5,723 | 31.9 | 82 | 472 | 9.8 | 8.5 |
| All classified owners | 17,950 | 100.0 | 268 | 4,816 | 100.0 | 100.0 |
| Unclassified | - | - | - | 273 | - | - |
| All owners | - | - | - | 5,089 | - | - |

The unusually large number of small ownerships in this study area influences the nature of the forest management on these holdings. The chief uses for these small ownerships are recreation and residence. Timber production is unlikely to be a major use because the owners generally lack the capital investment and the knowledge required to establish a timber operation if it is set up. And they lack markets for the small quantities of forest products they could produce.

Owners with marketable timber on small holdings could perhaps work together and establish continuous timber operations through cooperative logging, milling, and marketing agreements. Or, these owners might harvest timber periodically by contracting for its removal and sale according to the best management practices. Some of the owners have little, if any, interest in timber production. They prefer to retain the timber for its aesthetic value.

## Types of Owners and How They Use the Forest Land

Of the 17,950 classified owners of private land in this study area in 1949, 116 were timber operating companies engaged in commercial logging and milling of timber as a major enterprise (table 3 and figs. 12-14).[14] These companies owned 16 percent of the privately owned land and 25 percent of the private commercial forest land. Most of the commercial forest land (91 percent) was in redwood timber. About half was old-growth saw timber. These holdings were medium and large, averaging 6,595 acres. Nearly all of them were obtained by purchase (table 21).

All but 6 percent of this land was operated[15] by the owners. A small acreage was operated partly by owners and partly by others. None of these land holdings was leased completely to other operators (table 20).

About 89 percent of these holdings were used[16] exclusively for timber operations (tables 4 and 12). The others were used primarily for timber operations in combination with other minor uses, principally farming and recreation.

The land in these corporate holdings is used mainly for logging and milling operations of various kinds and sizes. The largest sawmills are in the redwood timber zone near the coast. Heaviest production of lumber comes from several large sawmills that were established here many years ago after steam became the popular source of power in the lumber industry. These large-scale timber enterprises are centered principally

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14/ For other detailed classifications of type of ownership, refer to tables 7 to 11 in the appendix.

15/ The term "operated" as used here refers to the conditions of tenure under which the land is managed and used. In this case "operated by the owners" means that this land was managed by the legal owners of the land and not by others through leases or other contractual arrangements.

16/ The term "use" as applied in this section refers to the enterprise or combination of enterprises from which the owner derives the greater part of his income or satisfaction from the ownership of land.

Table 4.- Private land holdings by major land use and by type of owner, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | All uses | Major land use | | | | | |
|---|---|---|---|---|---|---|---|
| | | Timber operations | Farming and ranching | Recreation | Residence | Other uses & combinations of 2 or more uses | No use |
| | Number of holdings | | | | | | |
| Timber operating company | 116 | 103 | - | - | - | 9 | 4 |
| Timber holding company | 141 | 8 | 8 | - | - | 4 | 121 |
| Timber operating individual | 220 | 181 | 1 | - | - | 35 | 3 |
| Timber holding individual | 1,228 | 64 | 27 | - | 18 | 8 | 1,111 |
| Range livestock farming company | 17 | - | 12 | - | - | 5 | - |
| Range livestock farming individual | 1,121 | 1 | 967 | - | 8 | 135 | 10 |
| Other farmers | 6,393 | 6 | 6,049 | 6 | 23 | 256 | 53 |
| Recreational property owners | 2,963 | 5 | - | 1,842 | 29 | 312 | 775 |
| Other classified owners | 5,699 | 7 | 633 | - | 2,939 | 504 | 1,616 |
| All classified owners | 17,898 | 375 | 7,697 | 1,848 | 3,017 | 1,268 | 3,693 |
| Unclassified | 52 | - | - | - | - | - | - |
| All owners | 17,950 | - | - | - | - | - | - |

in Humboldt and Mendocino Counties, the highest lumber-producing counties in the State.17/

The logging of redwood trees requires heavy, high-powered equipment. This heavy machinery is costly and considerable capital investment is needed to buy it. Corporations like those included here had the necessary capital with which to finance the ownership of large timber holdings and the costly equipment needed to handle the large logs.

During the war and postwar periods, timber-processing corporations from other States have acquired timber holdings here to obtain a new source of raw material with which to continue or expand their lumber business. A fairly recent development is the establishment of plywood and fibreboard plants in certain parts of this area. The plywood plants utilize mainly Douglas-fir and small quantities of redwood and other species. A large hardboard plant recently built utilizes low grade logs and sawmill residues of redwood and Douglas-fir.

During the more than 100 years of timber operations in the subregion, a number of redwood sawmills have been closed down and dismantled for want of timber. Even in earlier years, operators of some of the large timber holdings cut their timber at a rapid rate. With the advent of steam-powered logging machinery, they removed timber from the forests in the most expedient manner with little regard for either the remaining timber stands or the condition in which they left the land. The remaining timber stands could thus no longer support a profitable operation.

In recent years, operators of large timber holdings have become more progressive in managing their land. They now realize that to stay in business they must give attention to the way they manage their timberland. This has resulted in improved logging methods, better fire protection, and establishment of the "tree farm" movement in which considerable effort is made to restock cut-over land and to maintain sustained-yield operation.

About 141 owners were timber holding companies which kept timber principally for future commercial timber operations. These were investment companies, nonresident lumber manufacturers, former active lumber companies that have stopped operations because they have run out of old-growth saw-timber, and other private organizations holding timber either for their own use or to sell to others. These companies held 4 percent of the total privately owned land area and 6 percent of the private acreage of commercial forest land. About 95 percent of their land was commercial forest land. Almost four-fifths of the commercial forest land was in redwood timber. More than half was old-growth saw timber. Their holdings were of medium size, averaging 1,277 acres.

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17/ May, Richard H. Lumber Production in California and Nevada, 1951. Forest Survey Release No. 17: 1-14. Calif. Forest and Range Expt. Sta., Berkeley. December 1952.

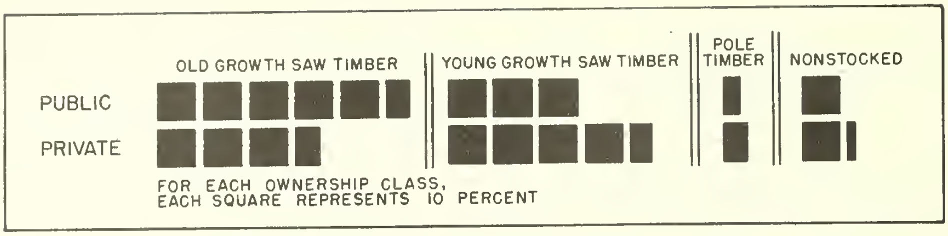


Figure 11.- Percentage of timberland acreage in public and private ownership by stand-size class.

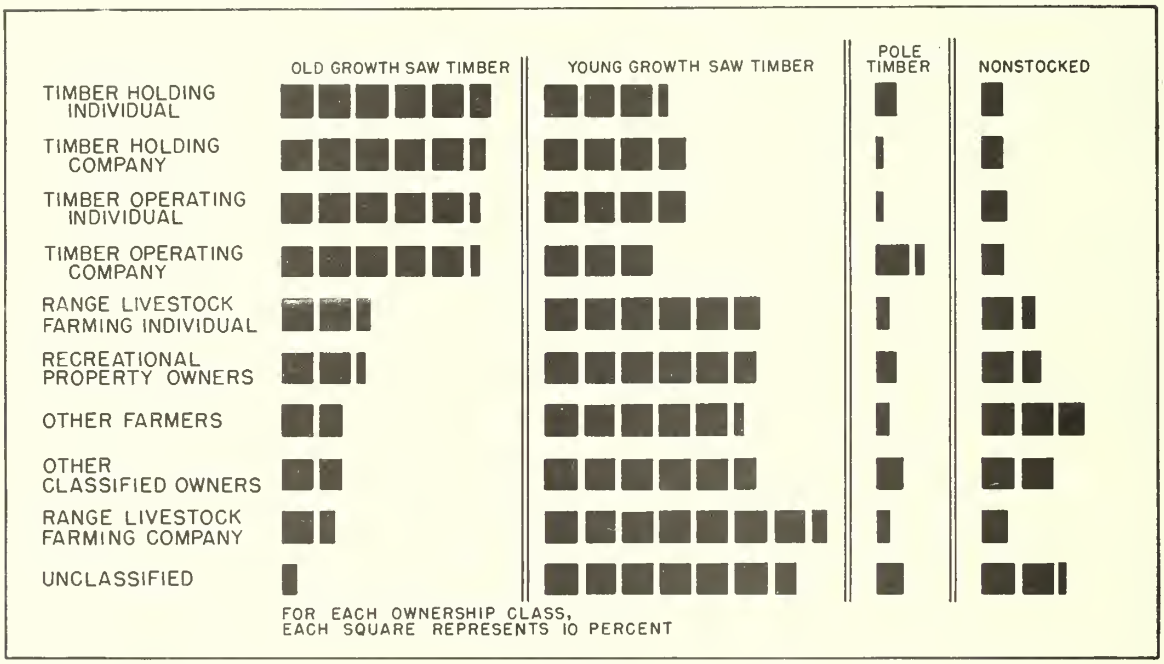


Figure 12.- Percentage of timberland acreage in each type of private ownership by stand-size class.

About 83 percent of the land was purchased, 6 percent was inherited by officials and stockholders of the companies, 2 percent was obtained by foreclosure, and the rest was acquired in other ways and by combinations of 2 or more methods of acquisition.

Most of the commercial forest land of these holding companies is rather well-stocked with old-growth and young-growth saw timber. This land is held and managed principally for timber production, but some land is also leased to nearby ranchers for livestock grazing. In 1949, land in approximately 6 percent of the holdings was used for grazing. During this same year, local loggers and lumbermen negotiated contracts with the owners to harvest timber from the commercial forest land in their holdings. About 6 percent of these ownerships, which included about 12 percent of the land, were operated in this way. About 2 percent of the ownerships with about 20 percent of the land were operated partly by the owners, principally for recreation and residence, and partly by others, mainly for logging and grazing. These are generally large holdings used for multiple purposes such as timber operations, grazing, recreation, and residence in various combinations.

The bulk of the land holdings in this ownership class, however, are reserved for future use, that is, the timber is not now being cut. Ordinarily, they remain in growing timber until the time arrives to start cutting the timber for the owners' own operations, to sell the timber to other operators, or to sell the timber and the land. In 1949, 86 percent of these holdings, comprising 66 percent of the land, were kept in growing timber for future use.

A number of these timber holding companies have had land in this area for many years. Some of them once had sawmills in operation on their holdings. Others have lumber businesses outside the State and have acquired timberland here to obtain raw material for future use. But some are strictly land-holding companies which manage their land for timber production but do not conduct their own operations. This land is operated by others who contract with the owners to cut the timber, or lease grazing land.

Some 220 owners were <u>timber operating individuals</u> engaged in timber operations of various kinds as a major business. These were persons logging timber, operating large and small sawmills, or splitting timber commercially for sale. These individuals owned 3 percent of the privately owned land and 4 percent of the privately owned commercial forest land. About 89 percent of their land was commercial forest land. Almost two-thirds of this was in the redwood timber zone. A little more than half was old-growth saw timber. These holdings averaged 541 acres in size.

About 91 percent of this land was purchased, 3 percent was inherited, and the rest was obtained in other ways and by combinations of various methods of acquisition.

This land was used principally by the owners in their own timber operations. About 82 percent of the land holdings supplied wood for the manufacture of timber products of various kinds. The other land holdings were used primarily for timber operations in combination with other minor uses--mainly farming, recreation, and residence.

During and after World War II the increased demand for lumber stimulated the establishment of small-scale timber enterprises. Small sawmills, operated mainly by individuals, are scattered throughout the forest area. They are generally found in small community centers, on farms, and in other favorable locations where timber, markets, labor, transportation facilities, and housing are available. The mill owners use timber from their own land for part of their log supply, but they also buy stumpage from other owners. Sometimes they buy logs from logging contractors, who usually deliver to the mill.

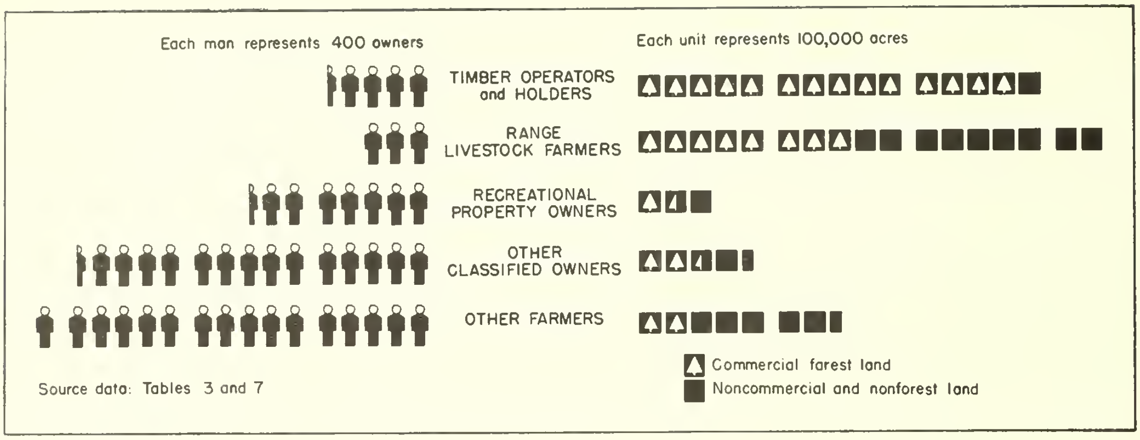


Figure 13.- Number of private owners and acreage owned, by type of owner.

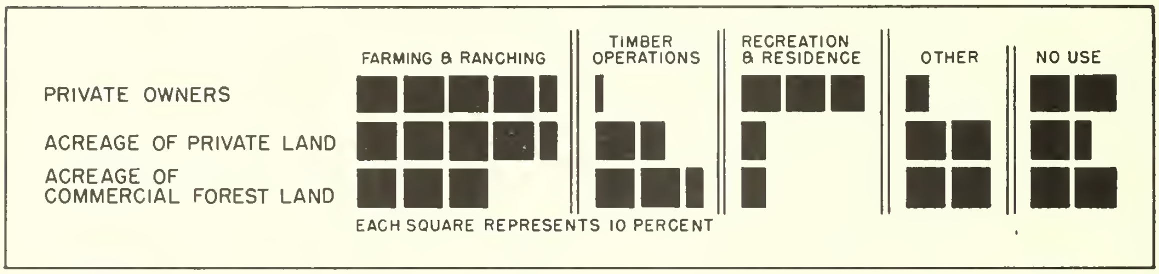


Figure 14.- Percentage distribution of owners and of acreage of private land, by land use.

About 1,236 owners were timber holding individuals who kept timber principally for future timber operations either for themselves or to sell to others. This group was made up of businessmen, tradesmen, mechanics, retired persons, professional people, housewives, white-collar workers, laborers, and others. These timber holders owned 10 percent of the private land, with 15 percent of the private commercial forest land. Three-fifths of their commercial acreage of forest land was in the redwood type. Almost three-fifths was old-growth saw timber. Their holdings were generally small, averaging 382 acres.

These individuals acquired 79 percent of their land by purchase, 15 percent by inheritance and gift, and the rest by other methods and by combinations of 2 or more methods.

About 6 percent of the owners operated their own land, 4 percent leased their land, and 90 percent left their holdings idle, that is, without any form of planned management.

In this, as in most forest regions, many small scattered timber holdings are not used by the owners. People acquire these holdings under many circumstances, but they fail to do anything with the land after they get it. Consequently, some pay taxes for many years until they finally dispose of their holdings by sale or trade, or pass them on to their heirs. A number of these properties are speculative purchases of land at tax sales. Some are the result of land exchanges; others are gifts from relatives. Most of the idle holdings are in remote areas without roads or other suitable means of access to them. Many belong to nonresidents who have never seen their land.

A large share of the individual owners know little about management and use of forest land. Some owners believe that forests require no care. Others lack sufficient interest to do anything constructive about forest management. The indifference of most of these owners prevents proper management and use of the timber on a rather sizable acreage of timber land.

This situation can be improved through consolidation of some of the smaller timber holdings of this type of owner in such a way as to simplify the present ownership pattern. Future sale or voluntary exchange of some of these properties should be encouraged whenever it involves consolidation with larger and better managed timber holdings. Management of some of these small timber holdings by consulting or public service foresters offers possibilities.

There were 17 <u>range livestock farming companies</u> engaged in range livestock ranching operations as a major business. These farming companies collectively owned only about 2 percent of the privately owned land and 2 percent of the private commercial forest land. A little more than half of their land consisted of commercial forest land. Half of this was classified in the redwood type and the other half in the Douglas-fir type. Their holdings were medium and large, averaging 5,941 acres.

About 92 percent of the land in these corporate holdings was purchased. The rest was partly purchased and partly inherited by stockholders and officials of the companies.

About 71 percent of these holdings were used almost exclusively for grazing of livestock. The rest were used principally for grazing livestock in combination with other secondary uses, mainly timber operations and recreation.

Most of the corporate ownerships are large-scale ranching enterprises operated by hired resident managers. These managers are generally well qualified for their jobs and know how to manage these large holdings properly, particularly for grazing. If there is sufficient acreage of good timberland in their ranch holdings, they may manage it for timber production, but usually as a secondary enterprise.

There were 1121 range livestock farming individuals whose major enterprise was range livestock farming. These ranchers owned the largest shares (34 and 27 percent respectively) of the private land and of the private commercial forest land. The redwood type occupied about one-third of the commercial forest land. The rest was mostly in Douglas-fir. Slightly less than a fourth of the commercial forest land was in old-growth saw timber. The land holdings were mostly of medium size, averaging 1,471 acres.

These owners acquired 72 percent of their land by purchase, 16 percent by inheritance and gift, 1 percent by homestead, 1 percent by foreclosure, and the rest by other methods and combinations of various methods, mainly purchase, inheritance, and homestead.

About 84 percent of the land in this class of ownership was operated by the owners, 8 percent was leased to other operators, 7 percent was partly operated by owners and partly leased to others, and only about 1 percent remained idle. Some 86 percent of the land holdings were used for grazing livestock. The rest of the land holdings were used principally for combinations of 2 or more uses, mainly ranching with timber operations or recreation as secondary uses.

These livestock ranchers are located primarily on the grass and woodland-grass lands that lie in the Douglas-fir timber type east of the redwood timber belt, and the grassland benches and slopes west of the redwood timber near the ocean. Cattle and sheep are the main types of livestock grazed. Although quite a large part of the commercial forest land acreage is in these ranch holdings, most of it was not acquired originally to grow timber. It was obtained as part of the ranch units along with larger acreages of grass and woodland-grass with which the timberland was intermingled. Some was obtained also from former timber operators as cut-over land after the old-growth timber was removed. The cut-over land was used by the ranchers for grazing livestock until brush and young timber grew back and displaced the grass. Because the major interest of these ranch owners is in grazing livestock, a comparatively large acreage of commercial forest land in their ranch holdings gets little or no management for timber production. Repeated burning has left a large share of the commercial forest land in these ranch holdings stocked with brush instead of timber. As a consequence, this land contributes little or nothing to the income of the owner.

Attempts to convert timber-producing land to grassland have met with varying degrees of success. One explanation for this is found in a recent study of soil-vegetation relationships in the redwood region.18/ This study rated some timberland soils as of little or no value for producing grass (figs. 15, 16). This work has emphasized the importance of knowledge about soils in deciding the best use for certain forest lands.

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18/ Storie, R. Earl and A. E. Wieslander. Dominant Soils of the Redwood--Douglas-fir Region of California. Soil Science Proceedings 16(2): 163-167. April 1952.

Figure 15.- An apparently successful conversion of timberland on a ranch holding to range by burning. Dead tree snags are mostly Douglas-fir.

Figure 16.- An apparently questionable clearing operation on a ranch holding by burning. Low brush species seem to be taking over the cleared land formerly in timber. Success of operations of this type is highly dependent on kind and quality of soil, slope exposure, and the climate.

Increased value of Douglas-fir in recent years has aroused interest in timber production, and discouraged conversion of timberlands to grazing lands. Because livestock ranchers own such a large share of the commercial forest land, consideration might be given to various ways of stimulating their interest in producing more timber. Educational programs to point out the economic benefits that can be derived from multiple-use management of timberland should be sponsored, particularly by agencies dealing with farm programs. Farm-forestry programs should be expanded so as to provide adequate guidance and assistance to ranchers and farmers in integrating the timber enterprises with the ranching activities. Sometimes, consolidation of the timberland in the ranch holdings with adjoining timber holdings could provide for more efficient operations. A good start in this direction has been made by the people of Humboldt County where considerable effort is currently being devoted to the formulation of a long-range forestry program for various kinds of forest land holdings.

Other farmers, engaged in types of farming other than range livestock ranching as a major enterprise, numbered 6,393. This group was the largest in number of all the ownership classes. It controlled 16 percent of the privately owned land. These holdings had 8 percent of the privately owned commercial forest land, about half of which was in the redwood timber zone. Only 16 percent of the commercial forest land was old-growth saw timber. Holdings were small, averaging 120 acres.

These farm owners bought 72 percent of their land, obtained 20 percent by inheritance and gift, 1 percent by homestead, and the rest by other methods and various combinations of methods, mainly purchase, inheritance, and homestead.

Owners operated 81 percent of their own land, 15 percent was leased to other operators, 3 percent was in holdings operated partly by owners and partly leased, and about 1 percent remained idle.

Ninety-five percent of these holdings were used for farming, and the remaining 5 percent were used primarily for farming in combination with other minor uses, principally recreation and timber operations.

Throughout the study area are many small acreages operated as general farms, dairies, orchards, vineyards, poultry farms, and part-time farms. Dairies are mostly near the coast and along the western fringe of the redwood timber zone throughout almost its entire length. Orchards and vineyards are principally in the large interior valleys, but some are also in the smaller valleys and natural openings in the timber (fig. 6). Some of these farms were developed on cut-over land where the soil and other natural attributes favored agricultural use (figs. 17, 18). Poultry farms are scattered throughout the area, but most are concentrated in Sonoma County. Part-time farms are located primarily near community centers. The owners work on the farms during the winter and other seasonal periods of unemployment, and in the nearby sawmills, logging camps, and other local industries in summer and at other times when labor is in demand.

Figure 17.- This scene shows two small adjoining general farms typical of many found in natural openings and on cut-over land in various parts of the redwood forest. Such farms were originally developed by "old timers" who settled here in the late 1800's. Some are now held by urban people as hunting lodges and rural residences. Others are still operated as farms.

Figure 18.- Former redwood timberland on a farm holding converted to agricultural use by cutting and burning. The land is now used as a vineyard. Size and number of the stumps in this scene indicate that the land once supported a heavy stand of timber. Because redwood stumps are large they are difficult to remove completely from the land.

But even though more than a fourth of their land consists of commercial forest land, these small-scale farmers rarely manage it for timber production. Consequently, their timberland (about 8 percent of the total acreage of private commercial forest land) contributes little to the forest production of the region. Improved programs of farm-forestry through public or private initiative would help this situation materially. The need for these programs is recognized in the following excerpt from the Report to the Legislature by the California Forestry Study Committee:

> "There are two important factors needed to bring about better care and more complete use of the farm forests of California. The first of these is a good prospect of future as well as present financial gain for the owner of such lands and the second factor is a means of getting information to the owner on such matters as what and where the markets are and how the products should be measured, prepared and sold ....To advise the rancher of the possibilities of his forest land and to assist him in determining how the land might be best managed there is need for 'high grade educational work by extension men. As soon as possible the State Forester should be given authority and the means to carry on this kind of work.'"[19]

In the study area, two large groups of owners had land holdings somewhat similar in terms of type of land, size, and use. The first group consisted of 2,983 recreational property owners who held land mainly for recreational use. This group included owners of resorts, dude ranches, summer cottages, and owners of land acquired for hunting, camping, and other forms of outdoor recreation. About two-thirds of the land holdings were used by the owners; about a fourth were left idle, and only a few were leased. Most of the land holdings were used for recreation, or for recreation in combination with other uses, mainly farming and timber operations. The idle holdings were reserved for future recreational use.

The second large group of owners were the 5,723 other classified owners. These owners could not logically be placed in any of the ownership groups previously described. In this class were owners of land held for residential or business purposes only, mining claims, watersheds, and reservoir sites, and miscellaneous owners who held land for various other reasons. Three-fifths of these holdings were used by the owners, chiefly for residence; about 10 percent were leased to others, principally for farming and ranching; and almost 30 percent were left idle.

More than four-fifths of the land holdings of these two ownership groups were acquired by purchase; about a tenth, by inheritance and gift; and the rest, by various other methods such as foreclosure, exchange, and combinations of various methods. Included in these two ownership classes were 16 percent of the privately owned land and 14 percent of the private commercial forest land. A little more than half of their commercial forest land was in the redwood type, but only about a fifth was stocked with

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19/ The Forest Situation in California. Report to the Legislature by California Forestry Study Committee. Created by Senate Resolution No. 151, Statutes of 1945. Vol. II, p. 18, 1947.

old-growth stands. These holdings were generally small, averaging 98 acres for recreational ownerships and 82 acres for other classified owners.

As indicated by these two relatively large groups of owners, recreation and residence are popular uses of rural land. Almost 5,000 private ownerships--more than a fourth of the total number--were used for these two purposes. About another 800 were acquired for these purposes but had not yet been put to the intended use by the owners.

The mild pleasant climate of this area; its accessibility to a large urban population; the scenic beauty of the forests, the beaches, and the rugged shoreline; and the splendid opportunities for fishing, hunting, swimming, camping, and other popular forms of outdoor recreation have attracted many part-time and permanent residents. The relatively low cost of land, taxes, and other overhead items in certain counties has been another inducement. This demand for land for recreational and residential use has influenced considerably the pattern of ownership in this area.

Recreational and residential holdings are particularly numerous in Santa Clara, Santa Cruz, San Mateo, Marin, Sonoma, and Mendocino Counties. These counties are near the San Francisco Bay region where a heavy concentration of population exerts considerable pressure on the land use pattern of the nearby rural land resources. Access to public forest land is also more limited here than elsewhere in the State. As a result, private timber and farm land is constantly being removed from commercial production and placed into recreational and residential use. These holdings are relatively small compared to those of other types of private owners, and often only a small part of each holding is actually used for residence or recreation. The unused portions are withdrawn from timber production or farm use because of the believed incompatibility between recreation and these uses. The result is a reduction in the area of timber-producing lands.

Commercial recreation in some of these counties has become a major industry. Elaborate resorts, dude ranches, motor courts, and many other commercial enterprises cater to a steady flow of weekend guests, vacationists, sportsmen, and out-of-State tourists that is particularly heavy in late spring, summer, and early fall. Recreational use of forest land is justified here to satisfy the needs of a large urban population and out-of-State tourists. Besides, the forest land in this region is unusually attractive and suited to this type of use. But recreational and residential development should be adequately planned so as not to create undesirable patterns of ownership and use. Scattered settlement should be avoided because it increases the fire hazard and makes protection difficult and costly. Furthermore, indiscriminate placement of tourist courts, cabin sites, and roadside commercial enterprises often destroy the scenic values of otherwise picturesque forest areas. Establishment of local planning groups to plan, organize and direct such settlement, and to develop additional public recreational areas, where necessary, seems desirable. Zoning ordinances to restrict recreational and residential development and other land uses within certain designated areas should also be considered.

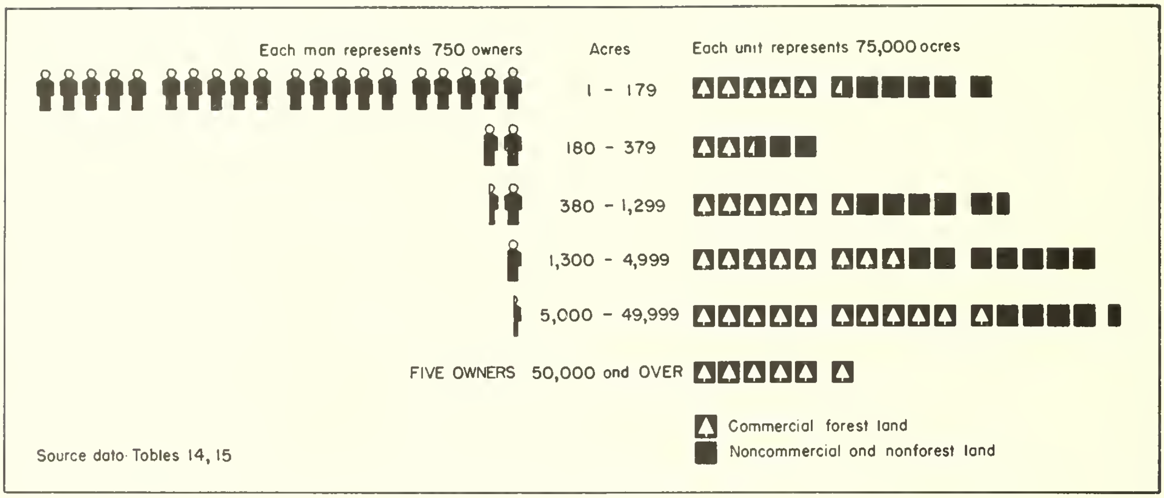


Figure 19.- Number of private owners and acreage owned by size of holding.

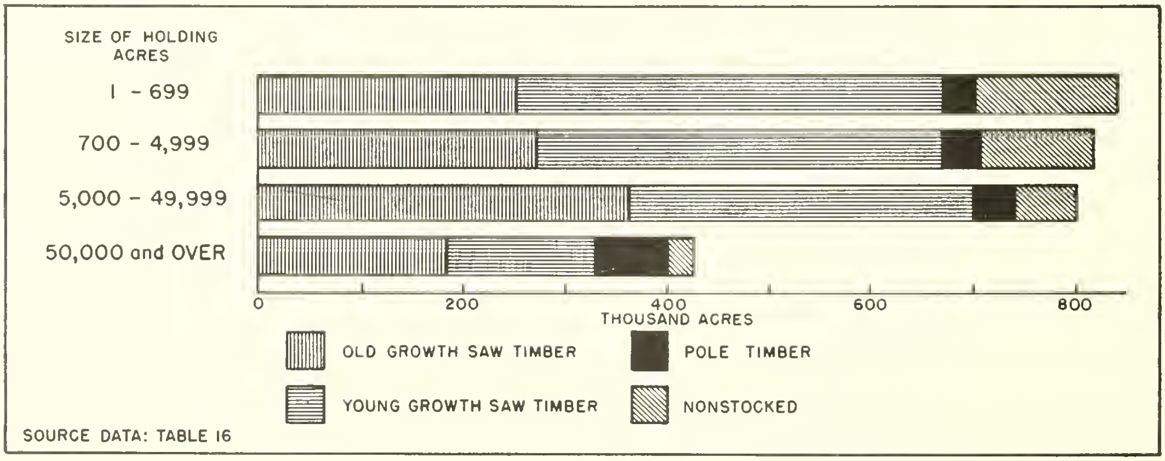


Figure 20.- Commercial forest land by stand-size class and by size of holding.

Size of the Forest Land Holdings

Private ownerships were grouped into 11 size classes, ranging from holdings of less than 180 acres to those of 50,000 acres or larger (table 14).[20/] In this subregion, an unusually large number of ownerships are in the small size classes. Eighty-four percent of the total number of ownerships are smaller than 180 acres; this is 11 percent more than in the adjacent Coast Range Pine subregion. Less than 1 percent are of 5,000 acres or larger (figs. 19, 20).

The smallest ownerships are found in Santa Cruz and Santa Clara Counties where recreation and residence are important uses of forest land. The largest holdings are in Humboldt and Mendocino Counties where large-scale timber operations and ranching prevail.

The unusually large number of small ownerships found in the study area is due principally to the recreation and residential use of small tracts of timberland. Also, the pattern of small ownerships fostered by early Federal laws has remained in certain parts of the study area where subsequent conditions favored small holdings.

It is difficult to arrive at definite conclusions as to the desirability or undesirability of an ownership pattern preponderantly of small holdings, particularly where the use pattern is as complex as it is here. Most foresters contend that a complicated pattern of small individual ownerships is not conducive to good forest management.[21/] This, of course, applies to forest land on which commercial timber production is presumably the best use economically.

In commercial forest land areas, the presence of small holdings used for a number of different purposes generally increases the fire hazard and makes protection more difficult. Satisfactory programs of forest land management are harder to develop and to administer because of the many and varying interests of the owners. If timber production is the major objective of management, small individual holdings generally lack sufficient growing stock to provide for efficient operation. The handling of logs from large trees, particularly redwoods, requires large capital investments in heavy machinery beyond the financial capability of most owners of small tracts. Suitable markets for timber from small holdings are also generally inadequate. These and other related factors usually discourage good forest management by owners of small holdings.

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20/ For other detailed classifications of size of ownership refer to tables 13, and 15 to 19 in the Appendix.

21/ The Forest Situation in California. op. cit., p. 17.

Folweiler, A. D. and H. J. Vaux. Private Forest Land Ownership and Management in the Loblolly-Shortleaf Type of Louisiana. Jour. Forestry 42 (11): 786. Nov. 1944.

U. S. Department of Agriculture. Forest Service. The Management Status of Forest Lands in the United States. Report 3 from a Reappraisal of the Forest Situation. pp. 6, 7. Washington, D. C., 1946.

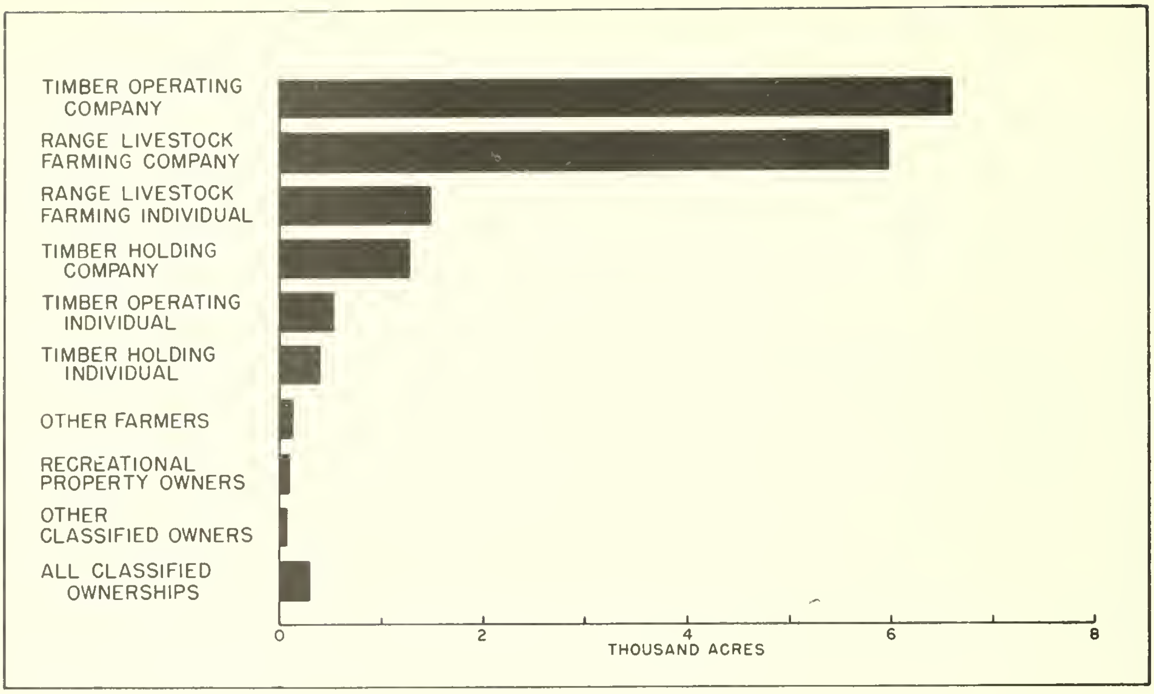


Figure 21.- Average size of holdings of private owners.

But where recreation has been established as the major use of a forest land area, as has been done in counties near the San Francisco Bay area, a pattern consisting of many small holdings is well suited to that particular use. If the recreational areas are properly blocked out and their development adequately planned, small forest land holdings are suitable units for recreational settlements. The main objective on recreational holdings is not producing timber but keeping and protecting the trees for their aesthetic values.

An important task in this study area is to consolidate some of the scattered small timber holdings in commercial timber areas that are not suitable for recreational or residential use. This is desirable so as to simplify the ownership pattern for efficient management of timberland.

<u>Relationship Between Size and Type of Ownership</u>

The largest private land holdings in this forest region are those of timber operating companies (table 19 and fig. 21). These large ownerships are concentrated in Humboldt and Mendocino Counties. Most of this land was bought many years ago and consolidated into a few rather well-blocked forest land holdings. About three-fifths of the land in this ownership class is in units of 50,000 acres and larger. These large holdings are held almost exclusively for commercial production of timber and timber products. Some of them offer excellent opportunities for the practice of sustained-yield forest management, and several of the operators are developing plans for long-range operations.

The second largest holdings are those of range livestock farming companies. None of these exceed 50,000 acres in size. A little more than half of the land in this ownership class is commercial forest land. Land in this ownership class is held principally for livestock range. Fairly large acreages of range land are required for efficient ranch operations.

The next largest holdings are those of range livestock farming individuals and timber holding companies. Most of the land of range livestock ranchers is in the medium size classes--a size generally suitable for efficient management of the type of livestock ranches found here. Although land of timber holding companies is mainly in units of medium size, some land is also in a few large holdings of 30,000 acres or more.

The smallest land ownerships are those of other classified owners, recreational owners, and nonlivestock farmers. Land of other classified owners is used principally for residence and other similar uses that require only small tracts of land. Recreational use of holdings generally demands little more than a camping area or summer home site, except for enterprises like dude ranches and resorts. Nonlivestock farmers have mostly small holdings because the intensive type of farming practiced can be done on relatively small tracts of land. Quite often only a small part of the entire ownership is cultivated. Timber cut from commercial forest land on these holdings is used primarily on the farm.

## Operating Tenure

Private ownerships and privately owned land were classified into 4 types of operating tenure (table 20 and fig. 22). A classification of tenure by type of ownership shows that 70 percent of the private owners operated their own land; 7 percent leased their land to other persons; 2 percent operated part of their own land and leased part to others; and 21 percent left their land idle.22/

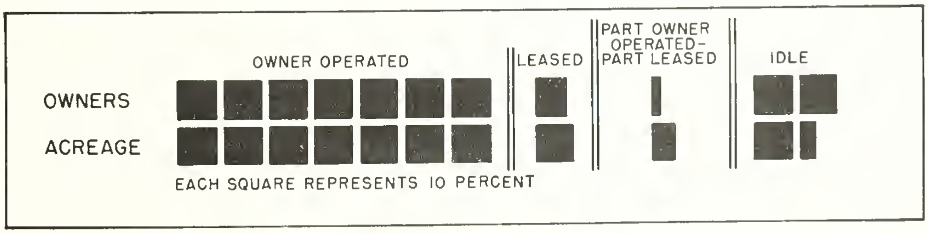


Figure 22.- Percentage distribution of owners and of acreage of private land, by tenure.

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22/ The term "idle" as used here means that at the time of survey the land was not intentionally managed for any specific purpose other than to let the timber and other vegetation grow, more or less in its natural state.

Timber operators used most of their land (94 percent) for their own business operations. They leased very little of their land to others and left very little of it idle. Timber operators own land principally to produce timber for sawmills and other processing plants which they operate themselves. Their land holdings constitute a significant part of their business enterprise upon which their plant operations depend. Hence, very little of their land is left unused or is used for purposes other than producing timber for their operations. A small acreage of land is leased occasionally to nearby ranchers for grazing livestock.

Farmers and ranchers operated more than four-fifths of their land in their own ranch and farm enterprises. A limited acreage was leased to other ranch operators, but very little of their land remained idle. Farmers and ranchers use their land holdings principally for their own farming and ranching enterprises. In other words, they are mainly operators, not landlords. The types of farming and ranching enterprises carried on here require close supervision by the operators. This is not conducive to tenant operation or to letting the land holdings stand idle.

Owners of recreational land holdings operated slightly less than two-thirds of their land themselves. They leased a small acreage to others, but they left a fourth of their land idle. The relatively large share of idle land probably belongs to persons who plan to develop their holdings at some future time. Some are holdings of owners who plan to retire in a few years and then spend all or part of their leisure time developing their land. Some of these holdings belong to nonresident owners who have acquired the land "sight unseen" and have yet to put it to the intended use. Because recreational holdings are small, unimproved, and include much forest land, they are not usually leased by ranchers or by others.

Timber holding individuals and timber holding companies operated a relatively small proportion (less than 18 percent) of their own land. More than two-thirds of this acreage was left in growing timber for use sometime in the future. Because these holdings consist largely of commercial forest land, they have only limited value for uses other than timber operations. Furthermore, much of the land of timber holding individuals is in small, undeveloped, isolated units. Even if some of this land is suitable for grazing, ranchers are reluctant to lease it because of the difficulty of managing a group of small, unfenced, and scattered holdings as an efficient economic unit.

Considerable land of timber holding individuals is held for resale at a profit. Owners of such land are not particularly interested in the long-term use of the land. Some of this land is owned by nonresidents whose major interests are in other business enterprises. These owners usually have neither the time nor the inclination to concern themselves with the management of their land.

A classification of tenure by size of ownership shows that leased land was principally in units smaller than 20,000 acres. There was no idle land in holdings of 20,000 acres and larger, but considerable idle land was concentrated in ownership units smaller than 180 acres. In contrast with conditions found in the Coast Range Pine subregion, where most of the land leased was in the large size classes, most of the leased land here is in medium-sized and small units. This is probably due to the fact that range land, the land most commonly leased, is in smaller units here than it is in the Coast Range Pine. The large holdings in the Redwood--Douglas-fir subregion consist almost entirely of commercial forest land with little range land to lease to ranchers. Nearly all of these large timber holdings are operated by owners almost exclusively for timber production.

## How the Owners Acquired Their Land

The way in which land is obtained often influences the way it is used and managed. Purchasers of land generally have more positive plans for its use and management than do persons who obtain land by involuntary means such as foreclosure or gift. The buying of land usually requires a certain amount of effort and financial sacrifice. To a buyer with limited means, the buying of a piece of property may represent the most significant business transaction of his career. Usually land becomes a part of a major business enterprise--a lumbering concern, a farm, or a resort. To succeed in his particular business, the buyer must give considerable thought to the location, type, quality, and size of his land holding. Because of these considerations, the person who invests his own money in land is likely to give it greater attention than one who obtains property in some easier way. Exceptions to this generality are purchases of relatively inexpensive land by speculators. As these buyers obtain land only for resale at a profit, they often do not care how the land is managed during the short time they hold it. Speculative deals like these, however, seldom involve large acreages of land because individual holdings are usually small.

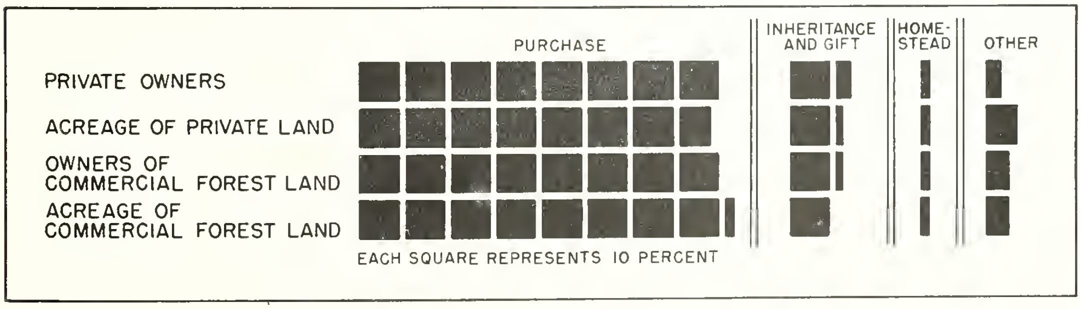


Figure 23.- Percentage distribution of owners and of acreage of private land, by method of acquisition.

In this study area, about four-fifths of the land holdings were acquired by purchase (tables 21, 22, 23, and fig. 23). The proportion of purchased land here is greater than that found in the adjacent Coast Range Pine subregion as well as in ownership studies of forest land elsewhere.23/ This may be due to the fact that much of the redwood timber land was obtained from the government by persons who sold it shortly afterward to timber operators and to land speculators. Or, the high proportion of purchases may reflect the great demand for redwood for commercial timber production and recreational use. Also, the many small holdings found in this forest area may be the result of subdivision and sale of land acquired by methods other than purchase. In other words, there may have been greater turnover of land from the original owners here than occurred in other forest regions. This fact is exemplified further by the low proportions of land holdings in the homestead, inheritance, and gift classifications when compared with similar figures from other forest areas. Relatively small proportions of the land remain with the original "homesteaders." Speculative purchases and sales of properties may have reduced the tendency to pass land to heirs of the original owners. Acquisition by other methods represented only a small percentage of the total.

Where the Land Owners Are

The distance an owner lives from his land influences, to some extent, the degree and quality of management he provides his property. A recent study in Central Mississippi found "that owners who live at distances above 50 miles from their forests have generally poorer management than owners who live closer to their properties."24/ In the present study it was not possible to compute distances for the owners sampled, but it was possible to obtain from the tax rolls the mailing addresses of the owners. These addresses were used as a basis for a generalized classification by residence of owner (table 5 and fig. 24).

This classification shows that about two-thirds of the owners reside or have business headquarters in the same county in which they have their land (tables 5, 24, and fig. 24). Included in these holdings is 63 percent of the privately owned land and 57 percent of the private commercial forest land.

About 29 percent of the owners of private land reside or have business headquarters within the State but outside the county in which they have their land. Included in these holdings is about a third of the privately owned land and of the commercial forest land. Land holdings of this class of owner are smaller on the average than holdings of similar owners in the Coast Range Pine subregion. Greater use of land in the Redwood--Douglas-fir subregion for recreation and part-time residence by city dwellers is probably largely responsible for this difference in size of holdings.

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23/ Barraclough, Solon and Jas. C. Rettie. The Ownership of Small Private Forest-land Holdings in 23 New England Towns. Northeastern Forest Experiment Station Paper No. 34. p. 7. Upper Darby, Pa. March 1950.

24/ James, Lee M., W. P. Hoffman, and M. A. Payne. Private Forest Landownership and Management in Central Mississippi. Miss. Agr. Expt. Sta. Tech. Bul. 33, p. 27. State College. April 1951.

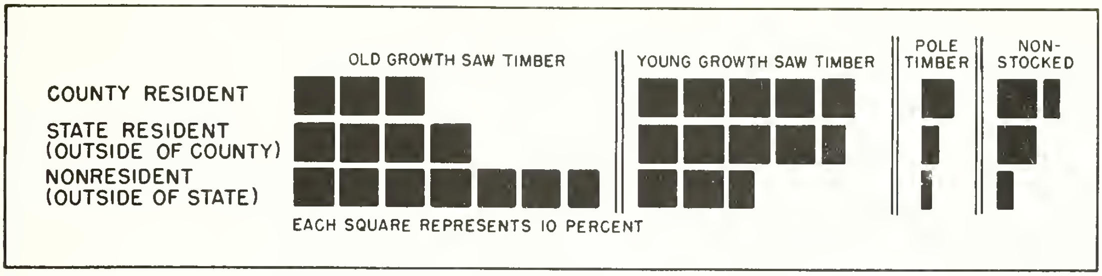


Figure 24.- Percentage distribution of acreage of timberland of resident and nonresident owners, by stand-size-class.

About 3 percent of the owners reside or have business headquarters outside the State of California. Included in these holdings are 6 percent of the privately owned land and 9 percent of the private commercial forest land.

Land of resident owners has the lowest percentage of old-growth saw-timber acreage and the highest percentage of nonstocked acreage. This is probably due to the fact that resident owners, particularly farmers and ranchers, use their land more intensively than do nonresident owners. Also, more of their old-growth timber has been cut, and the cut-over land put to nonforest uses.

Out-of-State nonresident owners, here as in the Coast Range Pine subregion, have the highest percentage of their acreage remaining as old-growth saw timber and the lowest proportion of nonstocked timberland. These out-of-State owners are keeping large holdings principally for future use. Because their land is not used intensively, much of their timber remains in its original state.

Occupation of Owners

Private owners were classified into 11 major occupational groups (tables 6 and 25). This classification reemphasizes the fact that a rather large share of the private commercial forest land is owned by persons with activities not directly related to production of timber and timber products. For example, ranchers and farmers combined own more commercial forest land than do persons now actively engaged in timber operations as a major business. Their share amounts to a third of the privately owned commercial forest land acreage. This fact stresses the need for effective farm-forestry programs to assist farmers and ranchers in managing the large acreage of timberland they control.

Considerably more commercial forest land here is controlled by timber operators than was found in the Coast Range Pine subregion. Timber operations started here sooner and were carried on on a larger scale than in the Coast Range Pine. More of the timberland in the Coast Range Pine subregion is owned by those holding it for future use.

Table 5.- Number of owners, privately owned land, and privately owned commercial forest land by residence of owner, Redwood--Douglas-fir Subregion, California, 1949

| Residence of owner | Owners | | Av. size of holding | Total land area | | Commercial forest land | |
|---|---|---|---|---|---|---|---|
| | Number | Pct. | Acres | Thousand acres | Pct. | Thousand acres | Pct. |
| Resident--in the county | 11,980 | 68.6 | 250 | 2,990 | 62.5 | 1,639 | 56.9 |
| Nonresident--outside the county (but within the State) | 5,018 | 28.7 | 301 | 1,508 | 31.6 | 993 | 34.5 |
| Nonresident--outside the State | 480 | 2.7 | 590 | 283 | 5.9 | 247 | 8.6 |
| All classified owners | 17,478 | 100.0 | 274 | 4,781 | 100.0 | 2,879 | 100.0 |
| Unclassified owners | 472 | - | 653 | 308 | - | 43 | - |
| All owners | 17,950 | - | 284 | 5,089 | - | 2,922 | - |

Operators of nontimber business enterprises hold a sizable share of the forest land. These are principally individuals and companies holding timberland for future use or for resale. They generally have fairly large holdings. Others are operators of small businesses who have acquired small tracts of timberland for various reasons.

The rest of the acreage of timberland is not heavily concentrated in any particular occupational group. It is significant, however, that forest land was owned by many different kinds of owners (table 6).

## Reasons for Acquiring Land and Plans for Future Use

Farming and ranching, residence and recreation, timber operations, and speculation were principal reasons for acquiring land in the study area. More than two-fifths of the total number of owners obtained land for farming and ranching; about a third acquired land for recreation and residence; and the remainder obtained land for resale at a profit, for timber operations, and for other miscellaneous uses and various combinations of two or more uses (tables 26, 27, and fig. 25).

Table 6.- Number of owners, acreage of privately owned land, and privately owned commercial forest land by occupation of owner, Redwood--Douglas-fir Subregion, California, 1949

| Occupation | Privately owned land | | | | Privately owned commercial forest land | | | |
|---|---|---|---|---|---|---|---|---|
| | Owners | | Land area | | Owners | | Land area | |
| | Number | Pct. | 1,000 acres | Pct. | Number | Pct. | 1,000 acres | Pct. |
| Range livestock farmer | 984 | 7.1 | 1,486 | 33.2 | 762 | 10.5 | 731 | 27.1 |
| Other farmer | 4,880 | 35.2 | 576 | 12.9 | 1,822 | 25.1 | 179 | 6.7 |
| Timber operator | 336 | 2.4 | 884 | 19.7 | 279 | 3.8 | 841 | 31.2 |
| Operator of other business | 1,929 | 13.9 | 712 | 15.9 | 1,134 | 15.6 | 476 | 17.7 |
| Professional | 790 | 5.7 | 135 | 3.0 | 501 | 6.9 | 63 | 2.3 |
| White-collar worker | 372 | 2.7 | 34 | 0.7 | 244 | 3.4 | 23 | 0.9 |
| Skilled wage earner | 1,071 | 7.7 | 59 | 1.3 | 628 | 8.6 | 39 | 1.4 |
| Unskilled wage earner | 207 | 1.5 | 16 | 0.4 | 117 | 1.6 | 9 | 0.3 |
| Housewife | 630 | 4.6 | 64 | 1.4 | 345 | 4.7 | 39 | 1.4 |
| Retired | 1,580 | 11.4 | 230 | 5.1 | 849 | 11.7 | 115 | 4.3 |
| Other | 1,086 | 7.8 | 286 | 6.4 | 588 | 8.1 | 179 | 6.7 |
| All classified owners | 13,865 | 100.0 | 4,482 | 100.0 | 7,269 | 100.0 | 2,694 | 100.0 |
| Unclassified | 4,085 | - | 607 | - | 2,548 | - | 228 | - |
| All owners | 17,950 | - | 5,089 | - | 9,817 | - | 2,922 | - |

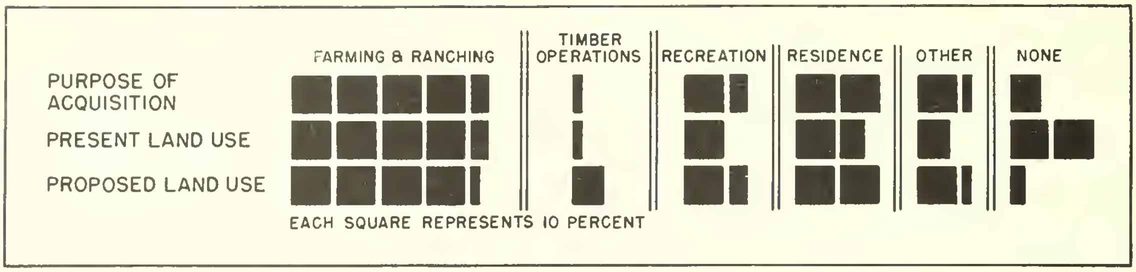


Figure 25.- Percentage distribution of owners of land by purpose of acquisition, and present and proposed land use.

A few more owners now use their land for timber operations than originally acquired land for that purpose. And there are many more who plan to cut timber on their holdings at some future time. The present brisk demand for redwood and Douglas-fir timber is stimulating operations on some of the small private timber tracts originally acquired for other reasons, principally speculation, residence, multiple use, and farming (table 28). Of 1349 owners of land who plan timber operations as a future use, 292 actually acquired their land for that purpose, and only 280 are now using their land for timber operations.

An analysis was made to determine how many owners actually use, or still intend to use, their land for the purpose for which they originally acquired it. Eighty-three percent of the owners who acquired land for single-use purposes actually followed through with their plans and placed their land in the intended use (table 30). Another 5 percent who have not yet placed their land into the use planned expect to do so at some future time. This means all but 12 percent of the owners will eventually adopt their original plans for utilization.

Relatively few (less than 10 percent) of those who acquired land for farming and ranching failed to use it for agriculture, but a small number (about 1 percent) plan to shift from farming and ranching to some other use in the future. Slightly more than two-thirds of those who acquired land for timber operations and for recreation now actually use their holdings for these purposes, and there are about 16 to 18 percent more who plan to do so in the future. Of the owners who acquired the land for residence, 75 percent are now using their holdings for that purpose, and 85 percent will eventually have their land in that use.

Many of the owners who acquired land to use for more than one purpose have either altered their original combination of uses or have not yet developed all of the enterprises planned. Some of these owners, however, still plan to eventually develop their original combinations of enterprises for their holdings.

Few (8 percent) of those who acquired holdings for speculation or with no specific purpose in mind made active use of their holdings. But many more (81 percent) plan to use their land if they retain ownership.

Figures indicate a slight downward trend in number of holdings used for farming (tables 27 and 29). There is also evidence of a shift from farming to residential use. Farm properties near urban centers are being acquired by city people and subdivided for residences. The demand for small holdings for this purpose is quite strong in certain parts of this subregion.

Many owners who originally acquired holdings for recreation have not yet developed them for this purpose. This fact, plus increased pressure from nearby population centers, will tend to augment further the number of holdings in recreational use.

# APPENDIX

## Ownership Survey Procedure

Conventional methods of obtaining data concerning ownership could not be used in this study because of the large acreage involved. Public records, especially those of assessors and tax collectors, provided much reliable basic data of the kind desired. But the existence of county plat maps showing the land of all owners in the county mapped in place made possible the development of the line-sampling technique used.25/ In utilizing these plat maps, parallel lines spaced 2 miles apart were drawn east and west on quadrangle base maps. Then intercepts of ownership boundaries, as shown on the county plat maps, were marked along these lines. The proportion of the total line traversing an ownership class was taken as the proportion of the total acreage in that particular class. The acreage obtained was an estimate of the true area within each ownership class. This acreage was further classified by measuring the intercepts of the various vegetation and timber stand classifications used in the Forest Survey.

Owners of properties traversed by the sample lines composed the ownership sample. The names of these owners were recorded on cards and all their land holdings were listed. Other related information was then obtained from the property tax rolls. These property records gave the address of the owner, and the acreage, legal description, and assessed value of each parcel of land. This information was used to classify private ownerships and land area by size and individual owners by residence.

To learn how the land was used, how and why the present owner acquired it, why he held it, and his principal occupation, each sample owner was mailed a questionnaire. These were simple, return-stamped, self-addressed questionnaire cards which contained a check list on which questions could be answered readily. Complete replies were received from about a third to half of the owners selected in each county. Information pertaining to land of nonrespondents was obtained by a field follow-up, in which key informants were questioned in local public offices and in communities in which the owners had their land.

All ownership and Forest Survey data were edited and placed on punch cards for machine tabulation. Acreages were then totaled by county, and adjusted if necessary to check with the Bureau of the Census acreages by counties.26/ Estimated acreage figures appearing in the tables were compiled and summarized by means of card tabulating equipment.

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25/ Hasel, A. A. and Adon Poli, op. cit., pp. 1-10.

26/ Areas of the United States 1940, U. S. Bureau of the Census. U. S. Govt. Print. Off., Washington, D. C.

## Accuracy of Estimate

Estimates of land areas in the various ownership categories are subject to two general types of error: (1) Nonsampling errors in mapping, reporting, canvassing, recording, measuring, and compiling the data, and (2) sampling errors which arise from taking a sample rather than making a complete inventory. Errors of the first type were kept to a minimum by frequent checking and close supervision of all phases of the work. If these nonsampling errors are negligible or compensating, then sampling errors provide measures of the reliability of the acreage estimates and can be computed by statistical methods. Magnitudes of the sampling errors depend on the intensity of the sampling and the variability of the data.

Statistics of land areas presented in this report are subject to increasing sampling errors as the class acreages decrease. A partial range of the sampling errors 27/ by area class are shown below.

| Area in class, acres | Standard error, percent |
|---|---|
| 10,000 | ± 21.0 |
| 20,000 | ± 14.5 |
| 40,000 | ± 10.5 |
| 100,000 | ± 6.5 |
| 200,000 | ± 4.5 |
| 500,000 | ± 3.0 |
| 1,000,000 | ± 2.0 |
| 2,000,000 | ± 1.5 |
| 4,000,000 | ± 1.1 |

## Definition of Terms

### Forest land classes

Forest land. Includes (a) lands which are at least 10 percent stocked by trees of any size and capable of producing timber or other wood products, or of exerting an influence on the climate or on the water regime; (b) lands from which the trees described in (a) have been removed to less than 10 percent stocking and which have not been developed for other use; (c) afforested areas; and (d) chaparral areas.

Commercial forest land. Forest land which is (a) producing, or physically capable of producing, usable crops of wood (usually saw timber), (b) economically available now or prospectively, and (c) not withdrawn from timber utilization.

Noncommercial forest land. Forest land incapable of yielding usable crops of wood products (usually saw timber) because of adverse site

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27/ For one calculated error; that is, the chances are 2 in 3 that the calculated acreages would not differ from the class acreages which would be obtained by 100-percent measurement by more than the errors shown.

conditions, or so physically inaccessible as to be permanently unavailable economically, or withdrawn from timber utilization and for special use through statute, ordinance, or administrative order.

Nonforest land. Land that does not qualify as forest land. Includes land which has never supported forest growth; land from which the forest has been removed to less than 10 percent stocking and has been developed for other use, such as grazing, agricultural, residential, or industrial; all land in thickly populated urban and suburban areas; and water classified by the Bureau of the Census as land.

Timber stand classes

Timber type. An extensive area of commercial forest land characterized by a predominant commercial conifer species28/ or group of commercial conifer species. Other vegetation (such as noncommercial conifers29/, hardwoods, and chaparral) and nonvegetation types (such as barren areas) may also occur in subordinate quantities within the same area.

a. Redwood. Areas with redwood comprising 20 percent or more of the commercial-conifer cover. Douglas-fir occurs as the principal associate of redwood throughout this type.

b. Douglas-fir. Areas with Douglas-fir comprising more than 80 percent of the commercial-conifer cover; or mixtures of Douglas-fir and the true firs in which Douglas-fir comprises 20 percent or more of the commercial-conifer cover.

c. Pine--Douglas-fir--Fir. Areas with mixtures of the commercial pines and either Douglas-fir or the true firs in which the pines, Douglas-fir, and true firs each comprise 20 percent or more of the commercial-conifer cover.

d. Fir. Areas with true firs comprising more than 80 percent of the commercial-conifer cover, or mixtures of the true firs and mountain hemlock, or western white pine, in which the true firs comprise 20 percent or more of the commercial-conifer cover.

e. Pine. Areas with ponderosa, Jeffrey, or sugar pine comprising more than 80 percent of the commercial-conifer cover.

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28/ Commercial conifer species are redwood, Douglas-fir, ponderosa pine, sugar pine, Jeffrey pine, California red fir, white fir, grand fir, incense-cedar, Port-Orford-cedar, western redcedar, Sitka spruce, western hemlock, western white pine, and mountain hemlock.

29/ Noncommercial conifers are Bishop pine, California torreya, knobcone pine, Brewer spruce, and Pacific yew.

Density classes of commercial-conifer stands on commercial forest land.

a. Dense and semidense. Commercial conifers cover 50 percent or more of the ground space.

b. Open. Commercial conifers cover from 20 to 50 percent of the ground space.

c. Very open. Commercial conifers cover from 5 to 20 percent of the ground space.

d. Nonstocked. Commercial conifers cover less than 5 percent of the ground space.

Stand-size classes

Saw-timber stands. Stands having a minimum net volume per acre of 4,000 board feet, International 1/4-inch rule, in saw-timber trees (11.0 inches d.b.h. and larger for all species).

a. Old-growth saw-timber stands. Saw-timber stands in which more than 50 percent of the net board-foot volume is in mature and overmature saw-timber trees.

b. Young-growth saw-timber stands. Saw-timber stands in which 50 percent or more of the net board-foot volume is in immature saw-timber trees.

Pole-timber stands. Stands failing to meet the saw-timber stand specifications, but at least 10 percent stocked with pole-timber and larger trees and with at least half the minimum stocking in pole-timber trees (5.0 to 10.9 inches d.b.h.).

Seedling and sapling stands. Timber stands not qualifying as either saw-timber or pole-timber stands but having at least 10 percent stocking of trees of commercial species and with at least half the minimum stocking in seedlings and saplings (0 to 4.9 inches d.b.h.).

Nonstocked areas. Areas of commercial forest land not qualifying as saw-timber, pole-timber, or seedling and sapling stands.

Tree-size classes

Pole-timber trees. Trees 5.0 inches d.b.h. and larger of commercial species that do not meet the specifications for saw-timber trees but do meet regional specifications of species, soundness, and freedom from defect.

Saw-timber trees. Trees of commercial species that contain at least one merchantable sawlog as defined by regional practice and which are at least 11.0 inches d.b.h. for all species.

Miscellaneous definitions

Annual timber mortality. The net volume removed from live saw timber or growing stock on commercial forest land during a specified year through death from natural causes.

Commercial species. Tree species considered in determining stocking and growing stock. Includes species presently or prospectively usable for commercial timber products, such as minor conifers and hardwoods.

Annual cut. The volume of live saw timber or growing stock removed from commercial forest land during a specified year as timber products and logging residue.

Cull trees. Live trees of saw-timber or pole-timber size that are unmerchantable for sawlogs now or prospectively because of defect or rot.

In commercial conifer species, a tree is considered a complete cull if less than 25 percent of the gross board-foot scale is in merchantable material. Pine logs must be at least 33-1/3 percent sound to be merchantable; other species at least 50 percent. No log scaling less than 30 board feet is considered merchantable.

In hardwood species, a tree is considered cull if less than 40 percent of the gross scale in board feet is in merchantable material. Logs must be at least 50 percent sound to be merchantable.

Trees that are culls on a board-foot basis are also considered culls on a cubic foot basis.

D.B.H. (Diameter breast height). Tree diameter in inches, outside bark, measured at 4-1/2 feet above ground.

International 1/4-inch log rule. A rule for estimating the board-foot volume of 4-foot log sections, according to the formula $V = 0.905 (0.22D^2 - 0.71D)$. The taper allowance for computing the volume in log lengths greater than 4 feet is 0.5 inch per 4-foot section. Allowance for saw kerf is 1/4-inch.

Live saw-timber volume. Net volume in board feet, International 1/4-inch rule, of live saw-timber trees.

Logging residue. The volume of live saw timber or growing stock cut or killed by logging on commercial forest land and not converted to timber products.

Net annual growth. The change during a specified year in the net volume of live saw timber or growing stock on commercial forest land resulting from natural causes.

Detailed Statistics

Table 7.- Major classes of land by type of owner, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | Total land area | | Major classes of land: Commercial forest land | | Noncommercial forest land | Nonforest land |
|---|---|---|---|---|---|---|
| | Thousand acres | Pct. | Thousand acres | Pct. | Thousand acres | Thousand acres |
| National Forest | 1,429 | 20.2 | 1,006 | 23.8 | 412 | 11 |
| Indian land | 113 | 1.6 | 103 | 2.4 | 2 | 8 |
| Other Federal | 199 | 2.8 | 98 | 2.3 | 93 | 8 |
| State Park | 61 | 0.9 | - | - | 57 | 4 |
| State Forest | 50 | 0.7 | 48 | 1.1 | 2 | (1/) |
| Tax deeded | 56 | 0.8 | 49 | 1.2 | 5 | 2 |
| Other State | 12 | 0.2 | 5 | 0.1 | 3 | 4 |
| County and municipal | 39 | 0.6 | 7 | 0.2 | 19 | 13 |
| Total public | 1,959 | 27.8 | 1,316 | 31.1 | 593 | 50 |
| Timber operating company | 765 | 10.9 | 735 | 17.3 | 12 | 18 |
| Timber holding company | 180 | 2.5 | 171 | 4.0 | 5 | 4 |
| Timber operating individual | 119 | 1.7 | 106 | 2.5 | 9 | 4 |
| Timber holding individual | 472 | 6.7 | 426 | 10.1 | 32 | 14 |
| Range livestock farming company | 101 | 1.4 | 56 | 1.3 | 21 | 24 |
| Range livestock farming individual | 1,649 | 23.4 | 782 | 18.5 | 421 | 446 |
| Other farmers | 767 | 10.9 | 219 | 5.2 | 172 | 376 |
| Recreational property owners | 291 | 4.1 | 155 | 3.7 | 100 | 36 |
| Other classified owners 2/ | 472 | 6.7 | 245 | 5.7 | 126 | 101 |
| Unclassified owners 3/ | 273 | 3.9 | 27 | 0.6 | 31 | 215 |
| Total private | 5,089 | 72.2 | 2,922 | 68.9 | 929 | 1,238 |
| All types | 7,048 | 100.0 | 4,238 | 100.0 | 1,522 | 1,288 |

1/ Less than 500 acres.

2/ All other land owners whose classification is known but does not logically fit the classes listed above. Examples are owners of land held for residential purposes only, mining claims, watersheds, and reservoir sites.

3/ Small urban, suburban, and industrial ownerships that are too small to map and classify properly, and ownerships that for other reasons cannot be classified and placed in appropriate categories.

Table 8.- Commercial forest land by timber type and by type of owner, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | Private holdings | All types | Timber type: Redwood | Douglas-fir | Pine--Douglas-fir--Fir | Fir | Pine |
|---|---|---|---|---|---|---|---|
| | Number | ------------- | Thousand acres | ------------- | | | |
| National Forest | - | 1,006 | 5 | 740 | 222 | 36 | 3 |
| Indian land | - | 103 | 9 | 94 | - | - | - |
| Other Federal | - | 98 | 27 | 70 | 1 | - | - |
| State Forest | - | 48 | 48 | - | - | - | - |
| Tax deeded | - | 49 | 31 | 16 | 1 | 1 | - |
| Other State | - | 5 | 4 | 1 | - | - | - |
| County and municipal | - | 7 | 4 | 3 | - | - | - |
| Total public | - | 1,316 | 128 | 924 | 224 | 37 | 3 |
| Timber operating company | 83 | 735 | 667 | 62 | 6 | - | - |
| Timber holding company | 141 | 171 | 135 | 33 | 1 | 2 | - |
| Timber operating individual | 196 | 106 | 67 | 36 | 2 | - | 1 |
| Timber holding individual | 1,201 | 426 | 254 | 157 | 15 | - | - |
| Range livestock farming company | 16 | 56 | 28 | 28 | - | - | - |
| Range livestock farming individual | 858 | 782 | 272 | 493 | 13 | - | 4 |
| Other farmers | 2,317 | 219 | 120 | 97 | 1 | - | 1 |
| Recreational property owners | 1,989 | 155 | 74 | 80 | 1 | - | (1/) |
| Other classified owners | 3,016 | 245 | 153 | 88 | 3 | (1/) | 1 |
| Unclassified | - | 27 | 20 | 7 | - | - | - |
| Total private | 2/9,817 | 2,922 | 1,790 | 1,081 | 42 | 2 | 7 |
| All Owners | - | 4,238 | 1,918 | 2,005 | 266 | 39 | 10 |

1/ Less than 500 acres.

2/ This figure represents only those private holdings with commercial forest land.

Table 9.- Commercial forest land by stand-size class and by type of owner, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | All classes | Stand-size class of timber | | | |
|---|---|---|---|---|---|
| | | Old-growth saw timber | Young-growth saw timber | Pole timber | Non-stocked |
| | Thousand acres | | | | |
| National Forest | 1,006 | 578 | 287 | 30 | 111 |
| Indian land | 103 | 79 | 9 | 2 | 13 |
| Other Federal | 98 | 47 | 32 | 2 | 17 |
| State Forest | 48 | 7 | 35 | 4 | 2 |
| Tax deeded | 49 | 28 | 17 | 1 | 3 |
| Other State | 5 | 3 | 2 | - | (1/) |
| County and municipal | 7 | 2 | 3 | (1/) | 2 |
| Total public | 1,316 | 744 | 385 | 39 | 148 |
| Timber operating company | 735 | 382 | 218 | 87 | 48 |
| Timber holding company | 171 | 94 | 64 | 4 | 9 |
| Timber operating individual | 106 | 56 | 39 | 2 | 9 |
| Timber holding individual | 426 | 244 | 136 | 23 | 23 |
| Range livestock farming company | 56 | 8 | 42 | 2 | 4 |
| Range livestock farming individual | 782 | 187 | 460 | 26 | 109 |
| Other farmers | 219 | 35 | 114 | 10 | 60 |
| Recreational property owners | 155 | 33 | 88 | 8 | 26 |
| Other classified owners | 245 | 37 | 138 | 19 | 51 |
| Unclassified | 27 | 1 | 18 | 2 | 6 |
| Total private | 2,922 | 1,077 | 1,317 | 183 | 345 |
| All owners | 4,238 | 1,821 | 1,702 | 222 | 493 |

1/ Less than 500 acres.

Table 10.--Commercial forest land by density of timber stand and by type of owner, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | All densities | Density of timber stand: Dense | Semi-dense | Open | Very open | Non-stocked |
|---|---|---|---|---|---|---|
| | ----- | ----- | Thousand acres | ----- | ----- | ----- |
| National Forest | 1,006 | 270 | 297 | 234 | 94 | 111 |
| Indian land | 103 | 21 | 29 | 20 | 20 | 13 |
| Other Federal | 98 | 13 | 24 | 35 | 9 | 17 |
| State Forest | 48 | 11 | 12 | 15 | 8 | 2 |
| Tax deeded | 49 | 3 | 22 | 15 | 6 | 3 |
| Other State | 5 | 3 | 1 | 1 | (1/) | (1/) |
| County and municipal | 7 | 1 | 3 | 1 | - | 2 |
| Total public | 1,316 | 322 | 388 | 321 | 137 | 148 |
| Timber operating company | 735 | 204 | 232 | 143 | 108 | 48 |
| Timber holding company | 171 | 43 | 58 | 47 | 14 | 9 |
| Timber operating individual | 106 | 26 | 38 | 23 | 10 | 9 |
| Timber holding individual | 426 | 111 | 145 | 106 | 41 | 23 |
| Range livestock farming company | 56 | 11 | 17 | 16 | 8 | 4 |
| Range livestock farming individual | 782 | 133 | 207 | 217 | 116 | 109 |
| Other farmers | 219 | 26 | 40 | 56 | 37 | 60 |
| Recreational property owners | 155 | 16 | 39 | 46 | 28 | 26 |
| Other classified owners | 245 | 28 | 49 | 73 | 44 | 51 |
| Unclassified | 27 | 3 | 5 | 9 | 4 | 6 |
| Total private | 2,922 | 601 | 830 | 736 | 410 | 345 |
| All owners | 4,238 | 923 | 1,218 | 1,057 | 547 | 493 |

1/ Less than 500 acres.

Table 11.- Net volume of live saw timber on commercial forest land by type of owner, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | Area | Volume | Average volume per acre |
|---|---|---|---|
| | Thousand acres | Million bd. ft. | Bd. ft. |
| National Forest | 1,006 | 32,559 | 32,365 |
| Indian land | 103 | 3,551 | 34,476 |
| Other Federal | 98 | 3,148 | 32,122 |
| State Forest | 48 | 1,260 | 26,250 |
| Tax deeded | 49 | 1,461 | 29,816 |
| Other State | 5 | 366 | 73,200 |
| County and municipal | 7 | 164 | 23,429 |
| Total public | 1,316 | 42,509 | 32,302 |
| Timber operating company | 735 | 31,374 | 42,686 |
| Timber holding company | 171 | 6,540 | 38,246 |
| Timber operating individual | 106 | 3,929 | 37,066 |
| Timber holding individual | 426 | 17,634 | 41,394 |
| Range livestock farming company | 56 | 1,590 | 28,393 |
| Range livestock farming individual | 782 | 20,768 | 26,558 |
| Other farmers | 219 | 4,361 | 19,913 |
| Recreational property owners | 155 | 3,446 | 22,232 |
| Other classified owners | 245 | 4,894 | 19,976 |
| Unclassified | 27 | 508 | 18,815 |
| Total private | 2,922 | 95,044 | 32,527 |
| All owners | 4,238 | 137,553 | 32,457 |

Table 12.- Number of holdings, privately owned land, and privately owned commercial forest land by major land use, Redwood--Douglas-fir Subregion, California, 1949

| Major land use | Holdings | | | Total land area | | Commercial forest land | |
|---|---|---|---|---|---|---|---|
| | | | | | | Pct. of total acreage | Pct. of all land in each major use |
| | Number | Pct. | Av. size acres | Thousand acres | Pct. | | |
| Timber operations | 375 | 2.1 | 2,051 | 769 | 16.0 | 25.4 | 95.4 |
| Farming and ranching | 7,697 | 43.0 | 280 | 2,159 | 44.9 | 29.1 | 39.0 |
| Recreation | 1,848 | 10.3 | 87 | 161 | 3.3 | 3.2 | 57.8 |
| Residence | 3,017 | 16.9 | 33 | 99 | 2.1 | 2.0 | 57.6 |
| Other | 309 | 1.7 | 227 | 70 | 1.5 | 1.4 | 60.0 |
| Timber operations and farming | 142 | 0.8 | 2,873 | 408 | 8.5 | 9.4 | 66.2 |
| Farming and recreation | 233 | 1.3 | 305 | 71 | 1.5 | 0.9 | 36.6 |
| Other combinations of 2 or more uses | 584 | 3.3 | 625 | 365 | 7.6 | 8.8 | 69.6 |
| No use | 3,693 | 20.6 | 190 | 701 | 14.6 | 19.8 | 81.6 |
| All classified owners | 17,898 | 100.0 | 268 | 4,803 | 100.0 | 100.0 | 60.2 |
| Unclassified | 52 | - | - | 286 | - | - | 11.2 |
| All owners | 17,950 | - | - | 5,089 | - | - | 57.4 |

Table 13.- Private land holdings by major land use and by size of holding, Redwood--Douglas-fir Subregion, 1949

| Size of holding | All uses | Major land use | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Timber operations | Farming and ranching | Recreation | Residence | Other uses and combinations of 2 or more uses | No use | Unclassi-fied |
| Acres | Number of holdings | | | | | | | |
| 1 - 179 | 14,992 | 207 | 6,042 | 1,683 | 2,951 | 920 | 3,138 | 51 |
| 180 - 379 | 1,322 | 66 | 704 | 103 | 32 | 107 | 310 | - |
| 380 - 699 | 665 | 28 | 378 | 43 | 27 | 69 | 120 | - |
| 700 - 1,299 | 402 | 21 | 247 | 13 | 6 | 47 | 67 | 1 |
| 1,300 - 2,599 | 305 | 21 | 194 | 5 | - | 55 | 30 | - |
| 2,600 - 4,999 | 147 | 13 | 91 | 1 | 1 | 31 | 10 | - |
| 5,000 - 9,999 | 67 | 5 | 28 | - | - | 22 | 12 | - |
| 10,000 - 19,999 | 35 | 6 | 10 | - | - | 13 | 6 | - |
| 20,000 - 29,999 | 5 | 2 | 2 | - | - | 1 | - | - |
| 30,000 - 49,999 | 5 | 3 | - | - | - | 2 | - | - |
| 50,000 and over | 5 | 3 | 1 | - | - | 1 | - | - |
| All owners | 17,950 | 375 | 7,697 | 1,848 | 3,017 | 1,268 | 3,693 | 52 |

Table 14.- Number of holdings, privately owned land, and privately owned commercial forest land, by size of holding, Redwood--Douglas-fir Subregion, California, 1949

| Size of holding | Holdings | | Total land area | | Comm'l. forest land | |
|---|---|---|---|---|---|---|
| | | | | | Percent of total acreage | Pct. of all land in each size class |
| Acres | Number | Pct. | Thousand acres | Pct. | | |
| 1 - 179 | 14,992 | 83.5 | 814 | 16.9 | 14.1 | 50.3 |
| 180 - 379 | 1,322 | 7.4 | 399 | 8.3 | 7.1 | 51.6 |
| 380 - 699 | 665 | 3.7 | 454 | 9.5 | 7.9 | 50.2 |
| 700 - 1,299 | 402 | 2.2 | 410 | 8.5 | 7.5 | 52.7 |
| 1,300 - 2,599 | 305 | 1.7 | 616 | 12.8 | 10.6 | 50.0 |
| 2,600 - 4,999 | 147 | 0.8 | 522 | 10.8 | 10.2 | 56.5 |
| 5,000 - 9,999 | 67 | 0.4 | 417 | 8.7 | 8.4 | 58.3 |
| 10,000 - 19,999 | 35 | 0.2 | 488 | 10.1 | 12.0 | 70.9 |
| 20,000 - 29,999 | 5 | | 106 | 2.2 | 2.7 | 72.6 |
| 30,000 - 49,999 | 5 | 0.1 | 140 | 2.9 | 4.7 | 97.9 |
| 50,000 and over | 5 | | 447 | 9.3 | 14.8 | 95.8 |
| All holdings | 17,950 | 100.0 | 4,813 | 100.0 | 100.0 | 60.1 |

Table 15.- Number of holdings and privately owned commercial forest land by timber type and by size of holding, Redwood--Douglas-fir Subregion, California, 1949

| Size of holding 1/ | Holdings | All types | Timber type: Redwood | Douglas-fir | Pine--Douglas-fir--Fir | Fir | Pine |
|---|---|---|---|---|---|---|---|
| Acres | Number | Thousand acres | | | | | |
| 1 - 179 | 7,614 | 409 | 217 | 184 | 7 | - | 1 |
| 180 - 379 | 935 | 206 | 99 | 103 | 3 | - | 1 |
| 380 - 699 | 486 | 228 | 109 | 115 | 4 | (2/) | - |
| 700 - 1,299 | 303 | 216 | 102 | 106 | 7 | - | 1 |
| 1,300 - 2,599 | 242 | 308 | 148 | 155 | 5 | - | (2/) |
| 2,600 - 4,999 | 126 | 295 | 156 | 138 | 1 | - | - |
| 5,000 - 9,999 | 62 | 243 | 116 | 116 | 9 | - | 2 |
| 10,000 - 19,999 | 34 | 346 | 233 | 110 | 1 | - | 2 |
| 20,000 - 29,999 | 5 | 77 | 53 | 21 | 3 | - | - |
| 30,000 - 49,999 | 5 | 137 | 131 | 4 | 2 | - | - |
| 50,000 and over | 5 | 428 | 406 | 20 | (2/) | 2 | - |
| All classified holdings | 9,817 | 2,893 | 1,770 | 1,072 | 42 | 2 | 7 |
| Unclassified | - | 29 | 20 | 9 | (2/) | - | - |
| Total acreage | - | 2,922 | 1,790 | 1,081 | 42 | 2 | 7 |

1/ Size of holding is based on total acreage of all kinds of land owned, only part of which may be commercial forest land.
2/ Less than 500 acres.

Table 16.- Privately owned commercial forest land by stand-size class and by size of holding, Redwood--Douglas-fir Subregion, California, 1949

| Size of holding | All classes | Stand-size class of timber: Old-growth saw timber | Young-growth saw timber | Pole timber | Non-stocked |
|---|---|---|---|---|---|
| Acres | Thousand acres | | | | |
| 1 - 179 | 409 | 123 | 208 | 17 | 61 |
| 180 - 379 | 206 | 62 | 96 | 8 | 40 |
| 380 - 699 | 228 | 70 | 113 | 7 | 38 |
| 700 - 1,299 | 216 | 59 | 111 | 12 | 34 |
| 1,300 - 2,599 | 308 | 120 | 133 | 10 | 45 |
| 2,600 - 4,999 | 295 | 94 | 153 | 15 | 33 |
| 5,000 - 9,999 | 243 | 71 | 129 | 14 | 29 |
| 10,000 - 19,999 | 346 | 145 | 162 | 17 | 22 |
| 20,000 - 29,999 | 77 | 48 | 20 | 5 | 4 |
| 30,000 - 49,999 | 137 | 99 | 26 | 5 | 7 |
| 50,000 and over | 428 | 185 | 146 | 71 | 26 |
| All classified holdings | 2,893 | 1,076 | 1,297 | 181 | 339 |
| Unclassified | 29 | 1 | 20 | 2 | 6 |
| Total acreage | 2,922 | 1,077 | 1,317 | 183 | 345 |

Table 17.- Privately owned commercial forest land by density of timber stand and by size of holding, Redwood--Douglas-fir Subregion, California, 1949

| Size of holding | All densities | Density of timber stand: Dense | Semi-dense | Open | Very open | Non-stocked |
|---|---|---|---|---|---|---|
| Acres | Thousand acres | | | | | |
| 1 - 179 | 409 | 76 | 100 | 115 | 57 | 61 |
| 180 - 379 | 206 | 29 | 57 | 50 | 30 | 40 |
| 380 - 699 | 228 | 39 | 54 | 66 | 31 | 38 |
| 700 - 1,299 | 216 | 29 | 59 | 61 | 33 | 34 |
| 1,300 - 2,599 | 308 | 54 | 93 | 76 | 40 | 45 |
| 2,600 - 4,999 | 295 | 54 | 81 | 87 | 40 | 33 |
| 5,000 - 9,999 | 243 | 54 | 59 | 62 | 39 | 29 |
| 10,000 - 19,999 | 346 | 90 | 111 | 78 | 45 | 22 |
| 20,000 - 29,999 | 77 | 29 | 27 | 11 | 6 | 4 |
| 30,000 - 49,999 | 137 | 41 | 51 | 30 | 8 | 7 |
| 50,000 and over | 428 | 102 | 132 | 90 | 78 | 26 |
| All classified holdings | 2,893 | 597 | 824 | 726 | 407 | 339 |
| Unclassified | 29 | 4 | 6 | 10 | 3 | 6 |
| Total acreage | 2,922 | 601 | 830 | 736 | 410 | 345 |

Table 18.- Net volume of live saw timber on privately owned commercial forest land by size of holding, Redwood--Douglas-fir Subregion, California, 1949

| Size of holding | Area | Volume | Average volume per acre |
|---|---|---|---|
| Acres | Thousand acres | Million bd. ft. | Bd. ft. |
| 1 - 179 | 409 | 11,444 | 27,980 |
| 180 - 379 | 206 | 5,304 | 25,748 |
| 380 - 699 | 228 | 6,166 | 27,044 |
| 700 - 1,299 | 216 | 5,531 | 25,606 |
| 1,300 - 2,599 | 308 | 9,863 | 32,023 |
| 2,600 - 4,999 | 295 | 9,379 | 31,793 |
| 5,000 - 9,999 | 243 | 7,262 | 29,885 |
| 10,000 - 19,999 | 346 | 12,969 | 37,483 |
| 20,000 - 29,999 | 77 | 4,082 | 53,013 |
| 30,000 - 49,999 | 137 | 6,696 | 48,876 |
| 50,000 and over | 428 | 15,797 | 36,909 |
| All classified holdings | 2,893 | 94,493 | 32,663 |
| Unclassified | 29 | 551 | 19,000 |
| Total acreage | 2,922 | 95,044 | 32,527 |

Table 19.- Percentage distribution of privately owned land by type of owner and by size of holding, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | All sizes | | Size of holding (acres) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1-179 | 180-379 | 380-699 | 700-1299 | 1300-2599 | 2600-4999 | 5000-9999 | 10,000-19,999 | 20,000-29,999 | 30,000-49,999 | 50,000 & over |
| | 1,000 acres | Pct. | Percent | | | | | | | | | | |
| Timber operating company | 765 | 100.0 | 0.9 | 0.3 | 0.5 | 1.7 | 3.2 | 5.0 | 3.4 | 11.4 | 6.9 | 8.6 | 58.1 |
| Timber holding company | 180 | 100.0 | 1.6 | 1.1 | 5.6 | 5.6 | 8.3 | 18.3 | 17.8 | 21.7 | - | 18.3 | 1.7 |
| Timber operating individual | 119 | 100.0 | 8.4 | 19.2 | 10.2 | 9.2 | 11.8 | 6.7 | 10.9 | 23.6 | - | - | - |
| Timber holding individual | 472 | 100.0 | 23.5 | 11.9 | 9.5 | 11.0 | 13.0 | 5.7 | 6.6 | 10.2 | - | 8.6 | - |
| Range livestock farming company | 101 | 100.0 | - | - | 2.0 | 1.0 | 6.0 | 19.8 | 25.7 | 45.5 | - | - | - |
| Range livestock farming individual | 1,649 | 100.0 | 3.2 | 3.5 | 8.2 | 11.8 | 22.1 | 20.5 | 14.6 | 12.9 | 3.2 | - | - |
| Other farmers | 767 | 100.0 | 40.0 | 20.0 | 15.6 | 10.8 | 8.9 | 2.7 | 2.0 | - | - | - | - |
| Recreational property owners | 291 | 100.0 | 45.7 | 17.5 | 17.9 | 8.6 | 7.6 | 2.4 | 0.3 | - | - | - | - |
| Other classified owners | 467 | 100.0 | 40.7 | 11.6 | 15.6 | 4.1 | 8.8 | 6.4 | 6.8 | 6.0 | - | - | - |
| All classified owners | 4,811 | 100.0 | 16.9 | 8.3 | 9.5 | 8.5 | 12.8 | 10.8 | 8.7 | 10.1 | 2.2 | 2.9 | 9.3 |

Table 20.- Number of holdings and privately owned land by operating tenure and by type of owner, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | All tenures | | Operating tenure | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Owner-operated | | Leased | | Part owner-operated & part leased | | Idle | |
| | Holdings | Land area | Holdings | Land area | Holdings | Land area | Holdings | Land area | Holdings | Land area |
| | Number | 1,000 acres | Number | 1,000 acres | Number | 1,000 acres | Number | 1,000 acres | Number | 1,000 acres |
| Timber operating company | 116 | 765 | 111 | 722 | - | - | 1 | 26 | 4 | 17 |
| Timber holding company | 141 | 180 | 9 | 22 | 8 | 5 | 3 | 35 | 121 | 118 |
| Timber operating individual | 220 | 119 | 214 | 110 | 3 | 8 | - | - | 3 | 1 |
| Timber holding individual | 1,236 | 472 | 71 | 83 | 52 | 51 | 2 | 4 | 1,111 | 334 |
| Range livestock farming company | 17 | 101 | 15 | 76 | 1 | 23 | 1 | 2 | - | - |
| Range livestock farming individual | 1,118 | 1,646 | 992 | 1,389 | 75 | 132 | 41 | 110 | 10 | 15 |
| Other farmers | 6,327 | 760 | 5,584 | 618 | 573 | 116 | 117 | 21 | 53 | 5 |
| Recreational property owners | 2,905 | 283 | 2,004 | 185 | 69 | 10 | 57 | 15 | 775 | 73 |
| Other classified owners | 5,564 | 458 | 3,318 | 181 | 564 | 96 | 66 | 43 | 1,616 | 138 |
| All classified owners | 17,644 | 4,784 | 12,318 | 3,386 | 1,345 | 441 | 288 | 256 | 3,693 | 701 |
| Unclassified | 306 | 305 | - | - | - | - | - | - | - | - |
| All owners | 17,950 | 5,089 | - | - | - | - | - | - | - | - |

Table 21.- Number of holdings and privately owned land by method of acquisition and by type of owner, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | All methods | | Method of acquisition: Purchase | | Homestead | | Inheritance and gift | | Other methods and combinations of 2 or more methods | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Holdings | Land area | Holdings | Land area | Holdings | Land area | Holdings | Land area | Holdings | Land area |
| | Number | 1,000 acres | Number | 1,000 acres | Number | 1,000 acres | Number | 1,000 acres | Number | 1,000 acres |
| Timber operating company | 116 | 765 | 115 | 761 | - | - | 1 | 4 | - | - |
| Timber holding company | 141 | 180 | 64 | 150 | - | - | 57 | 11 | 20 | 19 |
| Timber operating individual | 218 | 118 | 182 | 107 | 10 | 1 | 10 | 4 | 16 | 6 |
| Timber holding individual | 1,230 | 470 | 885 | 370 | 38 | 6 | 228 | 71 | 79 | 23 |
| Range livestock farming company | 17 | 101 | 14 | 93 | - | - | 2 | 2 | 1 | 6 |
| Range livestock farming individual | 1,116 | 1,646 | 805 | 1,185 | 17 | 11 | 172 | 270 | 122 | 180 |
| Other farmers | 6,298 | 760 | 4,964 | 544 | 70 | 10 | 919 | 151 | 345 | 55 |
| Recreational property owners | 2,945 | 291 | 2,597 | 242 | 34 | 5 | 237 | 36 | 77 | 8 |
| Other classified owners | 5,665 | 471 | 4,706 | 312 | 57 | 8 | 681 | 79 | 221 | 72 |
| All classified owners | 17,746 | 4,802 | 14,332 | 3,764 | 226 | 41 | 2,307 | 628 | 881 | 369 |
| Unclassified | 204 | 287 | - | - | - | - | - | - | - | - |
| All owners | 17,950 | 5,089 | - | - | - | - | - | - | - | - |

Table 22.- Number of holdings and privately owned commercial forest land by method of acquisition and by type of owner, Redwood--Douglas-fir Subregion, California, 1949

| Type of owner | All methods | | Method of acquisition | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Purchase | | Homestead | | Inheritance and gift | | Other methods and combinations of 2 or more methods | |
| | Holdings | Land area | Holdings | Land area | Holdings | Land area | Holdings | Land area | Holdings | Land area |
| | Number | 1,000 acres | Number | 1,000 acres | Number | 1,000 acres | Number | 1,000 acres | Number | 1,000 acres |
| Timber operating company | 83 | 735 | 82 | 731 | - | - | 1 | 4 | - | - |
| Timber holding company | 141 | 171 | 64 | 144 | - | - | 57 | 9 | 20 | 18 |
| Timber operating individual | 194 | 106 | 165 | 96 | 9 | 1 | 10 | 4 | 10 | 5 |
| Timber holding individual | 1,195 | 424 | 861 | 334 | 34 | 5 | 221 | 63 | 79 | 22 |
| Range livestock farming company | 16 | 56 | 14 | 53 | - | - | 1 | 1 | 1 | 2 |
| Range livestock farming individual | 854 | 781 | 615 | 574 | 16 | 5 | 123 | 114 | 100 | 88 |
| Other farmers | 2,295 | 217 | 1,729 | 153 | 64 | 7 | 324 | 35 | 178 | 22 |
| Recreational property owners | 1,985 | 155 | 1,749 | 131 | 34 | 4 | 170 | 14 | 32 | 6 |
| Other classified owners | 3,010 | 245 | 2,455 | 165 | 57 | 7 | 341 | 38 | 157 | 35 |
| All classified owners | 9,773 | 2,890 | 7,734 | 2,381 | 214 | 29 | 1,248 | 282 | 577 | 198 |
| Unclassified | 44 | 32 | - | - | - | - | - | - | - | - |
| All owners | 9,817 | 2,922 | - | - | - | - | - | - | - | - |

Table 23.- Privately owned land by method of acquisition and by size of holding, Redwood--Douglas-fir Subregion, California, 1949

| Size of holding | All methods | Method of acquisition | | | |
|---|---|---|---|---|---|
| | | Purchase | Home-stead | Inheri-tance & gift | Other methods and combinations of 2 or more methods |
| Acres | Thousand acres | | | | |
| 1 - 179 | 807 | 603 | 27 | 137 | 40 |
| 180 - 379 | 397 | 276 | 5 | 78 | 38 |
| 380 - 699 | 451 | 324 | 7 | 71 | 49 |
| 700 - 1,299 | 409 | 293 | 1 | 63 | 52 |
| 1,300 - 2,599 | 614 | 467 | 1 | 92 | 54 |
| 2,600 - 4,999 | 522 | 407 | - | 51 | 64 |
| 5,000 - 9,999 | 417 | 301 | - | 76 | 40 |
| 10,000 - 19,999 | 488 | 407 | - | 50 | 31 |
| 20,000 - 29,999 | 106 | 96 | - | 10 | - |
| 30,000 - 49,999 | 140 | 140 | - | - | - |
| 50,000 and over | 447 | 445 | - | - | 2 |
| All classified owners | 4,798 | 3,759 | 41 | 628 | 370 |
| Unclassified | 291 | - | - | - | - |
| Total acreage | 5,089 | - | - | - | - |

Table 24.- Privately owned commercial forest land by stand-size class and by residence of owner, Redwood--Douglas-fir Subregion, California, 1949

| Residence of owner | All classes | Stand-size class of timber: Old-growth saw timber | Young-growth saw timber | Pole timber | Non-stocked |
|---|---|---|---|---|---|
| | ---------- Thousand acres ---------- | | | | |
| Resident--in the county | 1,639 | 500 | 778 | 128 | 233 |
| Nonresident--outside the county (but within the State) | 993 | 405 | 449 | 46 | 93 |
| Nonresident--outside the State | 247 | 166 | 65 | 6 | 10 |
| All classified owners | 2,879 | 1,071 | 1,292 | 180 | 336 |
| Unclassified | 43 | 6 | 25 | 3 | 9 |
| All owners | 2,922 | 1,077 | 1,317 | 183 | 345 |

Table 25.- Privately owned commercial forest land by stand-size class and by occupation of owner, Redwood--Douglas-fir Subregion, California, 1949

| Occupation | All classes | Stand-size class of timber: Old-growth saw timber | Young-growth saw timber | Pole timber | Non-stocked |
|---|---|---|---|---|---|
| | ------------ | ------------ | Thousand acres | ------------ | ------------ |
| Range livestock farmer | 731 | 170 | 442 | 26 | 93 |
| Other farmer | 179 | 33 | 93 | 7 | 46 |
| Timber operator | 841 | 438 | 257 | 89 | 57 |
| Operator of other business | 476 | 210 | 199 | 22 | 45 |
| Professional | 63 | 17 | 30 | 4 | 12 |
| White-collar worker | 23 | 6 | 10 | 1 | 6 |
| Skilled wage earner | 39 | 12 | 20 | 3 | 4 |
| Unskilled wage earner | 9 | 2 | 5 | 1 | 1 |
| Housewife | 39 | 13 | 16 | 2 | 8 |
| Retired | 115 | 35 | 53 | 5 | 22 |
| Other | 179 | 74 | 73 | 11 | 21 |
| All classified owners | 2,694 | 1,010 | 1,198 | 171 | 315 |
| Unclassified | 228 | 67 | 119 | 12 | 30 |
| All owners | 2,922 | 1,077 | 1,317 | 183 | 345 |

Table 26.- Number of ownerships, total area of privately owned land, and privately owned commercial forest land by purpose of acquisition, Redwood--Douglas-fir Subregion, California, 1949

| Purpose of acquisition | All private land | | | | Commercial forest land | |
|---|---|---|---|---|---|---|
| | Ownerships | | Land area | | Land area | |
| | Number | Pct. | Thousand acres | Pct. | Thousand acres | Pct. |
| Timber operations | 336 | 1.9 | 775 | 16.4 | 739 | 26.0 |
| Sell timber and then farm or graze land | 117 | 0.7 | 90 | 1.9 | 64 | 2.2 |
| Farming and ranching | 7,598 | 43.5 | 2,174 | 46.0 | 851 | 29.9 |
| Recreation | 2,349 | 13.4 | 219 | 4.6 | 122 | 4.3 |
| Residence | 3,421 | 19.6 | 105 | 2.2 | 60 | 2.1 |
| Resell at a profit | 1,546 | 8.9 | 384 | 8.1 | 337 | 11.8 |
| Other | 603 | 3.5 | 205 | 4.3 | 144 | 5.1 |
| Combinations of 2 or more | 1,487 | 8.5 | 778 | 16.5 | 528 | 18.6 |
| All classified ownerships | 17,457 | 100.0 | 4,730 | 100.0 | 2,845 | 100.0 |
| Unclassified | 493 | - | 359 | - | 76 | - |
| All ownerships | 17,950 | - | 5,089 | - | 2,921 | - |

Table 27.- Private land holdings by purpose of acquisition, by present land use, and by proposed land use, Redwood--Douglas-fir Subregion, California, 1949

| Major land use | Purpose of acquisition | | Present land use | | Proposed land use | |
|---|---|---|---|---|---|---|
| | Number | Pct. | Number | Pct. | Number | Pct. |
| Timber operations | 336 | 1.9 | 375 | 2.1 | 1/ 1,349 | 7.6 |
| Farming and ranching | 7,715 | 44.2 | 7,697 | 43.0 | 7,605 | 42.6 |
| Recreation | 2,349 | 13.5 | 1,848 | 10.3 | 2,330 | 13.0 |
| Residence | 3,421 | 19.6 | 3,017 | 16.9 | 3,635 | 20.3 |
| Other uses and combinations of 2 or more uses | 2,090 | 12.0 | 1,268 | 7.1 | 2,207 | 12.4 |
| No planned use | 1,546 | 8.8 | 2/ 3,693 | 20.6 | 730 | 4.1 |
| All classified owners | 17,457 | 100.0 | 17,898 | 100.0 | 17,856 | 100.0 |
| Unclassified | 493 | - | 52 | - | 94 | - |
| All owners | 17,950 | - | 17,950 | - | 17,950 | - |

1/ See table 28 for breakdown of this group by present land use and by purpose of acquisition.
2/ See table 29 for breakdown of this group by purpose of acquisition.

Table 28.- Land holdings of 1,349 owners who plan timber operations as a future use, by present land use and by purpose of acquisition, Redwood--Douglas-fir Subregion, California, 1949

| Major land use classes | Present land use | | Purpose of acquisition | |
|---|---|---|---|---|
| | Number | Pct. | Number | Pct. |
| Timber operations | 280 | 20.7 | 292 | 21.6 |
| Farming and ranching | 5 | 0.4 | 24 | 1.8 |
| Recreation | 5 | 0.4 | 11 | 0.8 |
| Residence | 22 | 1.6 | 39 | 2.9 |
| Other uses and combinations of 2 or more uses | 9 | 0.7 | 99 | 7.3 |
| No planned use | 1,028 | 76.2 | 1/835 | 62.0 |
| Unclassified | - | - | 49 | 3.6 |
| Totals | 1,349 | 100.0 | 1,349 | 100.0 |

1/ These were acquired principally for speculative purposes.

Table 29.- Land holdings of 3,693 owners reporting no present planned use of their land, by purpose of acquisition and by future land use, Redwood--Douglas-fir Subregion, California, 1949

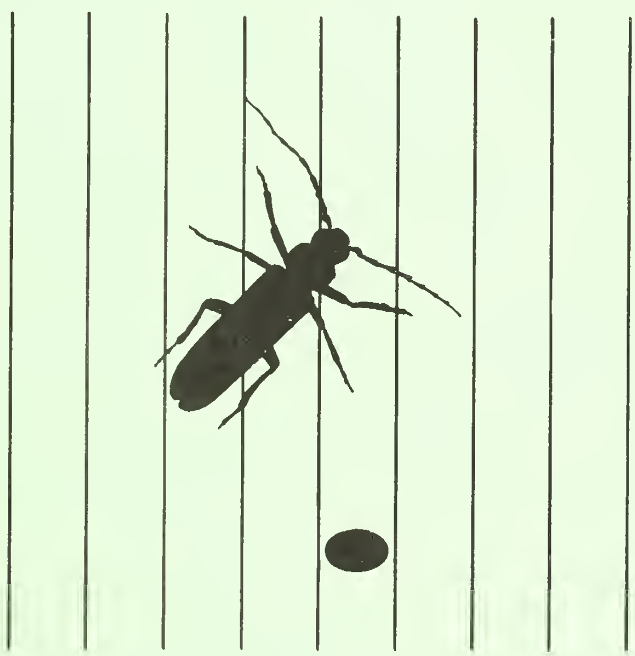
| Major land use classes | Purpose of acquisition | | Future land use | |
|---|---|---|---|---|
| | Number | Pct. | Number | Pct. |
| Timber operations | 79 | 2.1 | 1,026 | 27.8 |
| Farming and ranching | 303 | 8.2 | 192 | 5.2 |
| Recreation | 616 | 16.7 | 614 | 16.6 |
| Residence | 446 | 12.1 | 600 | 16.3 |
| Other uses and combinations of 2 or more uses | 451 | 12.2 | 559 | 15.1 |
| No planned use | 1,427 | 38.7 | 702 | 19.0 |
| Unclassified | 371 | 10.0 | - | - |
| Total | 3,693 | 100.0 | 3,693 | 100.0 |

Table 30.- Private land holdings by original purpose of acquisition, and by present and proposed use of land within each original group of holdings, Redwood--Douglas-Fir Subregion, California, 1949

| Major land use | Original purpose of acquisition | | Present land use of the original groups | | Proposed land use of the original groups | |
|---|---|---|---|---|---|---|
| | Number | Pct. | Number | Pct. | Number | Pct. |
| Timber operations | 336 | 100.0 | 229 | 68.2 | 291 | 86.6 |
| Farming and ranching | 7,715 | 100.0 | 7,068 | 91.6 | 7,020 | 91.0 |
| Recreation | 2,349 | 100.0 | 1,625 | 69.2 | 1,999 | 85.1 |
| Residence | 3,421 | 100.0 | 2,572 | 75.2 | 2,898 | 84.7 |
| All holdings with one classified use | 13,821 | 100.0 | 11,494 | 83.2 | 12,208 | 88.3 |
| Other uses and combinations of 2 or more uses | 2,090 | 100.0 | 758 | 36.3 | 985 | 47.1 |
| No planned use | 1,546 | 100.0 | 1,427 | 92.3 | 290 | 18.8 |
| All classified holdings | 17,457 | 100.0 | 13,679 | 78.4 | 13,483 | 77.2 |
| Unclassified | 493 | - | - | - | - | - |
| All holdings | 17,950 | - | - | - | - | - |

# *Arhopalus productus* (Lec.)
# A BORER IN NEW BUILDINGS

C. B. EATON
R. L. LYON



TECHNICAL PAPER No. 11
AUGUST 1955

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M. JEMISON, DIRECTOR

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

Technical Paper No. 11 August 1955

# *ARHOPALUS PRODUCTUS* (LEC.), A BORER IN NEW BUILDINGS

By C. B. Eaton and R. L. Lyon

Entomologists, Division of Forest Insect Research

The California Forest and Range Experiment Station is maintained at Berkeley, California, by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of California.

Agriculture-Berkeley

CONTENTS

# ARHOPALUS PRODUCTUS (LEC.), A BORER IN NEW BUILDINGS

By C. B. Eaton and R. L. Lyon

Arhopalus productus (Lec.) is a wood-boring beetle that infests dead or dying coniferous trees. The species has been known for more than a century but for many years has remained in relative obscurity. Since the 1930's, however, the borer has gained considerable notoriety on the West Coast because of its ability to complete development and emerge from infested lumber in new buildings. Reports from lumber suppliers, building contractors, and owners of new homes indicate that the source of most of the damage is Douglas-fir lumber cut from fire-killed, insect-killed, and windthrown trees.

The damage in buildings consists mainly of emergence holes made by the newly formed adult beetles when they complete their life cycle and bore out of the wood. Their borings are rarely, if ever, extensive enough to seriously weaken a structure, and the insect does not reinfest the lumber. But, when the beetles emerge through hardwood flooring, plasterboard on walls or ceilings, composition roofing, or other materials covering infested wood, the holes that they leave are unsightly. Furthermore, the holes are sometimes difficult and costly to repair, and often are a source of great concern to building owners.

Entomologists and foresters are often confronted with requests from the building industry and from home owners for information about the habits and control of the borer. This article has been prepared to help in providing answers to these inquiries. It brings together from the literature and from unpublished records in the files of the California Forest and Range Experiment Station what is known about this insect.

## THE INSECT

Arhopalus productus belongs to the long-horned beetle or roundheaded borer family, Cerambycidae. The species was described by LeConte (9) in 1850 from a single specimen taken in Oregon. It was originally placed in the genus Criocephalus; however, in 1940, Linsley (10) found that Criocephalus and Arhopalus were synonymous, and clarified the priority of Arhopalus. According to Craighead (2), Arhopalus (Criocephalus), Asemum, and Megasemum (Nothorhina) are closely related genera, inseparable in the larval stage on the basis of generic characters.

The adult is a narrow, black beetle from 3/4 to 1 1/4 inches long (fig. 1, A). The larva is yellowish-white, and when mature is about 1 1/2 inches long (fig. 1, B). Characters for separating the larva from closely related species are given by Craighead. The most distinctive are the caudal spines on the ninth abdominal segment, which are acutely conical in shape and slightly incurved toward each other. The pupa is similar to the pupae of other members of this group except that Arhopalus productus has a sparse, whitish pubescence on the prothorax.

## RANGE

The borer is distributed throughout most of western United States and western Canada. Some authors refer to its range as being the Rocky Mountains and Pacific Coast regions (2, 3). Essig (4) lists its occurrence in New Mexico, Colorado, California, Oregon, Washington, and British Columbia. Unpublished records show that various workers have collected the insect in California, Oregon, and Montana. The literature also records specific collections from Alberta (1), Washington (11), Utah (8, 11) and Colorado (11).

## HOSTS

The principal host of Arhopalus productus is Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco). This is the host most commonly listed in the literature (2, 4, 6); moreover, most reports of damage in buildings by this insect show Douglas-fir to be the source of infestation. The borer is also recorded as breeding in pines (Pinus spp.) and true firs (Abies spp.), but very little is known about its attacks on tree species in these two genera. One collection was taken from ponderosa pine (Pinus ponderosa Laws.) by F. P. Keen in 1926, and another from the same host in 1927.

Most observers agree that the host tree must be dying or dead before it is in suitable condition for attacks by the beetle. Whether attacks also are made on down or decked green logs is not known. The availability of dying or dead trees depends to a considerable extent upon how frequently other agencies, such as fire, wind, or other insects, become destructive. These agencies are probably important in determining which host species is most frequently attacked. Although Craighead (2, p. 33) reports the beetle as "being often found mining under the bark of trees infested by Dendroctonus," observations made by others suggest that it may breed more frequently in fire-killed hosts. Furniss (5) observed that the adults are sometimes attracted to burned trees before the trees have ceased to smoulder. The species has been reared from the wood of dead or dying trees on recently burned

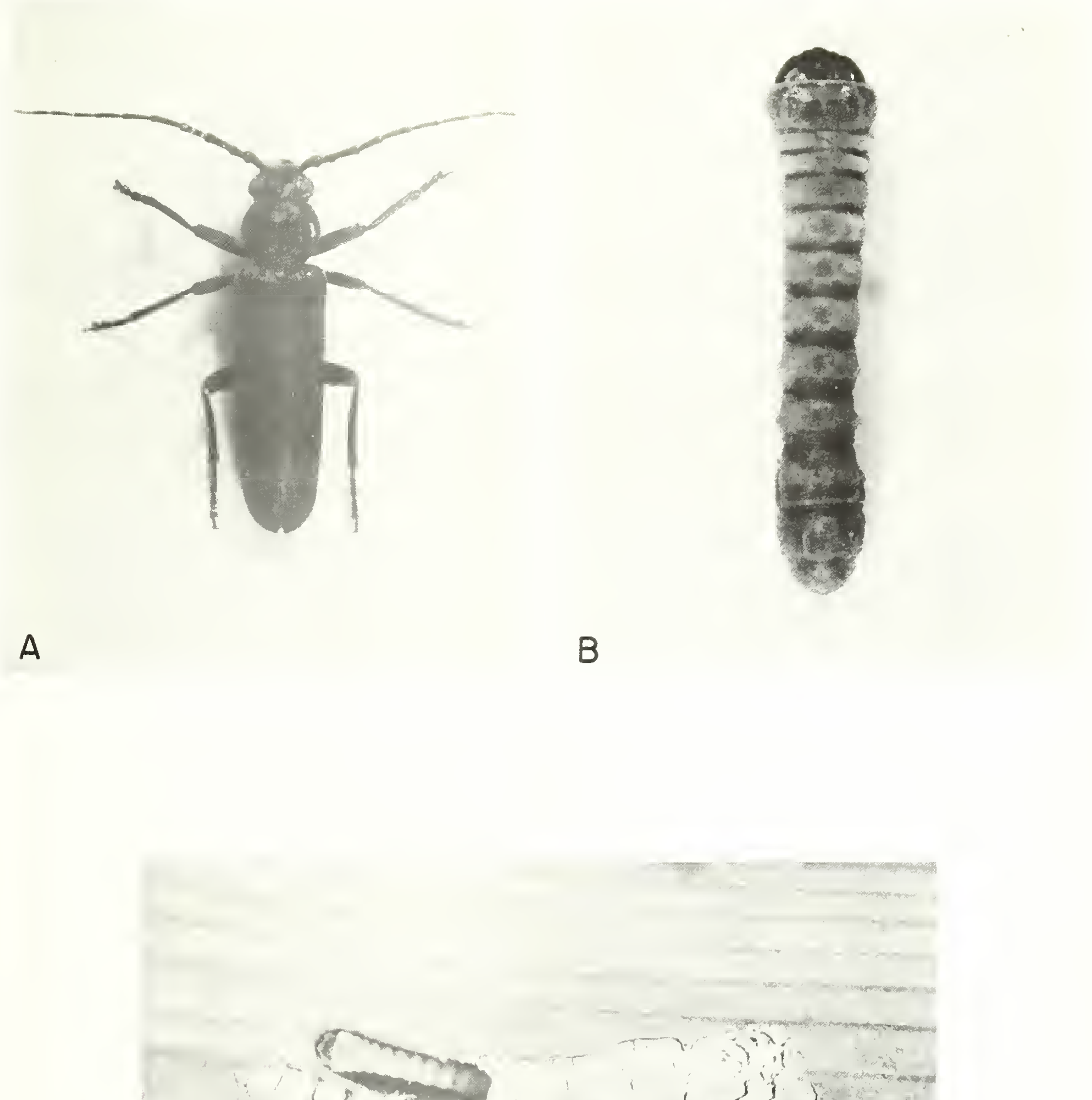


Figure 1. Arhopalus productus. A, adult male, 2x; B, full-grown larva, 2x; C, larva in pupal cell in wood, natural size.

areas. In Douglas-fir killed by fire, the beetle is important as a contributor to the deterioration of the wood (7).

## BIOLOGY

Present knowledge of the habits of this borer is very limited and is based almost entirely on observations of the beetle in burned timber.

Attacks on fire-killed trees probably take place during the first summer after a fire. They occur characteristically on the upper bole of the tree, although the basal portion may be infested (7). The female beetles lay their eggs in deep crevices of the bark. Upon hatching, the young larvae bore through the bark to the sapwood, where they feed for a time, scoring the outer surface of the sapwood and inner surface of the bark. The work of the larvae is similar in many respects to the work of the pine sawyers (*Monochamus* spp.). The initial feeding results in the formation of large depressed areas on the surface of the sapwood; these areas are choked with coarse, excelsior-like shavings. Later the larvae enter and mine within the sapwood and then penetrate the heartwood, forming galleries that are tightly packed with fibrous frass (fig. 3). In lumber the larvae sometimes tunnel from one piece of wood to another, if the two pieces touch. In lumber also, a larva will occasionally bore to the surface of the wood, then plug the hole at the surface, retreat, and continue mining in the interior.

When the larvae are full grown, they construct large open pupal cells (fig. 1, C). These cells may be so numerous and extensive as to severely limit the salvageability of the wood, or render it useless as lumber.

After pupation takes place, the adult beetles bore their way out of the wood, making clean-cut oval exit holes at the surface (fig. 2). Each hole marks the exit point of a single beetle. When the beetles emerge in houses, they chew their way through many different types of material overlaying infested wood. For example, they have bored through hardwood flooring, linoleum, plasterboard, and composition roofing.

Very little is known about the length of time required for this species to go through a complete cycle of development, or about the duration of the different life stages. Craighead (2) states that the larvae probably spend at least 2 years feeding in the heartwood. Kimmey and Furniss (7) concluded that the insect takes several years to reach maturity. They found larvae

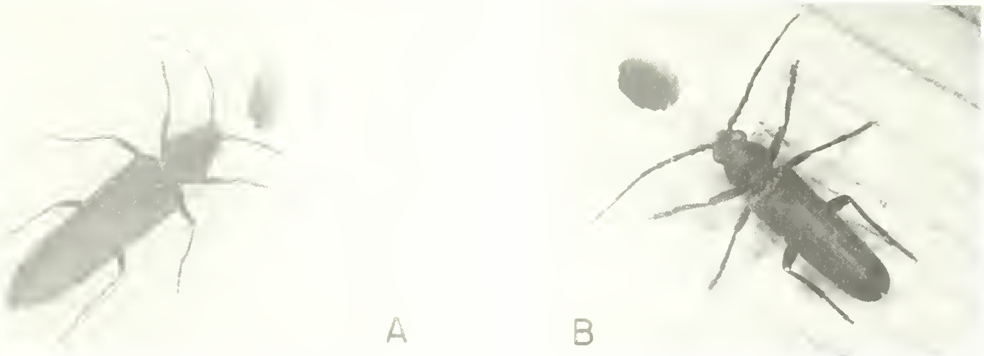



Figure 2. Emergence holes made by adults through plaster-board and Douglas-fir wood. A, female on plasterboard; B, male on wood.


Figure 3. Larval tunnels packed with borings in Douglas-fir. A, board with several tunnels in cross section (Photo courtesy R. D. Hodges); B, longitudinal section through part of tunnels.

constructing pupal cells in fire-killed Douglas-fir from 3 to 6 years after fire. The larvae commonly occur in trees that have been dead for 10 years. Evidence that the beetle does not re-attack fire-killed trees, once such trees have become infested, is not conclusive. Records of this beetle in ponderosa pine indicate that not less than 2 years are required for development.

Although the evidence suggests a fairly long life cycle in nature, it does not appear that infestations persist in buildings for long periods of time. The adults usually emerge within a few months after construction is completed. Reports are rare of continued emergence a year or more after a building has been occupied. It is probable that once a house is heated and the wood dries out, conditions become unfavorable for larval development, and only those insects that are nearly full grown are able to reach maturity. In their natural habitat, borers of this type are reported by Craighead (2) to require wood with a fairly high moisture content in order to develop successfully.

Arhopalus productus does not attack wood that has been converted into lumber. Consequently there is no hazard of reinfestation in a house where the beetles appear. Like many other wood-boring species to which it is closely related, the insect requires wood with the bark in place in order to establish itself successfully.

## EXAMPLES OF DAMAGE

The emergence of the borer from infested framing, sheathing, and construction timbers in new buildings has been a recurring problem on the West Coast for more than 30 years. Since the late 1930's, when lumber salvaged from fire-killed Douglas-fir on the Tillamook Burn in Oregon began to appear on the market (5), the number of complaints about this borer has been on the increase. Records concerning the emergence of the borer in buildings contain many examples indicating that the insect is most commonly little more than a nuisance problem. However, cases have occurred where the exit holes made by the beetles led to serious consequences. Examples of these are cited because they not only shed some light on the insect's behavior, but also help give perspective to the problem.

One of the most serious cases of beetle damage was one that involved a large warehouse in San Jose, California. An industrial building contractor erected the warehouse for a manufacturing concern during the latter part of 1951. In the spring of 1952, Arhopalus productus emerged through the roof surface from infested lumber used in the roof sheathing. The roof was constructed of 2- by 6-inch, tongue and groove Douglas-fir lumber with a protective covering of composition roofing. After boring their way out of the wood the beetles made holes through this covering, causing the roof to leak during the rainy fall months of 1952.

One of the most common sources of trouble is the 2-inch tongue and groove lumber. This material is being used rather widely at the present time for subflooring. In a number of new houses in a tract at Concord, California, beetles emerged from infested subflooring made of 2-inch lumber in the spring of 1953. They bored through both hardwood flooring and linoleum with which the subfloor was overlain. The subflooring in the houses was Douglas-fir, and there was some evidence that it came from a fire-killed stand. In this instance the problem was of the nuisance variety, for the average number of visible emergence holes per house was only 4, with a range of 1 to 8 for 8 houses examined.

The beetles sometimes emerge from infested wood framing in the walls or ceilings of buildings and bore out through the covering material. In a newly-built house in San Mateo, California, beetles in Douglas-fir studs chewed their way through the plasterboard with which the studs were covered (fig. 2). In a house in San Francisco they emerged from infested studs and bored through plaster on the interior walls. In this one building a total of 34 exit holes were counted in the plaster. Many similar cases of damage by this insect have been recorded.

## CONTROL

Borer infestations in buildings are practically never extensive enough to cause serious mechanical weaknesses in a structure. However, they may have other undesirable consequences such as those that already have been cited. Their nuisance value alone is great enough to generate some doubt among lumber users about the wisdom of using lumber that may be infested. For this reason, action should be taken wherever practicable to prevent the borer problem from arising.

The best time to control the beetles is at some stage in the manufacture or processing of lumber, before it becomes part of a finished structure. Once infested wood is built into a building, the prospects of keeping the insects from completing their development are poor.

Steps to prevent damage begin in the woods. The disposal of timber likely to be attacked should be expedited. Especially susceptible timber includes fire-killed, windthrown, or insect-killed trees. Such material should be manufactured into lumber as quickly as possible after the trees die, before the borers have had a chance to penetrate deep into the wood. If the wood is converted into lumber while the larvae are in the early stages of development, most of the insects will be in the slabs and edgings and will be destroyed when these are disposed of.

Often it is not possible to salvage trees before the borers have worked their way into the wood, especially when catastrophes occur in which large quantities of timber are killed, or when adverse economic conditions prevail. In such circumstances, by the time the lumber can be cut from the trees it is liable to be infested. When this happens, steps should be taken either to channel infested lumber to uses where the insects will not be a nuisance, or to get rid of the borers.

Lumber suspected of being infested should be examined carefully for evidence of borer work. This is an important step, for many cases of damage in buildings can be laid to the use of very small amounts of infested wood intermingled with sound material. Lumber in which the borers may be working, usually will have at least part of the larval galleries exposed (fig. 3), although this is not always the case. When pieces showing insect work are found, they should be separated from those that are free of injury.

Heat is an effective method for controlling roundheaded borers in lumber (12), and kiln-drying by the usual commercial schedules will kill the insects. For 1- and 2-inch Douglas-fir lumber, either green or air-dry, a heat sterilizing treatment in the dry kiln at a temperature of 140° and a relative humidity of 75 to 80 percent for a period of 6 to 8 hours is recommended. Since most of the cost of kiln-drying is in piling the lumber, loading and unloading the kiln, and unpiling, an overnight treatment (12 to 14 hours) in the kiln is advisable to make sure that all borers are killed. The longer treatment is required for material thicker than 2 inches.

Insecticides that might be used either as sprays or dips or by brush applications to treat lumber so as to control the larvae have not been tested against *Arhopalus productus*.

As stated earlier, little can be done to prevent beetles from completing their development in a building containing infested lumber. Fumigation with methyl bromide has been attempted in a few cases, but no experimental evidence is available to show how effective the method is against this particular insect. Since the insects are usually embedded in tunnels packed with borings deep in the wood, fumigants must be able to penetrate to them in order to exert any killing effect. Fumigation is a laborious and costly process. Because of this fact, and because the effectiveness of fumigation is questionable, it usually is simpler to plug and repair the holes made by the beetles.

The adults leave the wood permanently when they work their way to the surface. Therefore, insecticides introduced through the exit holes are of no value. Occasionally the larvae chew to the surface, then turn back into the wood. When this happens, the insect can sometimes be killed by probing into its burrow or introducing a small quantity of fumigant with an eye dropper.

## DISCUSSION

Borer-infested lumber is undoubtedly a very small fraction of the 10 billion board feet of Douglas-fir being marketed each year. Nevertheless, the occurrence of infested material in houses, even in small amounts, has some implications that are potentially serious to timber producers. The home owner who sees beetles coming out of the floors and walls of his new house is not easily persuaded to the view that the insects are simply a nuisance. He is likely to seek redress through legal action against the builder for furnishing substandard materials. To the builder or others who must repair or make good the damage, the problem is likewise quite real. In the export trade there are also some hazards. Shipments containing appreciable quantities of infested lumber could give rise to quarantines or trade barriers that would make it difficult to dispose of any lumber that might harbor borers. Thus, potentially at least, the small proportion of infested lumber now reaching the market is a threat to the entire industry.

Borer damage is liable to occur more frequently in the future than it has in the past unless greater effort is made to prevent infested lumber from being used in buildings. The increased value of wood has made it profitable to log trees that once would have been left to be decomposed by insects and fungi. Furthermore, salvaging dead or dying trees is good conservation and good forest management if adequate steps are taken to insure that the products from such trees are suitable for the purpose intended. In harvesting mature or overmature stands, foresters are giving priority to areas where large quantities of timber have been struck down by fire, wind, or other agents. Disturbances of this nature have been especially common in Douglas-fir stands of the Pacific Coast in the years since 1950, and have given rise to an extensive salvage program. Thus, it does not seem likely that production of lumber which is infested by borers will diminish in the near future. On the contrary, it is likely to increase.

Present information on the habits of this borer is fragmentary at best. Before satisfactory control methods can be developed, a much better knowledge of the insect's biology must be obtained. Also needed are better facts regarding the tree species and types of host material that the borer will attack. To establish the economic importance of the problem, quantitative information is needed on the occurrence of the borer in lumber and in new buildings. Finally, other methods than kiln drying need to be developed to control the insect in infested material.

## SUMMARY


Arhopalus productus (Lec.) is a wood-boring beetle that is occasionally a pest in new buildings. It causes damage by making holes in floor, wall, or roof materials when emerging from infested framing timbers. Its work in buildings is never so extensive as to seriously affect the structural strength of the wood. However, in fire-killed trees this species is an important cause of wood deterioration.

The borer occurs in most parts of western United States and western Canada. It breeds in dead and dying coniferous trees, especially Douglas-fir, and becomes a nuisance in houses where lumber cut from such trees has been used. Emergence of the adult beetles in houses usually takes place within a year after a house is built. The insect does not attack wood manufactured into lumber, and damage does not continue after the adults have emerged. The biology of the beetle is not well known. The life cycle in nature probably takes 2 to several years.

Effective methods are not known for controlling an existing infestation in a building. To prevent damage, lumber suspected of being infested can be examined, and the wormy material sorted from the sound. The infested lumber can then either be kiln-dried to destroy borers, or channeled to uses where the emergence of beetles would be no problem.

Emergence of the borer in buildings is principally a nuisance problem, but it is one that is potentially of considerable consequence to the lumber industry.

## LITERATURE CITED


(1) Anonymous.
1913. Notes of captures. Forty-third annual report, Ent. Soc. Ontario, 1912. Ontario Dept. Agr. 143 pp. illus. Toronto.

(2) Craighead, F. C.
1923. North American Cerambycid larvae. Canada Dept. Agr. Ent. Branch. Bul. 27, 239 pp., illus.

(3) Doane, R. W., Van Dyke, E. C., Chamberlin, W. S., and Burke, H. E.
1936. Forest insects, 463 pp., illus. New York.

(4) Essig, E. O.
1926. Insects of western North America. 1035 pp., illus. New York.

(5) Furniss, R. L.
1937. Salvage on Tillamook Burn as affected by insect activity. The Timberman 39(2): 11-13, 30, illus.

(6) Keen, F. P.
1952. Insect enemies of western forests. U. S. Dept. Agr. Misc. Pub. 273, 280 pp., illus.

(7) Kimmey, J. W., and Furniss, R. L.
1943. Deterioration of fire-killed Douglas-fir. U. S. Dept. Agr. Tech. Bul. 851, 61 pp., illus.

(8) Knowlton, G. F.
1930. Notes on Utah Coleoptera. The Florida Ent. 14(3):53-56.

(9) LeConte, J. L.
1850. An attempt to classify the Longicorn Coleoptera of the part of America north of Mexico. Jour. Acad. Nat. Sci. Philadelphia. Second Series. 2:5-38.

(10) Linsley, E. G.
1940. Notes and descriptions of West American Cerambycidae--IV (Coleoptera). Ent. News 51(9):253-258.

(11) Packard, A. S.
1890. Insect injurious to forest and shade trees. Fifth Report U. S. Ent. Commission. 955 pp., illus. Washington, D. C.

(12) St. George, R. A.
1929. Protection of log cabins, rustic work, and unseasoned wood from injurious insects. U. S. Dept. Agr. Farmers Bul. 1582. 20 pp., illus.

TECHNICAL
PAPER
NUMBER 12

# SUGAR PINE MANAGEMENT
## ...an annotated bibliography

CALIFORNIA
FOREST AND RANGE
EXPERIMENT STATION
GEORGE M. JEMISON, DIRECTOR
BERKELEY - DECEMBER 1955

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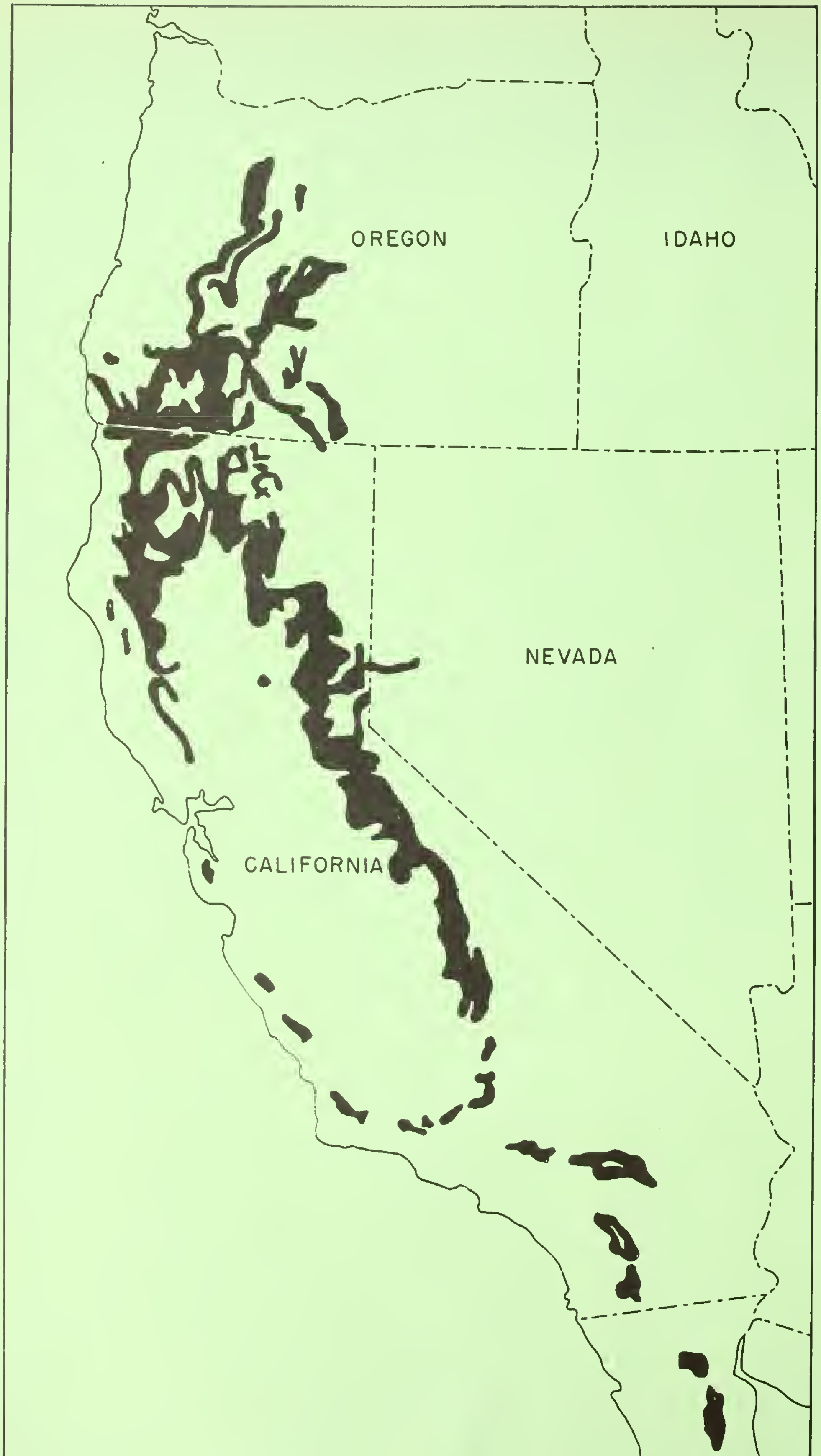


THE NATURAL RANGE OF SUGAR PINE
(From MUNNS, E. N. 1938. The distribution of important forest trees of the United States. U. S. Dept. of Agri. Misc. Pub. 287, 176pp)

# SUGAR PINE MANAGEMENT--AN ANNOTATED BIBLIOGRAPHY

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Technical Paper No. 12 December 1955

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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The Experiment Station is maintained at Berkeley, California in cooperation with the University of California.

Agriculture--Forest Service, Berkeley, Calif.

# FOREWORD

The purposes of this bibliography are to enumerate and describe publications that have a bearing on the growing of sugar pine for timber production. It is intended primarily for the information of forest managers, and it includes mainly those articles which appeared to pertain rather directly to management. Although a careful search was made for titles, no claim is made that all possible informative sources of information have been included.

Titles are listed alphabetically by authors. Pages 2 and 3 contain a brief subject index. Numbers in the index refer to serial numbers that appear to the left of the author names. Articles which contain considerable information on two or more subjects have been listed in more than one place in the index. However, indexing is not complete for reports that discuss numerous subjects or contain only minor references to other than the main topic.

## SUBJECT INDEX

1. ANONYMOUS.
1928. First discovery of sugar pine. Jour. Forestry 26:1054.

Quotes from the American Masonic Record and Albany Saturday Magazine, Vol. 1 No. 41, of November 10, 1827, a letter from Douglas written to Dr. Hooker, describing the discovery of sugar pine as "the most princely of the genus and probably the finest specimen of the American vegetation." The sugar pine trees that he saw were "two degrees south of St. Columbia, in the country inhabited by the Umftgun tribe of Indians."

2. ———
1949. A sugar pine regeneration cutting experiment. West Coast Lumberman 76(3):62, 64, illus.

Quotes Duncan Dunning's description of a cutting experiment in a virgin tract of sugar pine in the Stanislaus Experimental Forest, California. The discussion includes the position of sugar pine in virgin old growth, the deterioration of that position in cutover, and the regulated stand structure aimed for in old-growth conversion.

3. ———
1953. Recovery study made on sugar pine snags at mill. Timberman 54(8):151.

A mill study showed that sugar pine snag logs could be cut at a profit providing stumpage rates were kept low and fixed separately from green timber. Cull amounted to 34 percent for snags as compared with an average cull and breakage factor of 4 to 7 percent for normal timber. Net volume sawn at the mill dropped from a normal of 75,000 feet to 67,000 feet per day. Hidden defects were numerous and resulted in considerable degrading. Much of the defect was not apparent until after seasoning and surfacing.

4. ———
1954. Why grow sugar pine? Timberman 56(2):37

An editorial that speaks approvingly of reasons why efforts to manage and continue to grow sugar pine should be sustained.

5. AMERICAN FORESTRY ASSOCIATION.
1951. American tree monarchs. Separate 6 pp., illus.

The largest sugar pine tree recorded was 121 inches d.b.h. and 200 feet in height. It was reported from Girl Scout Camp at Dorrington, Stanislaus National Forest, California by J. R. Hall, Sonora, California. It exceeds the largest reported ponderosa pine (d.b.h. 103 inches, height 162 feet). It is exceeded in diameter but not matched in height by a bristlecone pine on the Inyo National Forest (144 inches d.b.h. but only 40 feet tall).

6. AUSTIN, LLOYD.
1929. Eddy Tree Breeding Station. Madrono 1:203-212.

Ovulate flowers of western yellow pine were hand-pollinated with pollen from 28 different species of pines, including sugar pine, in an attempt to produce species crosses. Also, some ovulate flowers of sugar pine were involved in attempted crosses.

7. AVERELL, J. L.
1953. Diamond Spring sugar pine management area, Plumas National Forest, Demonstration Plots Nos. 1 and 2. U. S. Forest Service, S-CONTROL-Disease-Blister Rust. 2 pp. (Processed)

Presents data to illustrate how a sugar pine area is analyzed by the Forest Service for purposes of management and protection from blister rust.

8. BAKER, FREDERICK S.
1944. Mountain climates of the western United States. Ecol. Monog. 14:223-254, illus.

Describes 28 western climatic areas and presents information for each on precipitation, temperature, and length of growing season. The climatic areas include several which embrace the principal natural range of sugar pine.

9. ———
1949. A revised tolerance table. Jour. Forestry 47:179-181.

Based on 55 returned questionnaires sent out to foresters and on published statements. Changes in tolerance of species with age, criteria for judging tolerance, and various opinions on tolerance are discussed. The degrees of tolerance considered were: (1) very tolerant, (2) tolerant, (3) intermediate, (4) intolerant, and (5) very intolerant. Sugar pine was rated by most foresters as intermediate. Several species commonly associated with sugar pine were rated as: incense-cedar and white fir, tolerant; Douglas-fir, intermediate; and ponderosa and Jeffrey pine, intolerant.

10. BAKER, F. S.
1951. Reproduction of pine on old railroad grades in California. Jour. Forestry 49:577-8.

Relationship was shown between type of abandoned logging railroad grades and natural reproduction. The pines, including sugar pine, were more abundant on mineral seedbeds where the brush competition was absent or light; they were scarce where the brush competition was more severe.

11. BALDWIN, HENRY IVES.
1942. Forest tree seed of the North Temperate Regions with special reference to North America. 240 pp., illus. Waltham, Mass.

A useful reference book on forest tree seed, including sugar pine. Chapter titles are: Structure and development of tree seeds, seed production of forest trees, seed origin or provenance, seed collection, extraction and cleaning of seed, storage and longevity, biotic enemies of tree seeds, germination, internal factors affecting germination, environmental factors influencing germination, chemistry of seeds and germination, seed stimulation, seed testing, purity analysis, determination of origin, the determination of seed viability without germination, the testing of germination, seed testing stations and seed certification, and tree seed research.

12. BARRETT, S. A., and GIFFORD, E. W.
1933. Sugar pine (Pinus lambertiana Dougl.) seed used by Indians as food. City of Milwaukee Public Museum Bul. 2:150-1.

Large quantities of sugar pine cones were reported collected by the women of the Miwok Indian Tribe for food. Some of the shelled nuts were eaten whole, while others were ground in a mortar to form a paste called lopa. Lopa was prepared especially for feasts.

Sugar pine sugar was also collected for food and, when dissolved in water, used as an eye wash.

13. BENEDICT, W. V. and HARRIS, T. H.
1945. White pine blister rust control in California and Oregon. U. S. Dept. Agr. Bur. Ent. and Plant Quar. 18 pp., illus. (Processed)

Location of blister rust infections and control units are shown for California and Oregon. Blister rust on sugar pine was shown to be moving south. It had spread to Yreka, California, in 1936, to Eureka and Downieville, California, by 1940, and to Point Reyes and the Calaveras Big Tree grove in 1945.

14. BERRY, SWIFT.
1917. Lumbering in the sugar pine and yellow pine region of California. U. S. Dept. Agr. Bul. 440, 99 pp., illus.

Largely of historic interest. Text and photographs describe a variety of logging processes such as big-wheel yarding, horse-chute yarding, horse-truck yarding, and traction-engine yarding that are no longer used.

15. BETTS, H. S.
1945. Sugar pine. U. S. Forest Service. American Woods. 6 pp., illus. (Processed)

Leaflet containing information on distribution, elevation, age, size, growth, reproduction, cones, supply, production, properties, and uses of sugar pine.

16. BOYCE, JOHN SHAW.
1948. Forest pathology. Ed. 2, 550 pp., illus. New York, Toronto, London.

Describes the comparatively few known diseases of sugar pine.

17. BRUNDAGE, M. R., KRUEGER, M. E. and DUNNING, DUNCAN.
1933. The economic significance of tree size in western Sierra lumbering. Univ. Calif. Agr. Expt. Sta. Bul. 549. 61 pp., illus.

The authors state, "This report, limited to a condensed account of current operating economics as related to log and tree sizes, is based on the first completely coordinated logging and milling study to be undertaken by public forest-research agencies in the California region. Entire trees were traced from the stump to the sawmill lumber-sorting table.... Beyond the green chain, part of the lumber was later reinspected for seasoning degrade and remanufacturing changes by grade, thickness, and width."

Zero-margin diameters for trees from a typical virgin stand of Site I on the west slope California pine region were: Sugar pine--23 inches, ponderosa pine--22 inches, white fir--34 inches, and incense-cedar--28 inches.

Margins per M b.m. for sugar pine were:

| Tree diameter, inches | Margin (Dollars) |
|---|---|
| 14 | -17.85 |
| 16 | -10.33 |
| 18 | - 6.19 |
| 20 | - 3.25 |
| 24 | 1.05 |
| 30 | 5.29 |
| 40 | 12.14 |
| 50 | 18.97 |
| 60 | 24.15 |
| 70 | 27.41 |
| 80 | 27.34 |

18. BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE.
1950. Control of white pine blister rust. U.S. Dept. Agr. Leaflet 265, 8 pp., illus. (Processed)

An information leaflet in popular form designed to tell of the menace of blister rust to sugar pine and the other white pines. The nature of the rust, its history in the U. S., and methods of control are stated. Brief, nontechnical, and suitable for general distribution.

19. BURK, CHARLES.
1953. Summary of sugar pine management field data for calendar year 1952 and 3-year averages for calendar years 1950, 1951 and 1952. U. S. Forest Service, Region 5. (Filed under S-PLANS-Timber Surveys--(Sugar pine management) 14 pp. (Processed)

Summary of cruise data on 151,000 acres of federally owned timber land delineated and approved for sugar pine management.

20. BURKS, GEORGE F.
1949. Estimated lumber production in California. 1948. Calif. Forest and Range Expt. Sta. Res. Note 65, 6 pp., illus. (Processed)

Estimated lumber production in California in 1948 was approximately 3,963 million board feet. Two-thirds was in the Pine Region, and the remaining third in the Redwood Region. Sugar pine made up 9 percent of the lumber production in the Pine Region, but only 0.1 percent in the Redwood Region.

21. CALIFORNIA DIVISION OF FORESTRY.
195?. Blister rust--scourge of sugar pines. 13 pp., illus. (Processed)

Pictorial leaflet dealing with the menace of blister rust to the sugar pines in California and Oregon. Designed for general distribution.

22. CALIFORNIA FOREST AND RANGE EXPERIMENT STATION.
1950. Annual Report (1949). 68 pp. (Processed)

Results of the pilot test of Unit Area Control cutting on the Stanislaus Experimental Forest in 1948:

1. Viable sugar pine seed which fell at the rate of 29,000 seeds per acre produced an average of 707 seedlings per acre.

2. At the end of the 1949 season the number of sugar pines were reduced to 440 per acre, and 25 percent of the mil-acre quadrats were stocked.

3. White fir seed fell at the rate of 161,000 good seeds per acre, and 53 percent of the mil-acres were stocked with one or more fir seedlings.

4. Small rodents were the principal cause of reduced germination. Forty-one percent of the screened sugar pine seed spots had seedlings, whereas only 18 percent of the unscreened spots produced seedlings.

5. Sugar pine seeds germinated at the rate of 2,975 per acre on raked spots, as against 1,550 on unraked areas.

23. ______
1952. Annual Report (1951). 53 pp. (Processed)

Tests indicate that sugar pine crop trees can be increased in number by removing competing white fir. Two decades after thinning the white fir, sugar pine crop trees had increased from 18 per acre to 36 per acre.

24. ______
1954. Annual Report (1953). 64 pp., illus. (Processed)

References to sugar pine:

1. Seed production and seedling establishment records for two periods totalling 16 years on the Stanislaus Experimental Forest showed that over 14 million viable sugar pine and ponderosa pine seed were produced on 46.8 acres. These resulted in only slightly more than 3,000 established seedlings.

2. The relationship between seed-tree size and seed crops was established for sugar pine, ponderosa pine, and white fir. Size for size, sugar pine trees are relatively less reliable cone producers than the other two species until they reach about 28 to 30 inches in diameter. For example, the average number of cones produced by 14-inch tree was: Sugar pine, 8 per tree; ponderosa, 36 per tree; and white fir, 50.

3. The total volume of sawtimber on the western Sierra slopes in California was estimated to be 125 billion board-feet (International 1/4-inch rule). One-tenth of this volume was reported to be sugar pine.

25. CALIFORNIA FOREST AND RANGE EXPERIMENT STATION.
1954. Forest statistics for California. Forest Survey Release 25. 66 pp., illus. (Processed)

Presents detailed statistics on forest area, ownership, stand-size classes, timber types, stocking, site quality, timber volume, growth, and annual cut. Most of the data are shown by species and subregions.

The volume, average annual net growth, and annual cut of sugar pine growing stock (trees 5.0 inches d.b.h. and larger) on commercial forest land in California by subregions were:

| Subregion: | Timber volume - 1953 | Average annual net growth - 1952 | Annual cut - 1952 |
|---|---|---|---|
| | - - - - (Million cubic feet) - - - - | | |
| Eastside Sierra | 216 | (1/) | 4.4 |
| Westside Sierra | 2,379 | 24 | 36.7 |
| Coast range pine | 1,023 | 3 | 8.7 |
| Redwood--Douglas-fir | 807 | 2 | 1.1 |
| Southern California | 7 | (1/) | (2/) |
| Totals: | 4,432 | 29 | 50.9 |

1/ Less than 0.5 million cubic feet.
2/ Less than 50 thousand cubic feet.

26. ______
1955. Forest research in California. Annual Report (1954). 70 pp., illus. (Processed)

Items pertaining to sugar pine:

1. The volume of standing live sugar pine sawtimber in California was estimated to be 27 billion board feet with an average annual cut of 330 million board feet.

2. Sugar pine trees in Dunning vigor classes 1, 3, and 5 were found to be the best cone producers. On the Stanislaus National Forest during two periods totalling 16 years the average number of cones produced per tree was:

| Dunning tree class | Average number of cones per tree |
|---|---|
| 1 | 45 |
| 2 | 3 |
| 3 | 555 |
| 4 | 31 |
| 5 | 712 |
| 6 | 0 |
| 7 | 2 |

3. Sugar pine seedlings were reported to have suffered considerable damage as a result of a late spring frost. An estimated minimum temperature of 20° F. on the 5th, 6th, and 10th of June killed 74 percent of the new seedlings and 66 percent of the new growth on 3-year old transplants; however, none of the transplants were killed.

27. CHILDS, T. W. and BEDWELL, J. L.
1948. Susceptibility of some white pine species to Cronartium ribicola in the Pacific Northwest. Jour. Forestry 46:595-599.

Studies on planted trees in Oregon and British Columbia indicated that sugar pine, of the 10 white pine species tested, was the most susceptible to Cronartium ribicola. Pinus albicaulis, which was not included in the test, was reported to be the most susceptible member of the genus.

28. CLEMENTS, V. A.
1953. Possible means of reducing mountain pine beetle attacks in young sugar pine. Calif. Forest and Range Expt. Sta. Res. Note 89. 5 pp. (Processed)

The study of stand conditions under which young sugar pines on the Sierra National Forest were attacked by mountain pine beetles showed: (1) the greatest losses occurred where the stand density index was high (2) and the greatest kill in the early stages of the epidemic was in the understory (intermediate and suppressed trees). Methods recommended to increase the resistance to attack were: (a) Reduce the stand density by removing the larger trees of sawtimber size to increase the vigor of the remaining trees, (b) remove the smaller more-susceptible trees which would also tend to reduce the stand density, and (c) a combination of the two methods.

29. CLEMENTS, V. A., STEVENS, C. W., and ROY, D. F.
1949. Form-class volume tables for sugar pine and red fir in California. Calif. Forest and Range Expt. Sta. Res. Note 61. 137 pp., illus. (Processed)

Contains form-class volume tables for form classes 65 through 90. The form class was defined as "the percentage ratio between the d.i.b. (diameter inside bark) at the top of the first log and d.b.h. o.b. (diameter breast high outside bark)." Volumes are given in board feet, Scribner Rule, by d.b.h. and log-height classes for each 16.3-foot log from a 1.5-foot stump to a 10-inch d.i.b. top, and to an average utilized top.

30. CORSON, C. W., and FOWELLS, H. A.
1952. Here's how--a guide to tree planting in the California pine region. Calif. Forest and Range Expt. Sta., Misc. Paper 8, 26 pp., illus. (Processed)

This booklet is designed primarily for use by the men in the field to do a better job of planting. The authors state that, although seeding and planting is a difficult job in California, it is not impossible. To be successful, the planting should be done--

"in the <u>right</u> <u>place</u>
at the <u>right</u> <u>time</u>
with the <u>right</u> <u>stock</u>
in the <u>right</u> <u>way</u>."

The recommendations and suggestions for doing a good job are based on practical experience and research findings.

31. COSENS, RICHARD D.
1952. Reducing logging damage. Calif. Forest and Range Expt. Sta. Res. Note 82, 10 pp., illus. (Processed)

Discusses methods used on the Stanislaus Experimental Forest in 1948 and 1949 in a sugar pine-fir type, to reduce logging damage resulting from: (1) unnecessary and improperly located roads, landings, and yarding trails; (2) improper falling; (3) use of tractor-arch unit in young stands; and (4) lax supervision of logging crews. Logging damage may be reduced by:

"1. Preparing and carrying out a detailed logging plan aimed at reduction of damage;

"2. Properly training and supervising logging crews; and

"3. Focusing engineering and logging ingenuity on designing equipment that will lessen damage to the advance growth as well as increase efficiency of yarding logs."

32. COSENS, RICHARD D., and TACKLE, DAVID.
1950. Costs of rodent control in pine regeneration in California. Calif. Forest and Range Expt. Sta. Res. Note 73, 5 pp. (Processed)

During 1948, a good seed year for sugar pine, 665 acres on the Stanislaus Experimental Forest were treated before seedfall with lethal bait to suppress white-footed mice, chipmunks, and ground squirrels. The bulk of the poison bait used was oat groats treated with "1080" (sodium fluoroacetate) at the rate of 3 ounces "1080" per 100 pounds of groats. Some bait treated with 1 pound of thallium sulfate per 100 pounds of groats was also used. The poison bait was distributed at the rate of 1/2 to 2/3 pounds per acre in pinches of 15 to 30 grains every 15 feet along lines approximately 50 feet apart. Treatment cost 46 cents per acre. Establishment of new seedlings was found to be moderately successful (707 sugar pine seedlings per acre). Timing of the treatment was considered to be an important element in the success of the project.

33. COX, WILLIAM T.
1911. Reforestation on the national forests. U. S. Dept. Agr. Forest Service Bul. 98, 57 pp., illus.

Sugar pine seed information was: Trees per acre bearing seed in appreciable quantities, 8; bushels of cones per tree, 7; pounds of seed per bushel of cones, 1.60; and pounds of seed per acre, 89.60. The average cost of sugar pine seed collected by the Forest Service in 1909 and 1910 was 85 cents per pound, compared to a cost of $1.25 to $2.25 from seed dealers during the same period.

34. CUMMING, W. C. and RIGHTER, F. I.
1948. Methods used to control pollination of pines in the Sierra Nevada of California. U. S. Dept. Agr. Cir. 792, 18 pp., illus.

Describes techniques used for controlling pollination of pines, which have proved effective and practical at the Institute of Forest Genetics. Methods of isolating the ovulate flowers, handling pollen, pollinating the flowers, and protecting the cones and seeds are described.

35. DOWNING, G. L.
1954. Ethylene dibromide sprays for controlling bark beetles in California. Calif. Forest and Range Expt. Sta. Misc. Paper 17, 2 pp. (Processed)

Ethylene dibromide was reported effective for controlling several bark beetles including the mountain pine beetle which attacks sugar pine. Infested trees are felled and bucked and then sprayed with a mixture of 1 pint (85 percent) ethylene dibromide in 5 gallons of diesel oil. The ethylene dibromide solution was applied with a garden sprinkling can when trees occurred in small isolated groups and with a power sprayer when the infested trees occurred in large groups.

36. DUFFIELD, J. W.
1953. Pine pollen collection dates--annual and geographic variation. Calif. Forest and Range Expt. Sta. Res. Note 85, 9 pp., illus. (Processed)

Pollen collection dates for sugar pine varied from May 21 to May 31 during 3 years at the Eddy Arboretum, Placerville, California, located at 2700 feet elevation. At 5,000 feet elevation, the collection dates were June 8 and July 8 for the 2 years in which pollen was collected. At 6,000 feet elevation, the collection dates for 4 years ranged from July 1 to July 9. The mean interval per 1,000 feet difference in elevation is 8 days.

37. ______ and RIGHTER, F. I.
1953. Annotated list of pine hybrids made at the Institute of Forest Genetics. Calif. Forest and Range Expt. Sta. Res. Note 86, 9 pp. (Processed)

Two sugar pine hybrids are reported. Sugar x Armand's (P. lambertiana x armandi Franch.) and sugar x Korean (P. lambertiana x Koraiensis Sieb. and Zucc.). Both crosses are difficult to make and the seed yield has been low. Since both the Armand's and Korean pines are highly resistant to blister rust, it is hoped that the crosses will inherit this characteristic. The sugar x Korean hybrid may be more cold resistant than the other hybrid.

38. DUNNING, DUNCAN.
1923. Some results of cutting in the Sierra forests of California. U. S. Dept. Agr. Bul. 1176, 26 pp., illus.

Site was the most important factor in the growth of stands left after cutting. A reserve volume of 6,000 to 10,000 board feet on Sites I and II was found to be justified for increased growth and to improve the quality of the second cut. On poorer sites, marking should be aimed to secure reproduction.

Sugar pine was found to rank second to white fir in rate of growth; however, sugar pine maintained a high growth rate to a greater age and diameter than the other associated species. Diameters for best growth on Site II or better were 30 inches for sugar pine, 26 inches for ponderosa pine, and 24 inches for white fir and incense-cedar.

Reserve trees should be immature, free from defect, and have pointed tops, dense dark green foliage, and 60 percent or more of their total height in live crown. These trees should not be left in groups because dense grouping reduces thinning effects and lessens the chances for pine reproduction within the group.

No appreciable increase in pine reproduction, except on Sites I and II, was noted on old cuttings which were relatively lightly thinned by the group selection or shelterwood methods. Leaving more sugar pine and ponderosa pine seed trees and cutting merchantable white fir and incense-cedar heavily was reported as resulting in no change in composition because enough unmerchantable firs and cedars are always present to supply abundant seed.

The primary considerations in marking should be to save the advance pine reproduction and to cut heavily enough to release it. The best advance reproduction was found to have occurred under conditions resembling a shelterwood system. Where reproduction is absent and the stand is even-aged, a heavy shelterwood or seed tree cutting with numerous well distributed seed trees larger than 18 inches in diameter was recommended as the most favorable condition for improved growth and reproduction. Every acre must be studied and marked individually because of the varying forest conditions.

39. DUNNING, DUNCAN.
1928. A tree classification for the selection forests of the Sierra Nevada. Jour. Agr. Res. 36:755-71, illus.

The Dunning tree classification is based on detailed crown and bole characteristics of ponderosa pine; however, it is also used for sugar pine. The four major factors considered were: age--young (less than 50 years), thrifty mature (50 to 150 years), mature (150 to 300 years), and overmature (over 300 years); crown classes--isolated, dominant, codominate, intermediate, and suppressed; crown development--length, width, form of top; and vigor--good, moderate, and poor. The tree classes as summarized by Dunning:

"Class 1: <u>Age class</u>, young or thrifty mature; <u>position</u>, isolated or dominant (rarely codominant); <u>crown length</u>, 65 percent or more of the total height; <u>crown width</u>, average or wider; <u>form of top</u>, pointed; <u>vigor</u>, good.

"Class 2: <u>Age class</u>, young or thrifty mature; <u>position</u>, usually codominant (rarely isolated or dominant); <u>crown length</u>, less than 65 percent of the total height; <u>crown width</u>, average or narrower; <u>form of top</u>, pointed; <u>vigor</u>, good or moderate.

"Class 3: <u>Age class</u>, mature; <u>position</u>, isolated or dominant (rarely codominant); <u>crown length</u>, 65 percent or more of total height; <u>crown width</u>, average or wider; <u>form of top</u>, round; <u>vigor</u>, moderate.

"Class 4: <u>Age class</u>, mature; <u>position</u>, usually codominant (rarely isolated or dominant); <u>crown length</u>, less than 65 percent of the total height; <u>crown width</u>, average or narrower; <u>form of top</u>, round; <u>vigor</u>, moderate or poor.

"Class 5: Age class, overmature; position, isolated or dominant (rarely codominant); crown, of any size; form of top, flat; vigor, poor.

"Class 6: Age class, young or thrifty mature; position, intermediate or suppressed; crown, of any size, usually small; form of top, round or pointed; vigor, moderate or poor.

"Class 7: Age class, mature or overmature; position, intermediate or suppressed; crown, of any size, usually small; form of top, flat; vigor, poor."

40. DUNNING, DUNCAN.
1942. A site classification for the mixed conifer selection forests of the Sierra Nevada. Calif. Forest and Range Expt. Sta. Res. Note 28, 21 pp., illus. (Processed)

Site-class curves, based on the height-age relationship for dominant trees, are presented. The site range was divided into 6 classes (25-foot intervals) of average total height of dominants at the age of 300 years. The site classes were designated A-200, I-175, II-150, III-125, IV-100, and V-75, with A-200 as the best and V-75 as the poorest. The curves defined as the mid-lines of the site-class zones are applicable for forest types which include varying combinations of ponderosa pine, Jeffrey pine, sugar pine, white fir, Douglas-fir, and incense-cedar.

41. ————
1945. Diameter-class volume tables for California old-growth timber. Calif. Forest and Range Expt. Sta. Res. Note 42. 4 pp. (Processed)

Contains volume tables for old-growth ponderosa and sugar pines and white fir. Volumes for sugar pine are for Sites I and II for trees from 12 to 100 inches d.b.h.

42. ———— and REINEKE, L. H.
1933. Preliminary yield tables for second-growth stands in the California Pine Region. U. S. Dept. Agr. Tech. Bul. 354. 23 pp.

Information given includes: Range and occurrence, conditions of establishment of second growth, relative importance of virgin and second-growth forest, age, site index, density of stocking and stand-density index, total basal area, number of trees per acre, average diameter of the stand, volume per acre in cubic feet, ratio of board-feet to cubic feet, volume per acre in board-feet, and mean annual increment. Composition of the types to which the data apply are:

| Species type | Percent of total basal area in-- | | | | | |
|---|---|---|---|---|---|---|
| | Ponderosa pine | Sugar pine | Douglas-fir | White fir | Incense-cedar | Red fir |
| Ponderosa pine-fir | 40 | 3 | 30 | 20 | 7 | - |
| Ponderosa pine-sugar pine | 40 | 37 | 3 | 10 | 10 | - |
| Ponderosa pine-sugar pine-fir | 40 | 25 | 10 | 20 | 5 | - |
| Sugar pine-fir | 5 | 33 | 20 | 35 | 7 | - |
| White fir--Douglas-fir | 5 | 3 | 45 | 45 | 2 | - |
| White fir-red fir | - | 3 | - | 68 | - | 29 |

43. ENGSTROM, W. H.
1954. Oregon cone crop, 1954. Oregon State Board of Forestry Res. Note 16. 7 pp. (Processed)

Sugar pine cone crop rating for Oregon in 1954 was reported as "6". This refers to a light crop having many cones on some trees and few cones on 75 percent of the trees. The 1954 cone crop was indicated to be the best since 1950. Some areas had a very good cone crop, while others had few to no cones. The best crops occurred on the east slope of the Cascades and in the Rogue River drainage.

44. FOWELLS, H. A.
1940. Cutworm damage to seedlings in California pine stands. Jour. Forestry 38:590-1.

Cutworm (Noctuidae larvae) damage on sugar pine was significantly higher in cutover stands than in virgin timber. Most serious damage occurred on young seedlings 1 to 2 months old. Cutworms were reported to have destroyed 7.9 percent of 1,536 sugar pine seedlings.

45. ———
1941. The period of seasonal growth of ponderosa pine and associated species. Jour. Forestry 39:601-8, illus.

Differences in seasonal height and radial growth are presented for several coniferous species including sugar pine on the Stanislaus National Forest. Radial growth on sugar pine was found to start about the middle of April; height growth did not begin until about the end of May.

46. ———
1944. Site preparation as an aid to sugar pine regeneration. Calif. Forest and Range Expt. Sta. Res. Note 41. 4 pp. (Processed)

The brush cover of bearmat (Chamaebatia foliolosa) and mountain whitethorn (Ceanothus cordulatus) was removed mechanically from 37 unstocked cutover areas on the Stanislaus National Forest. Plots were established to determine whether natural seedlings would result from the heavy cone crop on sugar pine trees within 150 feet of the plots, and to compare natural reproduction with seed spotting under screens and planting.

Natural reproduction failed in spite of the large numbers of sugar pine seed which fell on the plots (approximately 10,600 seed per acre). Rodent depredation was believed to be the cause of failure.

At the end of the third year seed spotting was less effective than planting on the plots cleared of bearmat (15 percent stocking from seed spotting compared with 34 percent for planting). But seed-spotting was more effective than planting on the areas cleared of whitethorn (67 percent as compared with 41 percent).

The results showed that successful establishment of sugar pine seedlings was possible before brush regained control of the ground.

Growth measurements of seedlings and transplants showed that the plants grew faster on the areas cleared of whitethorn than on those which had bearmat.

47. FOWELLS, H. A.
1946. Forest tree seed collection zones in California. Calif. Forest and Range Expt. Sta. Res. Note 51. 5 pp., illus. (Processed)

The forests of California were divided into 13 zones to insure that stock grown from seed of a particular habitat will be planted on reasonably similar habitats, and to simplify keeping records of seed origin. The zones were delineated on the basis of vegetational types, sites, and arbitrary latitudinal divisions.

48. ———
1948. The temperature profile in a forest. Jour. Forestry 46:897-9, illus.

Air and soil temperatures, recorded at several distances above and below the ground surface, are reported for a mature, mixed-conifer stand composed of ponderosa, Jeffrey, and sugar pines, white fir, and incense-cedar. Three-year average maximum and minimum monthly temperatures are shown for the months of May through October. The highest and lowest temperatures occurred at or near the ground surface. Maximum temperatures decreased and minimum temperatures increased both above and below the ground level. Average differences between temperatures 4.5 feet and 120 feet above ground surface were:

| | May | June | July | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|
| Minimum | +1.3 | +2.4 | +3.4 | +4.2 | +3.5 | +2.6 |
| Maximum | -2.0 | -1.7 | -2.6 | -3.2 | -2.8 | -2.8 |

49. FOWELLS, H. A.
1949. An index of ripeness for sugar pine seed. Calif. Forest and Range Expt. Sta. Res. Note 64, 5 pp., illus. (Processed)

Seed germination was highly correlated with the specific gravity of the cones. A specific gravity of 0.80 was recommended as the indicator that sugar pine cones are ripe enough for gathering. Owing to the variation in ripening dates for individual trees, cones from each tree should be sampled. If 3 or more cones from a sample of 5 freshly picked cones float in kerosene (Sp. Gr. 0.80 at 60° to 80° F.), the cones on that tree are suitable for seed harvesting. Seeds from cones in the study area were found to be mature during the last week in September in 1941 and the first week in October in 1948.

50. ———
1950. Some observations on the seedfall of sugar pine. Calif. Forest and Range Expt. Sta. Res. Note 70. 3 pp. (Processed)

The rate of fall of sugar pine seeds and their horizontal movement in wind currents are discussed. Studies were conducted with 3 isolated trees in 1941, a year of heavy seed production. The trees were from 150 to 175 feet in height and bore about 150 cones each. Four concentric zones were established around each tree, and the seeds were counted in each zone at 10-day intervals during October. Results indicated that the amount of seeds necessary to produce a few hundred natural seedlings per acre occurred only within a radius of about 100 feet from the seed trees.

51. ———
1953. Regeneration problems and research in California. Calif. Forest and Range Expt. Sta. Misc. Paper 10, 4 pp. (Processed)

Obstacles to successful artificial regeneration in California were described as adverse climate, competing brush, and rodent activity. To overcome these obstacles, several lines of research were suggested: Determine how to condition planting stock to produce a better functioning root system; lower the rate of transpiration of planted trees; find trees of hybrid or selected stock, better able to withstand adverse conditions; improve techniques of storing stock; work out minimum dosages and economical spray techniques to reduce brush competition; find more effective means of temporarily eliminating rodents from the areas; develop a repellent which will make seeds unattractive to rodents.

52. FOWELLS, H. A., and SCHUBERT, G. H.
1951. Natural reproduction in certain cutover pine-fir stands of California. Jour. Forestry 49:192-6, illus.

Reports natural reproduction on cutover pine-fir stands between 1923 and 1947. Plots were cut in 1923, 1928, and 1929 on the Stanislaus National Forest. Although numerous seed trees of sugar and ponderosa pine were left on the area, no wave of pine reproduction followed the logging disturbance. During a period of nearly 20 years, pines became established at the rate of only 70 per acre. White fir and incense-cedar seeded in to such an extent that pines comprised only 5 percent of the reproduction in 1947. Probably no more pines will become established to form a dominant part of the stand. These observations indicate that silvicultural methods for the mixed-conifer types must be changed in order to provide for adequate natural reproduction of the pines.

53. ________ and SCHUBERT, G. H.
1951. Recent direct seeding trials in the pine region of California. Calif. Forest and Range Expt. Sta. Res. Note 78, 9 pp. (Processed)

Describes several direct seeding trials in California with the following species: Ponderosa pine, Jeffrey pine, sugar pine, white fir, and incense-cedar. Forest rodents were the chief obstacle to successful direct seeding. Covering the seed spots with a wire screen was the only consistently effective means of protecting the seed from rodents. With adequate rodent protection, direct seeding was found to be a satisfactory method of regeneration.

54. ________ and SCHUBERT, G. H.
1953. Planting-stock storage in the California pine region. Calif. Forest and Range Expt. Sta. Tech. Paper 3, 12 pp. (Processed)

A series of experiments dealing with storage of pine nursery stock demonstrated that storage under refrigeration is feasible. Optimum storage temperature appeared to be within a narrow range from 32° to 36° F. All planting stock stored at below-freezing temperatures died when outplanted. Most stock stored at 41° became moldy. Over-winter storage of ponderosa and Jeffrey pines proved practicable, but results with sugar pine were not conclusive.

55. ________ and SCHUBERT, G. H.
1955. Seed crops of forest trees in the pine region of California. Calif. Forest and Range Expt. Sta., 90 pp., illus. (Manuscript report in preparation for publication as U. S. Dept. Agr. Tech. Bul.)

Summarizes 28 years of seed production of sugar pine, ponderosa pine, and white fir, chiefly on the Stanislaus National Forest. This information has been interpreted for application to cutting practices and seed collection. Sugar pine findings:

1. Almost all sugar pine cones were produced on dominant trees.

2. Dunning tree classes 3 and 5 were the best cone producers.

3. Only 6 sugar pine cone crops during the 28-year period were rated as heavy.

4. None of the trees bore cones every year and relatively few bore cones half the time.

5. In good seed years, seedfall per acre was as much as 180,000 seeds.

6. The proportion of sound seeds was usually higher in good seed years.

7. Two class 3 or 5 sugar pines per acre, about 50 inches in diameter, should produce enough seed for adequate regeneration.

8. Cone crops in some years were almost entirely destroyed by tree squirrels, birds, and cone insects.

56. FRITZ, EMANUEL.
1947. Seed production of a sugar pine tree. Jour. Forestry 45:201-3, illus.

The cone production of a sugar pine tree (52 inches d.b.h. in 1933) near Quincy, California during the period 1924-1946. In the 23-year period, the tree produced few to no cones 5 times and 9 crops of 200 or more cones. No records were available for 3 years. Heavy successive crops were produced in the 4 years 1936 to 1939 in the 3 years 1943-1945.

57. GORDON, DONALD T., and COSENS, RICHARD D.
1952. Slash disposal and site preparation in converting old-growth sugar pine-fir forests to regulated stands. Calif. Forest and Range Expt.Sta. Res.Note 81, 7 pp. (Processed)

Describes slash-disposal and site-preparation measures employed to establish sugar pine regeneration on chosen unit areas. The three objectives of slash disposal and site preparation discussed were: (1) To facilitate seeding and planting by clearing logging debris, brush, and unwanted trees from regeneration areas; (2) to provide a seedbed for sugar pine by disturbing the ground and exposing mineral soil; (3) to reduce the fire hazard.

Costs of slash disposal and site preparation are presented in three ways: (1) Per acre of regeneration area ($58.55 in 1948 and $37.38 in 1949); (2) per acre of gross area logged ($20.82 in 1948 and $8.83 in 1949); (3) per thousand board feet of all timber cut ($0.53 in 1948 and $0.22 in 1949). The lower cost in 1949 resulted from increased experience.

58. HADDOCK, PHILIP G.
 1954. Sapling sugar pines grown from excised mature embryos. Jour. Forestry 52:434-7, illus.

Young sugar pine trees were grown from excised embryos cultured on nutrient agar media. These trees averaged 7.7 feet in height at the end of 10 years.

59. HALL, RALPH C.
 1955. Insect damage to the 1954 crop of Douglas-fir and sugar pine cones and seeds in northern California. Calif. Forest and Range Expt. Sta. Misc. Paper 18, 4 pp. (Processed)

Damage caused by the sugar pine cone beetle in 1954 was reported as spotty in occurrence. Destruction of cones ranged from light to very heavy. A potential crop of 71 cones per tree was reduced to 18--a loss of 75 percent of the cones.

60. HALLIN, WILLIAM E.
 1951. Unit area control in California forests. Calif. Forest and Range Expt. Sta. Res. Note 77, 8 pp., illus. (Processed)

Unit area control is described as a silvicultural concept based on 30 years of research aimed at converting unmanaged sugar pine and ponderosa pine stands to regulated stands in which each age class through rotation is uniformly represented and adequately stocked. Experience has shown that previously used silvicultural methods have not provided adequate restocking of pine. The essential characteristic of unit area control is the detailed control of stocking on small areas.

The silvical characteristics of the major species, condition of the stand, treatments, and application of unit area control are discussed.

61. ______
 1954. Unit area control--its development and application. Calif. Forest and Range Expt. Sta. Misc. Paper 16. 10 pp.

Unit area control focuses attention upon the group-wise even-aged structure of sugar pine and ponderosa pine forests and the necessity for providing for harvesting and regeneration at appropriate times and places in order to create proper distribution of age-classes. When ready for final harvest, homogeneous groups in the stand are clear-cut. Stresses the importance of a regular planned program for regeneration cutting to secure prompt regeneration by natural means during seed years and by artificial means in other years.

62. HANSEN, HENRY P.
1943. Paleoecology of two sand dune bogs on the southern Oregon coast. Amer. Jour. Bot. 30:335-340.

An analysis of the pollen profiles of 2 peat bogs, developed in sand dune lakes, reveal forest succession for a period of 4,000 to 7,000 years. Except for two brief intervals in which <u>Tsuga heterophylla</u> predominated, <u>Pinus contorta</u> apparently was the most abundant species. Sugar pine pollen was present.

63. HAYES, G. LLOYD.
1952. Blister rust in sugar pine reproduction and the effectiveness of canker removal and weeding for promoting more sugar pine in the ultimate stand. Pacific Northwest Forest and Range Expt. Sta. (RS-NW-Special. Biological Factors. Diseases. Blister Rust Control) 21 pp. (Typewritten)

This study was undertaken on the South Umpqua Experimental Forest in southern Oregon to determine: (a) the degree of blister rust infection in selected stands of reproduction; (b) what the composition of the ultimate stand is likely to be if no effort is made to save infected trees but further infection is prevented; and (c) to find out how much the sugar pine component might be increased by canker removal and by weeding. Five plots (106 quadrats of 1/250 acre each) were examined in detail. Twenty-nine percent of the 685 juvenile pines examined were infected with rust.

The composition of the ultimate stand by species, based on the assumption of 250 crop trees per acre at rotation age, under the three conditions mentioned above, was calculated as follows:

| Species: | Complete absence of BR | If BR infected sugar pines are not counted | If BR cankers are removed and some weeding* |
|---|---|---|---|
| | (Percent) | | |
| Sugar pine | 69 | 45 | 81 |
| Douglas-fir | 18 | 35 | 12 |
| Grand fir | 8 | 12 | 4 |
| Hemlock | 5 | 6 | 3 |
| Ponderosa pine | 1 | 2 | 0 |
| Total | 100 | 100 | 100 |

*Potential crop trees have been released through weeding.

64. HODGKINS, EARL J.
1952. Effect of different heat treatments upon the viability and vigor of pine pollen. Jour. Forestry 50:450-2, illus.

Sugar pine pollen was completely killed when subjected to heat ranging from 80-82° C. for 15 to 18 hours. Other treatments had variable effects on germinative capacity and pollen vigor.

65. HUGHES, B. O., and DUNNING, DUNCAN.
1949. Pine forests of California. U. S. Dept. Agr. Yearbook 1949:352-388, illus.

An excellent general description of forest types, including sugar pine, and discussion of management problems. Presents Dunning's sketch, "Profile of central Sierra Nevada showing altitudinal limits of the principal forest types."

66. JACOBS, ALLEN W.
1924. Polyembryonism in sugar pine. Jour. Forestry 22:573-4, illus.

Reports the discovery of 12 twin seedlings from 1,200 sugar pine seeds while conducting a germination test.

67. ————
1925. Hastening the germination of sugar pine seed. Jour. Forestry 23:919-931.

Treatments which failed to increase germination were: Mechanical wounding, electrical stimulation, hot water, and too long exposure to acid. Beneficial treatments were: Soaking for 4 days in tap water and exposure to freezing for 48 hours.

68. JAMESON, E. W., JR.
1952. Food of deer mice, Peromyscus maniculatus and P. boylei, in the Northern Sierra Nevada, California. Jour. Mammalogy 33:50-60, illus.

Stomach contents of deer mice were examined in 1949 and 1950 from a mixed-conifer forest and nearby brushfields. The bulk of their diet consisted of seeds (both brush and tree species) and arthropods. Seasonal dietary changes were attributed to availability rather than preference. None of the coniferous seeds were positively identified as sugar pine; however, it was believed that many had been eaten. Although large quantities of coniferous seeds were consumed, the author warns against complete elimination of deer mice because of their beneficial effect by feeding on large numbers of destructive insects.

69. JEPSON, WILLIS L.
1923. The trees of California. Ed. 2, 240 pp., illus. Berkeley.

Excerpts from pages 155-158:

"For unnumbered centuries the mountain and valley country of California has been subjected to the influence of grass, brush, and forest fires."

"The Sierra Nevada forest, as the white man found it, was clearly the result of periodic or irregular firing continued over many thousands of years. Over large and small areas of this region wild fires have run in irregular succession......... the individual trees are extremely well-spaced and commonly form a very open forest, the degree of openness often being in direct ratio to the age of the stand......."

"The forest is not only a thin one over very extensive areas, but it is remarkably free from undergrowth or shrubs......Indeed, the main silvical features; that is, density, reproductive power, and dominance of types, are in great part expressions of the periodic fire status."

70. JOSEPHSON, H. R.
1941. Factors affecting income from second-growth forests in the western Sierra Nevada. Univ. Calif. Bul. 658. 72 pp., illus.

Data and estimates of forest incomes are presented which indicate the potential earning capacity of well-stocked stands of second-growth pine, including sugar pine. Measures needed to protect and build up the value of second-growth forest resources are also presented.

71. JOTTER, E. V.
1914. Squirrels and sugar pine reproductions. Soc. Amer. Foresters Proc. 9:98-101.

Examples are cited of the destruction of sugar pine cones by squirrels. Sometimes all cones, even immature ones less than 6 inches in length, have been cut from some trees. Many of the smaller cones, with undeveloped seed, were left intact on the ground after being cut. An estimated 50 percent of the sugar pines had no cones left on the tree at the time of maturity, and half of the remaining trees had very little of the original crop.

72. KEEN, F. P.
1929. Insect enemies of California pines and their control. Calif. Dept. Natural Resources, Div. Forestry Bul. 7, 113 pp., illus.

Annual loss due to insects in the California pine region was estimated at 500,000,000 board feet. Insects attacking pine trees from the seedlings to mature stand are discussed. A break-down of the insects attacking sugar pine indicated that 14 are found under the bark of the trunk or branches, 8 in the wood on the trunk or branches, 5 in smaller limbs and twigs, 2 in the cones, and 4 on the needles. Recommended control measures are listed and a key for field identification of the more destructive insects is included.

73. KEEN, F. P.
1952. Insect enemies of western forests. U. S. Dept. Agr. Misc. Publ. 273, 280 pp., illus.

A comprehensive treatise on the insects attacking western forest trees from seeds to the final product. Numerous insect pests of sugar pine are included.

74. KIMMEY, JAMES W.
1946. Notes on visual differentiation of white pine blister rust from pinyon rust in the telial stage. Plant Disease Reporter 30:59-61.

Five visually recognizable differences that may occur between the two rusts, *Cronartium ribicola* and *C. occidentale*, are described.

75. ———
1950. Cull factors for forest tree species in northwest California. Calif. Forest and Range Expt. Sta. Forest Survey Release 7. 30 pp., illus. (Processed)

Two types of cull factors are reported. One type, called an indicator factor, is applied to individual tree volumes. The other type, called a flat factor or general factor, is applied to stand volumes. The flat factor was found to be more suitable for sugar pine because of the relatively small cull percentage and because of "hidden" cull which reduced the reliability of the indicator factor. The percent cull in sugar pine in the Coast Range Pine Subregion of California by Dunning's tree classes was reported as:

| Tree classes: | Cull as percent of gross board-foot (Scribner Decimal C) merchantable volume |
|---|---|
| 1, 2, 6 and 7 | 5.6 |
| 3 and 4 | 6.1 |
| 5 | 11.4 |

76. KIMMEY, JAMES W.
1954. Cull and breakage factors for pines and incense-cedar in the Sierra Nevada. Calif. Forest and Range Expt. Sta. Res. Note 90, 4 pp. (Processed)

Cull and breakage factors for sugar pine growing in the eastside and westside Sierra subregions in California were reported as showing no significant difference. Factors for sugar pine were:

| Dunning tree class: | Percent of gross board-foot (Scribner Decimal C) merchantable volume | |
|---|---|---|
| | Cull | Breakage |
| 1, 2 and 6 | 1.2 | 0.3 |
| 3 and 4 | 3.7 | 3.7 |
| 5 and 5A | 6.3 | 3.8 |
| 7 | 6.7 | 0.0 |

77. ————
1954. Determining the age of blister rust infection on sugar pine. Calif. Forest and Range Expt. Sta. Res. Note 91, 3 pp. (Processed)

A study of infections occurring in a single season on 4 sugar pine plots in Oregon and 2 in California showed that: (1) The year of blister rust infection could be accurately determined for sugar pine; (2) Lachmund's method of determining the age of rust infection on western white pine could be safely applied to sugar pine.

78. KITTREDGE, JOSEPH.
1953. Influences of forest on snow in the ponderosa-sugar pine-fir zone of the central Sierra Nevada. Hilgardia 22:1-96, illus.

Describes the kinds, sizes, and densities of forests which are most effective in promoting accumulation of snow, in minimizing losses by evaporation, and in retarding and prolonging the period of melting. Results showed that rates of snow melt were less under forests than in the open and tended to decrease as the density of the forest increased. Recommends that cuttings should be light--either by the selection system or by clear cutting in narrow strips or small groups which do not exceed once or twice the heights of the trees.

79. LACHMUND, H. G.
1933. Method of determining age of blister rust infection on western white pine. Jour. Agr. Res. 46:675-693, illus.

A method was devised for postdating blister rust infections by tallying the cankers on interwhorls of recent growth wood. More than half of the cankers originating in a given year were found on wood grown in the year before the time of infection.

80. LANDQUIST, KARL B.
1946. Tests of seven principal forest tree seeds in northern California. Jour. Forestry 44:1063-6.

Presents data on number of seeds per pound, purity, and germinative energy and capacity for several coniferous species including sugar pine. The effect of stratification on germinative energy and capacity is also shown.

81. LARSEN, L. T., and WOODBURY, T. D.
1916. Sugar pine. U. S. Dept. Agr. Bul. 426. 40 pp., illus.

Comprehensive report on sugar pine. The bulletin covers such items as: Importance of sugar pine; geographical and commercial range; habit and root systems; bark, leaves, flowers, and seed; size and longevity; susceptibility to injury and disease; silvical requirements; reproduction; forest types; the wood; logging; milling; values and grades of lumber; markets; uses, stumpage prices; growth and yield; management; and management of private timberlands.

82. LITTLE, ELBERT L., JR.
1953. Check list of native and naturalized trees of the United States (including Alaska). U. S. Dept. Agr. Agr. Handb. 41. 472 pp. (Supersedes Misc. Cir. 92.)

For sugar pine gives correct botanical name--Pinaceae, Pinus lambertiana Dougl.; approved common name--sugar pine, with an alternate common name, California sugar pine; and range--"Mountains from western Oregon south to southern California and in Sierra Nevada to western Nevada. Also in northern lower California, Mexico."

83. McCLAY, THOMAS A.
1955. A preliminary statement on the economics of growing either sugar pine, ponderosa pine, or Douglas-fir on a specific area. Pacific Northwest Forest and Range Expt. Sta. (RE-NW-ECONOMICS OF MANAGEMENT. General) 5 pp. (Manuscript report)

The high stumpage value, fast growth rate, and freedom from defect of many sugar pines, compel foresters in southwest Oregon to consider it the most favorable species to grow as a future crop. An unknown factor is the silvicultural and pathological behavior of planted stands of pure sugar pine over a rotation. If no unusual complications arise in these fields, an economic comparison with ponderosa pine or Douglas-fir rests largely on the additional costs of blister rust control and the proper selection of site.

A comparative cost analysis between species involves only those initial costs to prepare the site and establish the stand; blister rust control costs are included if the crop is to be sugar pine.

Pruning costs, annual charges for administration, protection, and maintenance of improvements, and costs associated with noncommercial thinnings or release work, if any, are assumed to be about the same regardless of species and do not enter the comparison.

The initial cost ratio of sugar pine to ponderosa pine for a range of sites is shown in a table. The ratios indicate a justifiable expenditure for sugar pine for each dollar to be spent for ponderosa pine. If site index and establishment costs are the same for each species, a 30-percent additional cost might be incurred for blister rust control.

84. MacGREGOR, NEIL J.
1954. Project report on the sugar pine delineation of Mountain Home State Forest. U. S. Forest Service Region 5 Blister Rust Control Unit. 17 pp. (Processed)

This report presents an economic appraisal of proposed sugar pine management units and the formulation of blister rust control plans for areas qualifying for management on the Mountain Home State Forest located in the southern Sierra Nevada of California. The area consists of a 1,604-acre tract in the Bear Creek Unit, which was found to qualify economically for intensive sugar pine management. The report illustrates the economic approach to the selection of pine stands for management by applying directly the assumptions and methods of Vaux's analysis. Thus, the increased value expected to result from sugar pine management has been estimated and is compared with the estimated additional cost of the intensive management program. The conclusion drawn is that intensive management of the unit is justified economically.

85. McKENZIE, HOWARD L.
1941. Injury by sugar pine Matsucoccus scale resembles that of blister rust. Jour. Forestry 39:488-9.

A scale insect (Matsucoccus paucicicatrices) was reported as being injurious to the twigs and branches of young sugar pines from sapling to pole size. In the early stages, the injury is so similar to that caused by white pine blister rust that a microscopic examination is required for positive identification. Faded branchlets and twigs form conspicuous "flags," especially on the smaller branches.

86. MAGUIRE, W. P.
1952. Some observations on the use of the transpiration inhibitor "Plantcote" on lifted tree seedlings. U. S. Forest Service. Tree Planters' Notes 12:15-17.

During a 3-year period small quantities of seedlings of white fir, red fir, Douglas-fir, sugar pine, and redwood were treated by dipping the tops and roots in a solution of 1 part plantcote and 2 parts water. The seedlings were stored at $38^{\circ}$ F. for 2 months before out-planting. None of the sugar pine seedlings showed damage from drying out after 2 months in the field.

87. MASON, HERBERT L.
   1936. Principles of geographic distribution as applied to floral analysis. Madrono 3:181-190.

In a discussion relating to perpetuation and evolution of floras (pp. 187-188), Mason states as follows: "The Sierran flora as we know it does not occur in the fossil record. In every case, species belonging to it are found in close association with the redwood. In the Santa Clara lake beds of the Pliocene, for example, the (sugar) pine and Libocedrus are in association with Sequoia and Pseudotsuga. In the older tertiary beds to the north there are five-needled fascicles similar to those of Pinus lambertiana, although otherwise there exists no proof of the close relationship of this pine to the modern species."

88. ———
   1946. Edaphic factor in narrow endemism. Madrono 8:241-257.

In a consideration of some taxonomic aspects of certain endemic tree species (pp. 253-256), the author reports that sugar pine is known to grow over several types of rock but does not tolerate serpentine.

89. MARTIN, J. F. and GRAVATT, G. FLIPPO.
   1954. Saving white pines by removing blister rust cankers. U. S. Dept. Agr. Cir. 948. 22 pp., illus.

Discusses canker removal generally and the technique of removing them under different conditions of occurrence on the tree. Applicable to western species of white pines although more widely practiced in eastern states where the aesthetic values frequently exceed the timber values, depending upon the purpose of growing the trees. XX

This booklet tells how to recognize cankers, justification of removal, and explains how to best remove them. Care of wounds is discussed. Recommendations are made regarding pruning and thinning white pine stands. Reinspection of pruned trees is recommended the first and fourth years after treatment and every third year thereafter until no cankers can be found.

90. MARTINEZ, MAXIMINO.
   1945. Las pinacean Mexicanas. Section Ayacahuites. (Mex.) Univ. Nac., Inst. de Biol. An. 15:98-129

Concerns taxonomic characteristics and occurrences in Mexico of the following species and varieties of five-needled pines: (1) Pinus flexilis James, (2) P. reflexa Engelmann, (3) P. ayacahuite brachyptera Shaw, (4) P. ayacahuite veitchii Shaw, (5) P. ayacahuite Ehrl., (6) P. lambertiana Douglas, and (7) P. strobus chiapensis Martinez. Sugar pine occurs in Mexico only in Lower California, principally in the San Pedro Martir Mountains.

91. MAY, RICHARD H.
    1951. Production of logs and bolts for plywood, pulp, container veneer, shingles, cooperage, poles, and piling in California. 1950. Calif. Forest and Range Expt. Sta. Res. Note 79. 6 pp. (Processed)

The estimated production of sugar pine bolts for shingles and shakes in 1950 was 430,000 board-feet from the Pine Region in California. No sugar pine production was indicated for the other products listed in the title of the report or for the Redwood Region in California.

92. ———
    1953. A century of lumber production in California-Nevada. Calif. Forest and Range Expt. Sta. Forest Survey Release No. 20. 33 pp., illus. (Processed)

Lumber production for California-Nevada is given for the period 1869-1951. Sugar pine lumber production was estimated to have been about 35 million board feet in 1869, and 327 million in 1951. For the period 1920-51 (except for 1949 and 1950), the lumber production is subdivided into the portions produced in the Pine Region and Redwood Region. In 1920 more than 141 million board-feet of sugar pine lumber came from the Pine Region in contrast to only 75,000 board-feet from the Redwood Region. In 1951 the production figures show approximately 320 million from the Pine Region and about 7 million from the Redwood Region.

93. ———
    1954. Output of forest products in California. Calif. Forest and Range Expt. Sta. Forest Survey Release 23. 10 pp. (Processed)

The sugar pine lumber production and estimated production of logs and bolts for plywood, shingles, and shakes in California for 1952 were reported as:

| Location: | Lumber (Million bd.-ft.) | Plywood | Shingles and shakes |
|---|---|---|---|
| | | ---(Thousand bd.-ft.)--- | |
| Redwood Region | 7.0 | 20 | -- |
| Pine Region | 311.1 | 5,615 | 70 |

94. MIELKE, J. L.
    1938. Spread of blister rust to sugar pine in Oregon and California. Jour. Forestry 36:695-701, illus.

Blister rust was first detected on sugar pine in 1936 at several places in Oregon and two in California near the Oregon boundary. The following year the rust was found on ribes over a wide area extending south about 125 miles in the coastal mountains and in the Sierra Nevada. The distribution of blister rust and its behavior on sugar pine in the two states are described.

95. MIELKE, JAMES L.
1943. White pine blister rust in western North America. Yale Univ. School For. Bul. 52, 155 pp., illus.

A detailed review of the introduction of white pine blister rust into western North America and its spread from 1910 to 1942. The report discusses the epidemiology of the rust (Cronartium ribicola Fischer) and the rust infection on the white pines.

96. MILLER, JOHN M.
1914. Insect damage to the cones and seeds of Pacific Coast conifers. U. S. Dept. Agr. Bul. 95. 7 pp., illus.

Describes the character and cause of blighted cones, wormy and aborted cones, wormy seed, and maggoty cones. Practically all serious damage to cones and seeds is caused by four classes of insects: cone beetles, cone worms, seed chalcids, and fir-cone maggots. Cone beetles were noted in some seasons to destroy from 25 to 75 percent of the sugar pine cone crops over large areas.

97. MILLETT, M. A.
1952. Chemical brown stain in sugar pine. Jour. For. Prod. Res. Soc. 2:232-236.

Results showed that sugars and other materials present in the fraction of high water solubility are the substances primarily responsible for staining in sugar pine. These soluble substances are present in the sap and are concentrated at the surface of the lumber during drying. Stain retardant chemicals showed little promise of correcting this defect when used as dip treatments. It was suggested that the best means of controlling brown stain at the present time was to secure better coordination between cutting and processing operations, and to use moderate kiln-drying schedules.

98. MIROV, N. T.
1936. A note on germination methods for coniferous species. Jour. Forestry 34:719-723.

Recommends cold stratification as a pre-germination treatment for all California conifers. Untreated sugar pine seed had a germinative percent of only 28, compared to 89 percent for seed stratified for 3 months at $40^{\circ}$ F.

99. MIROV, N. T.
1940. Tested methods of grafting pines. Jour. Forestry 38:768-777, illus.

Five methods of grafting pines are reported. Sugar pine seedlings were successfully grafted on Monterey pine seedlings and on ponderosa pine transplants. The author states, "....at least for experimental purposes, the scions of any pine species can be grafted on any other pine species."

100. ———
1944. Experiments in rooting pines in California. Jour. Forestry 42:199-204.

Rooting experiments were conducted chiefly on ponderosa pine. Cuttings from sugar pine developed excellent callus and remained alive for more than 18 months, but only 2 percent rooted.

101. ———
1944. Possible relation of linolenic acid to the longevity and germination of pine. Nature (London) 154:218-9.

The ability of seeds of certain pine species to retain viability after prolonged storage may be related to the amount and activity of the unsaturated linolenic acid.

102. ———
1946. Pinus: A contribution of turpentine chemistry to dendrology and forest genetics. Jour. Forestry 44:13-16.

Discusses the present knowledge of turpentine composition, subjects needing investigation, and identification of species from turpentine. The author states that it appears "each pine species as a whole has a specific turpentine by which the pine can be easily identified." Sugar pine turpentine was found to contain a sesquiterpene, aromadendrene.

103. ———
1946. Viability of pine seed after prolonged cold storage. Jour. Forestry 44:193-5.

Report on germination of 21 species of pine after storage at 41° F. in airtight containers for periods ranging from 5 to 15 years. Sugar pine seed stored for 8 to 14 years showed considerable loss in viability.

104. ———
1948. The terpenes in relation to the biology of genus Pinus. Ann. Rev. of Biochem. 17:521-540.

This paper consists of a detailed summarization and discussion of available information on the terpene chemicals found in the genus Pinus L. A number of white pines, including sugar pine, briefly enter the summary tables and the discussion.

105. MIROV, N. T.
1953. Taxonomy and chemistry of the white pines. Madrono 12:81-89.

No definite chemical relationship was established between sugar pine and the other white pines.

106. ———
1954. Composition of turpentines of Mexican pines. Unasylva 8:167-73.

Sugar pine is found in Baja California in admixture with Jeffrey pine on high plateau range. Gives physical characteristics and chemical composition of turpentines of Mexican pines including sugar pine. Refers to book by Maximino Martinez, Los Pinos Mexicanos. Ediciones Botas, 1948, Mexico, page 361.

107. ——— , HAAGEN-SMIT, A. J., and THURLOW, JAMES.
1949. Composition of gum turpentine of Pinus lambertiana. Jour. Amer. Pharmaceutical Assoc. 38:407-8.

Describes the procedure used in analyzing the composition of turpentine from sugar pine and lists the components. Results differ from an earlier study conducted by A. W. Schorger.

108. NEWLIN, J. A. and WILSON, THOMAS R. C.
1917. Mechanical properties of woods grown in the United States. U. S. Dept. Agr. Bul. 556, 47 pp.

Lists the mechanical properties of 126 species, including sugar pine, based on tests performed on small clear pieces in a green and air-dry condition.

109. PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION.
1954. Annual Report (1953). 68 pp. (Processed)

Studies and problems dealing with sugar pine:

Sugar pine was direct seeded successfully by the use of Keyes screens preloaded with soil or vermiculite treated with Semesan and fertilizer. Sugar pine apparently can be seeded successfully at any time from August through May. Sugar pine and ponderosa pine seed coated with tetramine and dextrin also were successful in direct seeding tests.

A pilot-plant test was started to explore costs, methods, and results of pruning sapling and pole sugar pine crop trees to save them from blister rust. Some 4,000 sugar pines on a 35-acre portion of the South Umpqua Experimental Forest were marked by station personnel and pruned by a contractor. Problems concerning establishment of good natural regeneration of sugar pine and ponderosa pine were surveyed on 60 clearcut burns in the South Umpqua drainage, Umpqua National Forest.

110. PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION.
1955. Annual Report (1954). 68 pp. (Processed)

Progress report on activities pertaining to sugar pine:

The increasing use of rodenticides and rodent repellents took a set-back late in 1954 when tetramine became unavailable. Sugar pine and ponderosa pine seed, surface coated with tetramine in dextrin, fall planted in 1953, gave excellent 1-year stands of seedlings. Restocking conditions on older cutovers, largely in the South Umpqua drainage, were studied on 2,440 4-milacre plots on 61 sample cutovers. Douglas-fir was the dominant species on 62 percent of stocked plots; sugar pine and ponderosa together were dominant on 10 percent. The remaining 28 percent stocking was in less desirable species. Control of rodents by "1080" and thallium holds great promise for improving regeneration from natural seed fall. Some 4,600 sugar pine potential crop trees in the 30- to 40-year age class on the South Umpqua Experimental Forest were pruned by contract to rid them of, and to protect them from, blister rust infection. A check late in 1954 showed blister rust infection in only 6 percent of the pruned crop trees; prior to pruning 63 percent were infected.

111. POLI, ADON and BAKER, HAROLD L.
1953. Ownership and use of forest land in the Coast Range Pine Subregion of California. Calif. Forest and Range Expt. Sta. Tech. Paper 2. 64 pp., illus. (Processed)

The net volume of live sugar pine sawtimber on commercial forest land was reported as (million board-feet):

| | |
|---|---|
| Old growth sawtimber stands | 4,521 |
| Young growth sawtimber stands | 1,730 |
| Pole timber stands | 87 |
| Non-stocked | 16 |
| Total: | 6,354 |

112. POLI, ADON and BAKER, HAROLD L.
1954. Ownership and use of forest land in the Redwood--Douglas-fir Subregion of California. Calif. Forest and Range Expt. Sta. Tech. Paper 7. 76 pp., illus. (Processed)

Net volume of live sugar pine saw-timber on commercial forest land was reported as 4,694 million board-feet, which amounts to 3.4 percent of the net volume of live saw-timber in the subregion. The distribution by stand-size classes was: 3,490 million board-feet in old growth saw-timber, 829 million in young growth saw-timber stands, 372 million in pole timber stands, and the remaining 3 million in non-stocked stands.

113. QUICK, CLARENCE R.
1939. Precipitation in the Sierra Nevada, growth rate of conifer saplings, and the distribution of Ribes. Blister Rust Control, Methods Development Unit. Serial Report 103. 13 pp., illus. (Typewritten)

Precipitation records for the period 1918-1938 from four groups of weather stations in the Sierra Nevada were compiled and reduced to percentage average seasonal (July 1-June 30) precipitation. Height growth of a number of selected saplings, sugar pine and white fir, was measured at four locations in the mountains (Chowchilla Mtn., Sierra National Forest; Cow Creek, Stanislaus National Forest; Big Silver Creek, Eldorado National Forest; and Humbug Road, Lassen National Forest). Growth data were reduced to percentage average annual height growth, and compared with precipitation data. Annual height growth of saplings conformed roughly to amount of seasonal precipitation. Cumulative effects on height growth of consecutive dry years and of consecutive wet years were considerable. Differences between the two sets of averages (growth and precipitation) were sometimes marked, and unexplainable from the compiled data. A graph summarizing the increase in amount of precipitation with increase of altitude in the Sierra Nevada is appended.

114. ______
1945. Growth of Ribes, Ceanothus, and sugar pine seedlings (in the greenhouse). Blister Rust Control, Methods Development Unit. Serial Report 128. 8 pp. (Typewritten)

Report of growth tests in forest loam in large tin cans in the greenhouse (1) of gooseberry and ceanothus seedlings in mixed-species cultures and subsequent growth of sugar pine seedlings in the same soil, (2) of sugar pine and ceanothus seedlings in mixed-species culture, (3) of various densities of planting of sugar pine seedlings, and (4) of ceanothus seedlings in soil inoculated with nitrogen-fixing nodule bacteria from three sources.

Sugar pine seedlings made much better growth in general following ceanothus cropping, or mixed ceanothus and gooseberry cropping, than following gooseberry cropping alone. In first-crop cultures, sugar pine did better alone than when mixed with ceanothus. Sugar pine varied relatively little in weight per plant whether 2, 4, 5, 7, or 8 seedlings were grown for 2 years in forest loam in a #10 can (capacity 0.825 gal.). Ceanothus cordulatus seedlings grew better in soil inoculated with macerated tubercles from other plants of the same species than in uninoculated soil. Inoculation with macerated root tubercles from lupine and burclover appeared to reduce vigor of snowbrush seedling growth.

115. QUICK, CLARENCE R.
1945. Growth of sugar pine saplings on Crocker Ridge in an area of stagnated reproduction. Blister Rust Control, Methods Development Unit. Serial Report 130. 9 pp., illus. (Typewritten)

Size and growth of 15 sugar pine saplings studied in an area of dense and somewhat stagnated sugar pine reproduction along the Coulterville-Crane Flat road on a southwesterly shoulder of Crocker Ridge, Stanislaus National Forest. In 1944 the 15 sugar pine saplings averaged 5.3 feet in height, an estimated 37 years of age, and a diameter of 1.35 inches. The 15 saplings averaged 4.1 inches of mean annual height growth for the 5 years 1940-1944, and 3.2 inches mean annual height growth for the 10 years 1935-1944. Height growth was closely related to seasonal precipitation (July to June 30). Since about 1938, the 5 fastest growing saplings are rapidly pulling away from two other groups of 5.

116. ______
1947. Germination tests on sugar pine seed. Blister Rust Control, Methods Development Unit. Serial Report 136. 11 pp., illus. (Typewritten)

A group of 11 papers concerned with sugar pine germination is reviewed. Methods for germination tests in sand culture are described. Sixty to 90 days of stratification at 0° C. (32° F.) resulted in immediate 100 percent germination in the greenhouse. Stratification at 2.2° C. (36° F.) and at 5° C. (41° F.) produced similar results. Sugar pine seed planted and stratified at depths up to 1.5 inches in forest loam emerged 100 percent. Seeds at depths of more than 2.0 inches did not emerge. The more shallowly buried seeds germinated more rapidly. Of 150 seedlings on which cotyledons were counted, about 83 percent had 13 to 16 cotyledons, and about 50 percent had 14 or 15 cotyledons; the total range was from 11 to 19 cotyledons. Sugar pine seed samples varied in number of seeds per pound from 1,050 (25 "colossal" seeds picked out of a collection of large seeds) to 4,650 (100 fully-formed, presumably viable seeds extracted from other samples by shaking on a 4-mesh sieve). Seventeen seed samples averaged 2,140 seeds per pound.

117. QUICK, CLARENCE R.

1949. Some ecologic aspects of the pine inventory method for control area analysis on old cutover. Blister Rust Control, Methods Development Unit. 11 pp., illus. (Typewritten)

Reports an analysis and ecologic interpretation of experimental sugar pine inventory data collected in October and November 1948, by Roy Blomstrom, et al. Data from 7 quarter sections on the Stanislaus National Forest--2 from Bumble Bee area (northwest of Pinecrest), 3 from Cleveland Hollow (southwest of Pinecrest), and 2 from Thompson Meadow (south of Longbarn). Several tables present detailed summaries of trees by species (sugar pine, ponderosa pine, white fir), by size class, and by crown class. Tables and graphs emphasize the marked unevenness of distribution of sugar pine regeneration on old cutovers. The report points up the difficult problem of selecting sugar pine areas and boundaries of areas for Blister Rust Control units in old cutovers.

118. ———

1949. A comparison of sugar pine inventory data from one forty: Stocked quadrat versus continuous strip. Blister Rust Control, Methods Development Unit. 6 pp., illus. (Typewritten)

A single "40" of Blister Rust Control area near Bumble Bee Camp (northwest of Pinecrest), Stanislaus National Forest, was systematically sampled three times by hand compass and pacing to determine amount and distribution of sugar pine regeneration. Sampling methods were: (1) Stocked quadrat sample--quadrats of 4 milacres, spaced 1 chain apart on survey lines 2 chains apart and (2) Continuous strip survey--strips 1/4 chain wide and 2.5 chains apart, run east-west; transects 1 chain long, a 10 percent sample. (3) Continuous strip survey--strips 1/2 chain wide and 2.5 chains apart, run southwest-northeast; transects 1 chain in length, a 20 percent sample.

Seven out of 200 quadrats (4 milacres each) were found stocked with one or more dominant sugar pines, or with 2 or more codominant sugar pines, 18 inches d.b.h. or less. Similarly, 26 out of 160 1/4- x 1-chain transects, and 44 out of 160 1/2- x 1-chain transects, were found stocked with dominant sugar pine regeneration. The continuous strip samples gave a much better distribution pattern of sugar pine regeneration than did the stocked quadrat samples. The stocked-quadrat sample was considered grossly inadequate on small areas.

119. ———

1950. Compound interest and sugar pine investments. Blister Rust Control, Methods Development Unit. 2 pp., illus. (Typewritten)

Cites Rietz, H. L., et al -- Mathematics of Finance, as a general mathematical treatment of compound interest. A general formula for the amount of $1 at compound interest is: $s = (1 + i)^n$, where s = the eventual sum, i = the interest rate, and n = the number of periods of compound interest. The sum of $1 increased by interest compounded annually, at various percentages of interest up to 7 percent, and for lengths of time up to 100 years, is presented in table and graph. The amount of $1 at 2.5 percent interest climbs to $2 at 30 years, $3 at 45 years, $5 at 65 years, $11.81 at 100 years, and $52 at 160 years.

120. QUICK, CLARENCE R.
1950. Trees per acre in the Sierran mixed-conifer forest. Blister Rust Control, Methods Development Unit. 6 pp. (Typewritten)

Considers the mathematical approach to figure 2 of Dunning and Reineke (42, page 9). This figure, a log-log graph published in 1933, defines the relationship between number of trees per acre and average diameter in inches for various stand-density indices. The stand-density index of 800 was taken "as a fair index for full stocking in these mixed-conifer stands." Figure 2 is compared with a similar graph, "Number of dominants and all trees in relation to average dominant," prepared by Dunning in 1949 for the Region 5 training school in timber management. The 1949 curve declines much less rapidly than the 1933 curve in number of trees with increase in tree size. The "Dominants" line of Dunning's 1949 graph is approximated by a formula. Values for number of dominants per acre for diameters from 4 inches to 30 inches are computed from this formula and presented in a table.

121. ———
1950. Ribes regeneration on the Fanianni (Collins Pine) 1-acre timber plot. Blister Rust Control, Methods Development Unit. Serial Report 146. 14 pp., illus. (Typewritten)

Analyses data collected from a 1-acre plot established in the fall of 1940 on the Lassen National Forest. Development of gooseberry populations after ribes eradication in 1940 and 1947, and after road building and light logging in 1942-43, is described in relation to abundance of mature timber, advance coniferous regeneration, and other vegetation. There were 54 sugar pines on the acre at time of plot initiation, and 37 in 1945 after light logging in 1942-43. Five big overmature and 12 smaller sugar pines were removed.

122. ———
1951. Ribes persistence and regeneration on the Pilot Peak 1-acre plot. Blister Rust Control, Methods Development Unit. Serial Report 147. 17 pp., illus. (Typewritten)

Describes persistence of old gooseberry plants, the occurrence of seedlings, and the establishment of young gooseberry plants in well-developed vegetation on old cutover at an altitude of about 4800 feet on the Sierra National Forest. The plot was established in July 1937. Ribes were eradicated in 1937, 1940, and 1948. In 1945, 100 of the 152 sugar pines on the 1-acre plot were between 2 feet and 11 feet in height. There were no sugar pines under 6 inches in height, and no merchantable sugar pine trees on the plot.

123. QUICK, CLARENCE R.

1951. Natural regeneration of sugar pine following a burn in mature timber. Blister Rust Control, Methods Development Unit. 6 pp. (Typewritten)

Reports natural regeneration of sugar pine and of other tree species on a burn in overmature timber just southwest of Cow Creek Guard Station, Stanislaus National Forest. The burn, of about 1.5 acres, occurred in August 1936, near the west end of plot MC-12 of the California Forest and Range Experiment Station. Intensity of the burn varied greatly--from a slow ground fire at the west edge to an intense fire which killed merchantable trees toward the east margin of the burn. Dense sugar and ponderosa pine regeneration--approximately 6,500 seedlings per acre--started in the spring of 1937 following a very heavy seed crop the preceding fall. Pine regeneration dominated the burn in 1951, and vigorous young pine trees were growing in some places where fire destroyed dense thickets of white X fir regeneration.

124. ———

1953. Search for plant-indicator species on blister rust infection areas. Blister Rust Control, Methods Development Unit. 14 pp. (Typewritten)

Reports an attempt to discover plant species or combinations of species which would identify or which would help to define local areas in the Sierra Nevada where sugar pine would be seriously attacked by blister rust. All areas studied were in good sugar pine habitats. More than 125 species of plants were observed and recorded on 17 areas on the Lassen (5), Plumas (6), and Stanislaus (6) National Forests. No clear-cut plant indicators of areas particularly hazardous to sugar pine were found.

125. ———

1954. Ecology of the Sierra Nevada gooseberry in relation to blister rust control. U. S. Dept. Agr. Cir. 937. 30 pp., illus.

A comprehensive treatise on the ecology of Sierra Nevada gooseberry (Ribes roezli Regel), an alternate host of white pine blister rust which threatens to destroy sugar pine on several million acres in California and southern Oregon. Approximately 175 million ribes plants were destroyed during the period 1926-1948 for the protection of sugar pine. About 90 percent of the time and money expended on the removal and suppression of ribes was on the Sierra Nevada gooseberry.

Mature gooseberry plants are intolerant and may be completely crowded out of well-stocked timber stands. They grow most abundantly on denuded areas and can endure long summer drought. Mortality in the seedling stage is very high. Summer drought and competition with other larger plants prevent the establishment of large numbers of seedlings. Seeds are produced on plants 3 years or older. Although the seeds are small, they remain viable for many years in the duff and germinate vigorously following fire or logging. The best time to start eradication is immediately after a major disturbance such as logging or fire. The second best time is just prior to logging. All seed producing plants should be destroyed before the fruit matures.

126. RIGHTER, F. I.
1939. Early flower production among the pines. Jour. Forestry 37:935-8.

The average minimum age of ovulate flower production for 55 species and varieties of pine was reported as 5.2 years at the Institute of Forest Genetics at Placerville, California. The average minimum age for pollen production was 4.4 years. Sugar pine produced pollen at the age of 7 years; however, no minimum age was given for ovulate flower production.

127. ROY, D. F.
1955. The Clements growth prediction charts for residual stands of mixed conifer in California. Calif. Forest and Range Expt. Sta. Tech. Paper 9. 12 pp. (Processed)

Describes alinement charts for predicting growth of residual trees, ingrowth, and mortality during the first 20 years after partial or selective cutting.

128. ——— and SCHUBERT, G. H.
1953. K-screen seed spots. Calif. Forest and Range Expt. Sta. Res. Note 88. 2 pp. (Processed)

Describes a small tube-shaped protective screen used in seed spotting with sugar pine, ponderosa pine, Jeffrey pine, and Douglas-fir seed. (In Oregon the device is sometimes called a Keyes screen.) Results of direct seeding trials using the K-screen have been erratic. Under certain conditions, seed germination in the screen has been disappointing. The screens have been frost heaved, and they sometimes were knocked out of the ground by livestock, deer, and some of the larger rodents.

129. SACHER, J. A.
    1954. Structure and seasonal activity of the shoot apices of *Pinus lambertiana* and *Pinus ponderosa*. Amer. Jour. Bot. 41:749-59, illus.

Seasonal changes in the shoot apices of sugar and ponderosa pines were studied near Berkeley, California. New bud formation began about the middle of May and was completed by the first of October; terminal bud scales were produced at the end of the season's growth; buds were dormant from October through March; bud expansion and shoot elongation began the first of April through the first week of May.

130. SAMPSON, ARTHUR W., and DAYTON, WILLIAM A.
    1913. Relation of grazing to timber reproduction. Rev. Forest Service Invest. 2:18-24.

Describes grazing damage by cattle, sheep, and goats on a series of plots located on the Shasta National Forest. Coniferous species found on the 43 sample plots, 12 of which were fenced, were: Sugar pine, ponderosa pine, Douglas-fir, white fir, and incense-cedar. Of the 215 sugar pines under 5.5 feet high, none were killed by grazing, 4 were trampled (1 by cattle, 2 by sheep, and 1 by goats), and 65 were grazed (10 by cattle, 14 by sheep, and 41 by goats). A large part of the grazing injury was very minor--removal of a few needles or lateral buds--and was not considered serious except that the lesions might serve as entrance places for parasites.

131. SARGENT, CHARLES SPRAGUE.
    1933. Manual of the trees of North America (exclusive of Mexico). Ed. 2, 910 pp., illus. Boston and New York.

Detailed description of taxonomic characteristics and natural ranges of trees including sugar pine. Class *Gymnospermae*, Family *Pinaceae*, Genus *Pinus*, Species *lambertiana* Dougl.

132. SCHUBERT, G. H.
    1950. Quintuplet seedlings in a sugar pine seed. Jour. Forestry 48:128-9, illus.

A case is cited in which 1 sugar pine seed had 5 developed embryos. In the group of 1,600 sugar pine seeds, there were also 14 with twins and 3 with triplets.

133. SCHUBERT, GILBERT H.
    1950. Viability losses of sugar pine (*Pinus lambertiana*, Dougl.) seed infected with certain fungi. Thesis, M.S., Univ. of Calif., Berkeley, Calif. 57 pp., illus. (Typewritten)

Viability losses of sugar pine seed infected with several fungi were investigated. Losses due to *Cylindrocarpon*, *Mucor*, and *Rhizopus* were found to be low--generally no greater than would be expected through normal sampling errors. Poor stratification technique and improper collecting and handling of seed were believed to be the main causes for the low viability of some of the seed tested.

134. SCHUBERT, G. H.
1952. Germination of various coniferous seeds after cold storage. Calif. Forest and Range Expt. Sta. Res. Note 83. 7 pp. (Processed)

Results of germination tests show that seed of most conifers, including sugar pine, can be collected in large quantities during good seed years with assurance that they will retain high viability for intervals sufficiently long to tide over poor seed years--providing the seed is properly handled and stored. Several conditions pertaining to proper handling and storing of seeds are listed and explained.

135. ———
1953. A trial of three chemicals as rodent repellents in direct seeding. Calif. Forest and Range Expt. Sta. Res. Note 84. 2 pp. (Processed)

Three chemicals--sodium fluoroacetate (compound "1080"), red lead, and zinc phosphide--were tested as rodent repellents. The chemicals were applied as a thin coat over the seed. Dowax and asphalt were used as carriers. A total of 464 sugar pine seed spots were sown with 5 seeds per spot. None of the three chemicals proved effective as rodent repellents.

136. ———
1953. Ponderosa pine cone cutting by squirrels. Jour. Forestry 51:202, illus.

Cites an instance in which 863 out of 926 ponderosa pine cones from a single tree were destroyed by squirrels. Little cone cutting was evident on several nearby large sugar pines bearing 50 or more cones each.

137. ———
1954. Viability of various coniferous seeds after cold storage. Jour. Forestry 52:446-7.

Report on the results of germination tests on 42 coniferous species which had been stored in 5-gallon cans with tight lids at 41° F. from 2 to 24 years. The length of time sugar pine seed remained viable varied considerably and depended on the condition of the seed when collected and on how it was handled. One seed lot, stored for 15 years, had 50 percent viability. However, another lot with an original viability of 90 percent dropped to 10 percent in 3 years.

138. SCHUBERT, GILBERT H.
1955. Freezing injury to sugar pine cones. Calif. Forest and Range Expt. Sta. Res. Note 96, 2 pp., illus. (Processed)

Immature sugar pine cones were reported to have been killed by a severe late spring freeze on the Stanislaus Experimental Forest in 1954. Although no other instances of freezing injury to young sugar pine cones have been reported, it is believed that some frozen cones may have been erroneously classified in the past as "next year's cones."

139. ———
1955. Freezing injury to young sugar pine. Jour. Forestry 53:732.

Young sugar pine seedlings and transplants were reported to be susceptible to late spring and early fall freezing temperatures of about 18° F. An early fall freeze severely damaged all of the 1-0 seedlings in two 4- by 12-foot seedbeds. A late spring freeze killed 74 percent of the seedlings in unscreened seed spots sown earlier that spring and damaged all or most of the new growth on 66 percent of the 3-year old transplants. Seedlings which were under wire screens sustained less freezing injury than the seedlings in unscreened seedspots--31 percent as compared to 74.

140. ———
1955. Effect of ripeness on the viability of sugar, Jeffrey, and ponderosa pine seed. (Paper presented at annual meeting, Soc. Amer. Foresters, Portland, Oregon, Oct. 17-20, 1955, and submitted for publication in Proceedings.) Illus.

Immature sugar pine and Jeffrey pine seed were observed to produce a large number of abnormal seedlings--nearly half of the sugar pine and a third of the Jeffrey pine. No abnormal seedlings were observed among the ponderosa pines or the seedlings derived from mature sugar and Jeffrey pine seed. Therefore, it was believed that abnormal seedling development was associated with immature seed. The viability of immature ponderosa pine seed was about half that of mature seed for both fresh and stored seed. Less than 1 percent of the immature sugar pine seed was viable after 3 years' storage compared to 72 percent for mature seed.

141. SHOW, S. B.
1926. Timber growing and logging practice in the California pine region. U. S. Dept. Agr. Dept. Bul. 1402. 75 pp., illus.

The measures considered necessary to keep forest lands productive and to produce full timber crops are discussed. One of the most stressed points is to protect the advance reproduction from fires and logging. Others are to leave sufficient trees for seed production to insure restocking and to maintain the pines in the new stands; to combine in the reserve trees the highest possible qualities of growth and seed production; and to remove all the mature and poor risk trees. These measures have to be attained while making the operation profitable.

Under conditions affecting the private timber operator, current expenses incurred to protect and carry the operation as a whole should not be carried at compound interest but should be wiped off the books annually as the necessary current costs for doing business. That is, they should be handled in the same way that a storekeeper charges his rent and taxes to determine his yearly net operating profit.

142. SHOW, S. B.
1930. Forest nursery and planting practice in the California Pine Region. U. S. Dept. Agr. Cir. 92, 75 pp., illus.

One of the most complete reports on forest nursery and planting practice in California. This circular is out of print; however, reference copies are available in most libraries. Many of the practices recommended are still applicable today. The report covers such items as: germination and viability of seed; season, density, and depth to sow seed; shading, watering, and cultivation of seed beds; class of stock and season for planting; and problems encountered with nursery and planting stock.

143. ——— and KOTOK, E. I.
1929. Cover type and fire control in the national forests of northern California. U. S. Dept. Agr. Dept. Bul. 1945. 35 pp., illus.

Describes 9 major cover types of the California pine region with distinct and characteristic differences which bear directly on fire danger, fire risk, rate of spread, and ease of control. Sugar pine occurred in two of the major types: mixed-conifer and sugar pine-fir. These two types are generally subject to surface and ground fires; most of the fires were caused by lightning. The average length of fire seasons was 5-1/3 months in the mixed conifer and 4 months in the sugar pine-fir types; most fires occurred in August.

144. ——— and KOTOK, E. I.
1930. The determination of hour control for adequate fire protection in the major cover types of the California pine region. U. S. Dept. Agr. Tech. Bul. 209. 46 pp., illus.

"Hour control" is the speed-of-attack factor. It includes the total time elapsing from the start of the fire until the first suppression crew begins work onthe fire. Based on the analyses of fire records for the period 1923-28, the average hour control necessary to give adequate protection were: For the mixed conifer type, 3/4-hour; for the Douglas-fir type, 2-hour; and for the sugar pine-fir type, 4-hour.

145. SIGGINS, HOWARD W.
1933. Distribution and rate of fall of conifer seeds. Jour. Agr. Res. 47:119-128, illus.

The rate at which seeds fell was found to vary greatly with size, weight, and shape, with area and conformation of wing, and with combinations of these seed and wing characteristics. Sugar pine seed with its single, large terminal wing had an average rate of fall of 8.7 feet per second in still air. Average rates for several common associates were: Jeffrey pine, 7.25 feet per second; ponderosa pine, 5.0; white fir, 5.7; red fir, 5.3; and incense-cedar, 5.9.

The distribution of seeds from the cones varies with the height from which released, the rate of release, and the direction and velocity of the wind. A steady wind from one direction deposited the seed in the form of a "V" with the apex at the base of the tree. No data are presented for the number of seeds deposited per square foot; however, the statement is made that the concentration of seed decreases gradually with increasing distances from the base of the tree.

146. SKINNER, EDGEL C.
1955. Log position volume tables for western conifers based on the Girard and Bruce form class volume tables for 16-foot logs. Pacific Northwest Forest and Range Expt. Sta. 54 pp. (Processed)

Contains board-foot volumes by the Scribner rule for individual logs of coniferous trees with form classes from 65 to 90, for diameters at breast height from 10 or 12 to 90 inches, and for merchantable heights from 1 to 11 logs.

147. SMITH, CLARENCE F. and ALDOUS, SHALER E.
1947. The influence of mammals and birds in retarding artificial and natural reseeding of coniferous forests in the United States. Jour. Forestry 45:361-9.

A review of past efforts at artificial and natural reseeding of coniferous forest beginning with the first attempt at direct seeding in 1901 on the San Bernardino National Forest, California. Based on 65 literature references and the authors' own studies, 44 mammals and 37 birds were listed which were found to eat coniferous seeds. The tree squirrels, chipmunks, white-footed mice, and a few species of seed-eating fringillid birds were reported as responsible for the greater part of all seed depredation.

Several protective measures discussed were: reductional control--removal of all or almost all seed eating animals; repellents or mechanical barriers--lethal baits applied to the seed or ground and use of mulches or screens; cultural measures--ground preparation, time of planting, and methods of seeding.

Although occasional successes were noted, no consistently good results were reported for any of the techniques with the exception of wire cone screens which were considered too expensive except on experimental areas.

148. SOCIETY OF AMERICAN FORESTERS, COMMITTEE ON FOREST TYPES.
1954. Forest cover types of North America (exclusive of Mexico). 67 pp., illus. Washington, D. C.

Sugar pine occurs in nine cover types of western North America. It is one of the major components in the ponderosa pine-sugar pine-fir type and a minor component in the following cover types: red fir, white fir, Pacific Douglas-fir, Port-orford-cedar--Douglas-fir, Pacific ponderosa pine--Douglas-fir, Pacific ponderosa pine, California black oak, and Jeffrey pine.

149. SOVULEWSKI, ROBERT and HARRIS, THOMAS H.
1948. A method for the classification of sugar pine lands. Jour. Forestry 46:432-7.

A method is presented to aid in selecting stands of sugar pine for protection against blister rust. Based on productivity judged by forecasting yield on various sites with different stocking of sugar pine.

This method is now superseded by the delineation method based on Vaux's rating tables of 1954. (See Vaux, 1954.)

150. SPENCER, D. A. and KVERNO, N. B.
1953. Research in rodent control to promote reforestation by direct seeding. U. S. Fish and Wildlife Service Prog. Report 3, 66 pp., illus. (Processed)

Deals mainly with application of tetramine to coniferous tree seed to prevent their consumption by rodents. The results with tetramine-treated sugar pine seed were reported as erratic with present techniques of seed treatment. The tests have shown that the injury to the seed was due to the acetone carrier and not due to the tetramine. Seedlings grown from tetramine treated seeds were also protected from rodents during the first few weeks after germination.

151. STEIN, WILLIAM I.
1955. Some lessons in artificial regeneration from southwestern Oregon. Northwest Science 29:10-22, illus.

Several methods of artificial regeneration were tested: Planting nursery stock, sowing seed in unprotected seedspots, and planting seedspots protected with conical screens and K-screens. Trials with several insecticides (aldrin, dieldrin, chlordane, and benzene hexachloride) and fertilizers (bonemeal, superphosphate, muriate of potash, and ammonium phosphate) were also included in the studies.

In several studies conical screens failed to give good protection, whereas properly installed K-screens consistently protected both seeds and seedlings. Results of several planting and direct seeding tests showed:

| | Planting | | Direct seeding protected with K-screens | | |
|---|---|---|---|---|---|
| | Trees planted (Number) | First-year survival (Percent) | Seedspots (Number) | Initial stocking (Percent) | First-year stocking (Percent) |
| Douglas-fir | 50 | 16 | 160 | 52 | 16 |
| Ponderosa pine | 550 | 76 | 160 | 74 | 49 |
| Sugar pine | 400 | 60 | 820 | 96 | 59 |

The four insecticides had no harmful effect on the germination of sugar pine, ponderosa pine, or Douglas-fir; however, benzene hexachloride killed all the seedlings within a few weeks after germination.

No consistent effects on survival, beneficial or detrimental, were noted for the addition of fertilizers to the soil used in the K-screens.

152. ______
1955. Preliminary recommendations for seedspotting sugar pine in southwest Oregon. Pacific Northwest Forest and Range Expt. Sta. Res. Note 118. 6 pp., illus. (Processed)

Recommendations are presented for seedbed preparation, rodent control, seeding method, time to seed, and choice of seedspot locations. Recommendations include: Sow seedspots in mineral soil free of vegetative competition; prevent rodent damage with repellents or poison baits; sow 2 seeds per spot; space seedspots 4 x 8 feet; plant seed in the fall. Based on past experiments, 20 guides as to choice of seedspot locations are presented.

153. STOCKWELL, PALMER
1942. Pinus embryo size compared with growth rate. Amer. Nat. 76:431-2.

Tests made with sugar pine seed failed to show a significant correlation between size of embryo and size of resultant seedlings.

154. STONE, E. C. and DUFFIELD, J. W.
1950. Hybrids of sugar pine by embryo culture. Jour. Forestry 48:200-1, illus.

Describes a modified embryo culture technique successfully used to germinate sugar pine.

155. STRUBLE, G. R.
1947. Twig damage in sugar pine caused by cone beetle. Jour. Forestry 45:48-50, illus.

The sugar pine cone beetle (Conophthorus lambertianae Hopk.) was reported as a twig miner in the adult stage. Twig killing appeared to be associated with cone production. Trees in areas where cones were infested and killed by the cone beetles were most heavily flagged.

156. SUDWORTH, GEORGE B.
1908. Forest trees of the Pacific slope. U. S. Dept. Agr., Forest Service. 441 pp., illus.

Detailed description of identifying characters, range, and occurrence.

157. TEVIS, LLOYD JR.
1953. Effect of vertebrate animals on seed crop of sugar pine. Jour. Wildlife Management 17:128-31, illus.

In 1951, 20 mature cone-bearing sugar pine trees were tagged near Lake Almanor in Plumas County, California. The cones were counted on 5 dates between August 14 and September 23. Of the original 1,656 cones counted, 896 (54 percent) were reported as cut by pine squirrels (Tamiasciurus douglasii), 559 (34 percent) were destroyed by white-headed woodpeckers (Dendrocopus albolarvatus), and only 201 (12 percent) were undamaged. Squirrels cut some cones from all 20 trees, whereas woodpecker damage was noted only on half of the trees. Woodpeckers destroyed 85 percent of the original 358 cones on one tree and 7 pines lost all cones to squirrels and woodpeckers.

Stellar jays (Cyanocitta stelleri) were noted picking seed from the few cones left undamaged on the trees after the cones began to open.

White-breasted nuthatches (Sitta carolinensis), red-breasted nuthatches (Sitta canadensis), and mountain chickadees (Parus gambeli) were observed removing seeds from cones cut by squirrels which opened on the ground.

Seeds which were shed from open cones on tree or accidentally dropped by birds were consumed by chipmunks (Eutamias amoenus, E. speciosus, and E. townsendi ), by white-footed mice (Peromyscus maniculatus), and by mantled squirrels (Citellus lateralis).

As a result of seed depredation by all the birds and mammals noted, it was stated that probably none of the seeds from the 1,656 cones remained to develop into seedlings.

158. TEVIS, LLOYD, JR.
1953. Stomach contents of chipmunks and mantled squirrels in northeastern California. Jour. Mammalogy 34:316-24, illus.

The feeding habits of four species of chipmunks (Eutamias amoenus, E. speciosus, E. townsendi, and E. quadrimaculatus) and one species of mantled squirrels (Citellus lateralis) were studied in a mixed-conifer forest composed of ponderosa, Jeffrey, and sugar pines, Douglas-fir, white fir, and incense-cedar.

Although the sugar pine seed crop was very light in the study area in 1951, no significant quantities were found in stomachs of animals trapped under a few productive sugar pines. The reasons presented were that chipmunks generally cached the seeds and mantled squirrels consumed relatively few coniferous seeds because hypogeous fungi were common. Chipmunks were observed to prefer pine seed over cedar and white fir seed.

159. TILLOTSON, C. R.
1917. Reforestation on the national forests. U. S. Dept. Agr. Bul. 475. 63 pp., illus.

Early seed collecting and processing, direct seeding, and planting practices are described. The primary value of this bulletin is for comparisons with present-day practices. The cost of sugar pine seed ranged from 50 to 65 cents per pound; direct seeding was not recommended because of rodent depredation; and spring planting was recommended for northern California, Oregon, and Washington and fall planting for southern California. In order of preference, recommended classes of sugar pine stock for field planting were 2-1 and 1-2.

160. U. S. FOREST SERVICE, California Region.
1940. Timber management handbook. (Pages revised as needed.) (Processed)

This handbook gives procedure and differs from the Forest Service Manual which states and explains timber regulations and policies. The Handbook includes prescribed standards and information about Dunning's tree classes, slash disposal, sale inspection, annual reports on sales, intensity of cruises, general facts on blister rust control, insect reports, and permanent plots for growth and mortality. Many additional procedures are covered in separate handbooks and special memoranda concerning planting, delineation of sugar pine management areas, ribes control, timber appraisal, intensive timber surveys, and related subjects.

Mimeographed copy in each Supervisor's office and Ranger Station in the California Region. Not available for distribution.

161. U. S. FOREST SERVICE, California Region.
1948. Volume tables. Form 191, R-5 1948, Division of Timber Management, Regional Office San Francisco. (Processed)

Sugar pine volume tables based on Site I and II, prepared by Dunning in 1925. (Scribner Decimal C. Stump height 18 inches, 16-foot logs, 0.3-foot trim allowance, top utilization 8 inches inside bark.) Use Site II tables for poorer sites.

162. ______
1948. Wood plant seed manual. U. S. Dept. Agr. Misc. Pub. 654, 416 pp., illus.

Comprehensive treatise on seed development, production and dispersal, source, collection, extraction, storage, treatments such as stratification, and testing. Section on Pinus includes information about sugar pine: Flowering, May-June; ripening, August-September; seed dispersal, August-October; commercial seed bearing age, minimum, 40-50 years; optimum, 125-175 years; frequency of good crops, 3-5 years; time of collection, August-September; closed cones per bushel, 20; extraction practice, sun dry or convection; cleaned seed per bushel of cones, 25-32 ounces; seed per 100 pounds of cones, 3.0 pounds; clean seed per pound, low--1,500, average--2,100, high--3,200; purity 99 percent; soundness 83 percent; cost per pound, $1.25 to $2.00; viability in sealed storage, 10 + years; dormancy, probably embryo; occurrence of dormancy, variable; stratification, moist sand or peat at 35-50° F. for 90 days; test germination 60° F. at night and 70° F. in day for 120 days with untreated seed and for 40 days with pretreated seed; average germination capacity 56 percent.

163. U. S. FOREST SERVICE.
1953. Sugar pine (Pinus lambertiana). Useful trees of the United States No. 4. 4 pp., illus.

An illustrated leaflet on sugar pine containing general information on distribution and identifying characteristics.

164. ——— California Region.
1953. Proposed Region 5 work specification for sale-area betterment. Prune crop trees to make clear lumber or veneer. 3 pp. (Processed)

Describes proposed pruning guidelines within and outside sugar pine management areas on national forests in California. If within, recommends: Prune crop trees and release and prune potential crop trees. If outside, recommends: Where rust hazard is low, prune crop trees; where hazard is medium, prune only sugar pine 11 inches d.b.h. and larger (only Site II and better will qualify for pruning under the proposed guidelines); where hazard is high, prune no sugar pine.

165. ——— California Region.
1954. Forest facts about your national forests in California Region of U. S. Forest Service. 64 pp. (Processed)

Appraised and bid price per M b.m. for sugar pine and ponderosa pine (includes K-V payment of about 90¢ per M b.m.):

| Year | Sugar pine | | Ponderosa pine | |
|---|---|---|---|---|
| | Appr. price | Bid price | Appr. price | Bid price |
| 1951 | $37.05 | $40.43 | $27.48 | $33.64 |
| 1952 | 33.45 | 38.00 | 26.70 | 28.43 |
| 1953 | 30.35 | 31.55 | 26.18 | 28.39 |

Sales made of green timber (excludes salvage), national forests in California, 1953 (includes K-V payment of about 90¢ per M b.m. for each species):

| Species | Vol. | Appr. per M b.m. | Bid per M b.m. | Pct. bid exceeded appraisal |
|---|---|---|---|---|
| | M b.m. | | | |
| Ponderosa | 143,038 | $26.18 | $28.39 | 8.4 |
| White fir | 122,892 | 3.87 | 4.83 | 24.8 |
| Douglas-fir | 112,770 | 5.42 | 6.10 | 12.5 |
| Sugar pine | 58,920 | 30.35 | 31.55 | 4.0 |
| Incense-cedar | 13,258 | 3.47 | 3.68 | 6.1 |
| Others | 4,000 | - | - | - |
| Total or ave. | 454,878 | $14.74 | $16.04 | 8.8 |

166. U. S. FOREST SERVICE.
1954. The answer to the menace of white pine blister rust. U. S. Dept. Agr. 14 pp., illus. (Processed)

Prepared for public distribution. Discusses the spread of white pine blister rust in California and the threat to sugar pine. Explains methods of control and objectives of control. Much of the leaflet is in the form of questions and answers about technical points of control work, pathological features of the disease, economic factors in control work and progress in control work to date. A brief but thorough coverage of the blister rust control problem.

167. ——— and OFFICE OF BLISTER RUST CONTROL.
1952. Sugar pine delineation manual. Forest Service, California Region and Bur. Ent. and Plant Quarantine, Off. Blister Rust Control. 52 pp. (Processed) (Supersedes instructions issued separately in 1951.)

Gives instructions for sampling sugar pine areas on private and national-forest land to evaluate them for sugar pine management, based upon rating tables developed by Vaux (170).

168. VAUX, HENRY J.
1948. Some economic aspects of growing sugar pine in California. Calif. Forest and Range Expt. Sta. Res. Note 58. 33 pp., illus. (Processed)

Forms the initial groundwork for Vaux's bulletin of 1954 on "Economics of the young-growth sugar pine resource," Univ. Calif. Agr. Exp. Sta. Bul. 738.

Discusses the need for research, sugar pine types, areas, and volumes. Investigates sugar pine markets, consumption, principal uses, competitive positions, and long-run market outlook; also, trends in sugar pine values of stumpage and lumber, and the cost elements in growing sugar pine.

169. VAUX, HENRY J.

1954. An economic viewpoint on Pacific Coast forest planting. 1954. Univ. of British Columbia, Lecture Series 23. 17 pp.

Economic problems of planting must be answered in reference to future markets in which the planted timber will be sold rather than to present markets.

Expansion of demand for Pacific Coast timber crops is possible. The present cut of all species in British Columbia, Washington, Oregon, and California is 25 billion board-feet per year. At this rate, the mature stand will last 40 years more. Immature stands, which are the growing stock, would last another 35 years if cut at the same rate. During the past 10 years, the demand has increased one-half of 1 percent per year. If this increase continues, the Pacific Coast deficit will be one-half of its growing stock within 70 years.

Costs of planting always appear as a cash outlay, whereas most costs of natural regeneration do not. For example, natural regeneration of sugar pine in California requires 3 to 5 seed trees per acre. Good sugar pine seed producers usually must be at least 30 inches in diameter and often contain high quality lumber. Reserving them from cutting means leaving as much as $300.00 worth of stumpage on each acre. Because effective sugar pine seed crops occur infrequently, this seed-tree investment has to be maintained for at least 5 years before it can be liquidated by cutting. At 3 percent per year, the interest costs thus incurred have a value of more than $40 per acre, a little more than the current cost of sugar pine planting. Additional real costs of natural regeneration include such items as slower establishment and consequent lengthening of the production period, risk to the large seed-tree investment, and damage to the young stand when seed trees are removed. Thus, planting of sugar pine shows up clearly as a less costly alternative than natural regeneration.

This view of planting problems on the Pacific Coast indicates that the economic advantage of the area would be best served by rehabilitating through planting at least the more productive part (Site III and better) of the existing idle forest land.

170. ______

1954. Economics of the young-growth sugar pine resource. Calif. Agr. Sta. Bul. 738. 56 pp., illus.

Sugar pine occurs on more than 2 million acres of commercially available land outside of national parks. Three-fourths of this is in California and one-fourth in Oregon. In California, half is privately owned and half federally. Blister rust control is the key to production, but pruning and release of potential crop trees and other management measures also are essential. The objective of management must be to extend efforts to grow sugar pine just to the point where additional returns from sugar pine production are offset by the additional costs which are incurred.

Average annual production of sugar pine from 1949 to 1951, inclusive, was 400 million board-feet. Even in old-growth timber, less than 40 percent of the sugar pine cut is premium quality. The rest is common grades which could be replaced by ponderosa pine commons. The old-growth supply will last about 60 years more (until 2014).

Cost per acre of growing sugar pine, for 1950 dollars, 2-1/2 percent rate of interest, and a risk allowance of 25 percent of other costs, is estimated as follows:

| | |
|---|---|
| Rust control | $27.00 |
| Two releases of potential crop trees | 5.40 |
| Pruning | 4.80 |
| Additional roads and other capital development | 8.80 |
| Replacement factor | 3.50 |
| Total extra cost of management: | $49.50 |

Size of sugar pine at maturity:

| Site class: | d.b.h. | Volume, board-feet |
|---|---|---|
| A-200 | 38 | 2,780 |
| I-175 | 34 | 1,750 |
| II-150 | 30 | 1,050 |
| III-125 | 26 | 700 |

An average annual yield of 155 million board-feet of sugar pine can be produced at a marginal cost of $50 per M or less. Also, the anticipated price of sugar pine is $50 per M b.m. This annual production of sugar pine will require intensive management on 650,000 acres of the most productive sugar pine land. Careful selection of these areas for sugar pine management is essential. A system for rating cutover land for sugar pine management is offered.

171. WAGENER, WILLIS W., and MIELKE, JAMES L.
1936. First blister rust found in California. Plant Disease Reporter 20:220-21.

The first blister rust reported from California was found on June 29, 1936, near Monumental, Del Norte County, about 1.5 miles south of the California-Oregon line. A single branch canker on a young sugar pine was found and removed. Infection probably occurred in 1931, since 1929 blister rust infection had been known on ribes near the coast in Curry County, Oregon, about 50 miles north of the California-Oregon line.

172. WESTERN PINE ASSOCIATION.
1951. Sugar pine: the king of pines. 54 pp., illus.

Discovery of sugar pine by Douglass (1 p.); character and properties of the tree and products (8 pp.); manufacture of products (2 pp.); building uses and industrial uses of lumber (10 pp.); grading and grades of lumber (described and illustrated); select grades (6 pp.); common grades (4 pp.); factory grades (13 pp.); recommended grades (3 pp.); standard manufacture sizes of lumber (1 p.). From Douglass' account of his discovery of sugar pine in 1826 is mentioned a wind-thrown tree with a circumference of 37 feet 9 inches at 3 feet above roots, 17 feet 5 inches at 134 feet, and a total length of 215 feet.

173. WRIGHT, ERNEST.
1931. The effect of high temperatures on seed germination. Jour. Forestry 29:679-87.

Describes a study conducted to determine the effect of various temperatures on seed germination. Results on the effect of high temperatures on sugar pine seed were inconclusive. The seeds were not stratified prior to germination. Only 2 percent of the controls germinated.

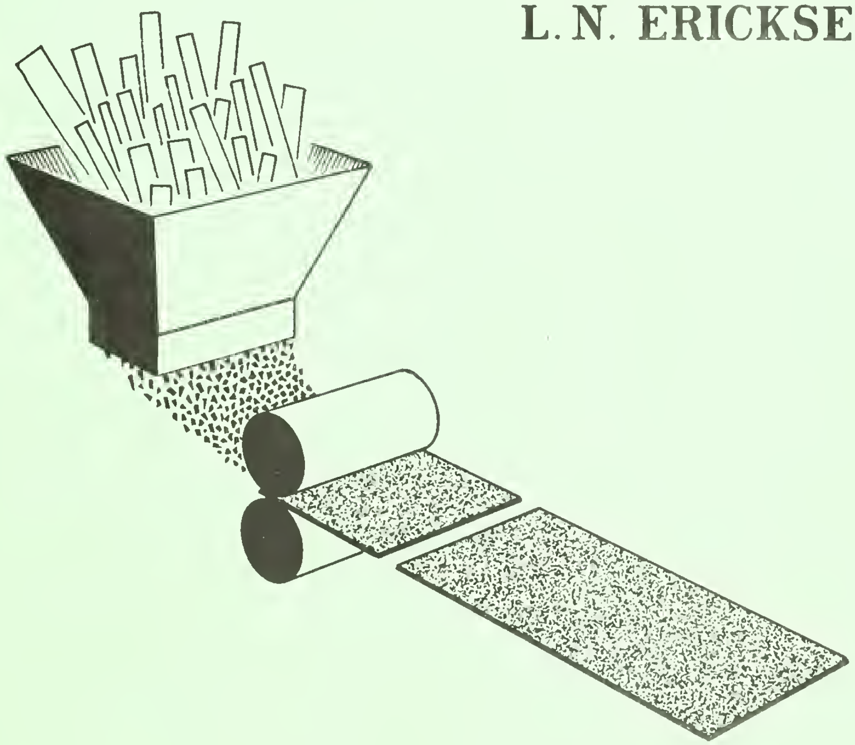
174. ZACH, LAWRENCE W., BAUER, DON, and GOODYEAR, HAL.
1943. Practical application of plant hormones in forest-tree propagation. Jour. Forestry 41:214.

Preliminary experiments to determine the effectiveness of indolebutyric acid in forest-tree propagation seemed to show positive results for treated sugar pine seeds.

TECHNICAL
PAPER
NUMBER 13

# WOOD RESIDUE
## FROM PRIMARY WOOD-USING INDUSTRIES IN CALIFORNIA

R. H. MAY
L. N. ERICKSEN



CALIFORNIA
FOREST AND RANGE
EXPERIMENT STATION
GEORGE M. JEMISON, DIRECTOR
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The California Forest and Range Experiment Station greatly appreciates the contribution to this survey by the lumber and plywood companies and other industries whose information made this report possible.

The authors are indebted to Harvey H. Smith, E. V. Roberts, E. M. Hornibrook and A. L. Hartong, co-workers at the California Forest and Range Experiment Station, for assistance in the collection and preparation of material presented in this report.

# WOOD RESIDUE FROM PRIMARY WOOD-USING INDUSTRIES IN CALIFORNIA

By

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and
L. N. Ericksen, Chief, Forest Utilization Service

Technical Paper No. 13 December 1955

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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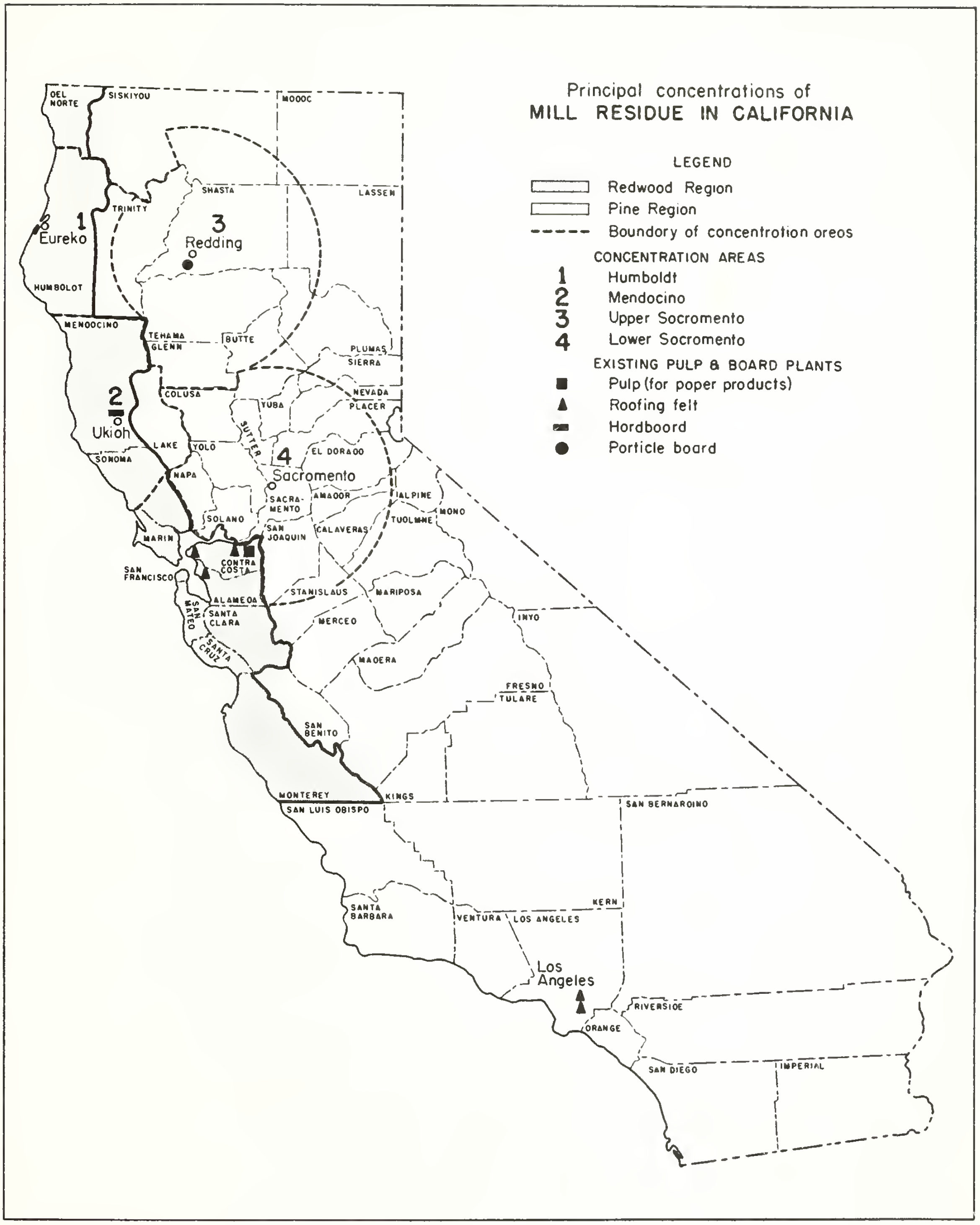
The Experiment Station is maintained at Berkeley, California in cooperation with the University of California.

Agriculture--Forest Service, Berkeley, Calif.


Principal concentrations of
MILL RESIDUE IN CALIFORNIA
LEGEND
Redwood Region
Pine Region
Boundary of concentration areas
CONCENTRATION AREAS
1 Humboldt
2 Mendocino
3 Upper Sacramento
4 Lower Sacramento
EXISTING PULP & BOARD PLANTS
Pulp (for paper products)
Roofing felt
Hardboard
Particle board
Eureka
Redding
Ukiah
Sacramento
Los Angeles
DEL NORTE
SISKIYOU
MODOC
SHASTA
LASSEN
TRINITY
HUMBOLDT
MENDOCINO
TEHAMA
GLENN
BUTTE
PLUMAS
SIERRA
NEVADA
PLACER
COLUSA
YUBA
SUTTER
LAKE
YOLO
EL DORADO
SONOMA
NAPA
SACRAMENTO
AMADOR
ALPINE
MONO
SOLANO
SAN JOAQUIN
CALAVERAS
TUOLUMNE
MARIN
CONTRA COSTA
SAN FRANCISCO
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO
SANTA CLARA
MERCED
INYO
SANTA CRUZ
MADERA
FRESNO
TULARE
SAN BENITO
MONTEREY
KINGS
SAN LUIS OBISPO
SAN BERNARDINO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
RIVERSIDE
ORANGE
SAN DIEGO
IMPERIAL

# WOOD RESIDUE FROM PRIMARY WOOD-USING INDUSTRIES IN CALIFORNIA

Richard H. May and L. N. Ericksen

Wood residues from sawmill and plywood plants in California could support a substantial fiber-processing industry. A survey by the California Forest and Range Experiment Station shows that in 1952 these plants sent more than 160 million cubic feet of slabs, edgings, and other coarse trimmings to waste burners. This amount is equivalent to the annual net growth on 4.8 million acres of California's commercial forest land. It is enough wood to supply ten 250-ton-capacity pulp mills.

Not all of this wood can be used economically. Some is produced in plants with too low a volume, or too isolated, to pay the cost of collecting and transporting the wood to fiber industries. Nevertheless, the survey shows that most of the unused wood is concentrated in four sections of northern California and is strategically located to encourage development of new residue-using industries. They could create new jobs and income without requiring an increased drain on the state's timber resources.

The manufacture of lumber and other primary wood products inevitably results in a large volume of residues--slabs, edgings, trimmings, sawdust, shavings, and other material. In the past much of this residue was used for fuel to produce power, and some was manufactured into lath or other by-products. A large part, however, went to the waste burner. In recent years the increased use of diesel fuel and electric power has resulted in a decline in the proportion of wood residue used for fuel. Production of lath has declined greatly since 1941. These declines are being offset by increased use of wood residues for fiber, particularly in western pulp mills. Many sawmills and plywood plants convert their wood residues to chips for sale to pulp or fiber-board plants.

In California use of wood residue for pulp is a comparatively recent development. Roofing-felt manufacturers here have used wood fiber in composition roofing for many years, but the total volume used annually was small. In 1944, for example, only 11,000 cords were used. In 1948 a pulp mill of 250-tons-per-day capacity was built at Antioch, and in 1950 a hardboard plant of about 150 tons capacity was completed at Ukiah. The companies operating these plants originally planned to use low-grade logs, logging residue, and forest thinnings as their main source of material. But within the past few years they have been using increasingly greater volumes of residues from wood manufacturing plants. Total wood used for pulping in California in 1952 was equivalent to 311,000 cords. One-third of this was mill residue. Since 1952 an even greater part of the state's pulpwood requirements has come from chipped mill residues, but the amount consumed is still small compared to chip consumption in Washington and Oregon.

As the market for wood residue increased, a need has developed for more accurate information on the volume, kind, and source of residues from primary wood-using industries. A survey to obtain this information for California was made by the California Forest and Range Experiment Station in 1953, as a part of the nation-wide Timber Resource Review. The results of this survey, which covered the year 1952, are presented in this report.

A considerable volume of wood residue is produced in secondary wood manufacturing plants, such as planing mills separate from sawmills, moulding plants, flooring mills, furniture factories, and box mills. These were not covered in this survey. Los Angeles is the main center for these secondary plants, which ship some of their residue to pulp mills and roofing plants.

## SURVEY RESULTS

The survey showed that about 370 million cubic feet of residue material were derived in primary forest products plants in California in 1952. This was about equally divided between the Pine and Redwood regions. Coarse residue (slabs, edgings, trimmings, veneer clippings, and veneer cores) amounted to 242 million cubic feet, or 65 percent of the total; and fine residue (sawdust and shavings) accounted for the remaining 129 million cubic feet, or 35 percent (fig. 1 and table 1). These volumes are in solid wood equivalent and do not include bark.

Thirty-eight percent (143 million cubic feet) of the wood residue was used (table 2). The remaining 62 percent was unused, and was largely disposed of in waste burners. About a third of the coarse residue was used and half of the fine residue.

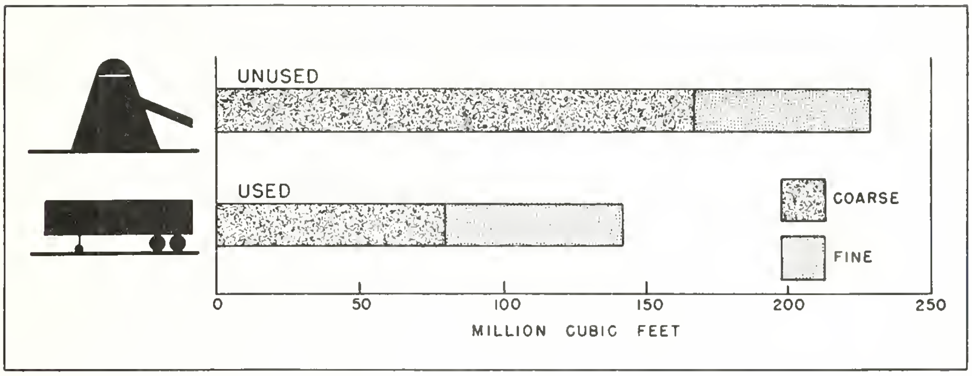



Figure 1.--Residue produced at primary wood-using plants, California, 1952.

The greatest use of residue was for fuel--86 percent of the volume used (fig. 2). The fuel went principally to generate power for plant use. Equal volumes of coarse and fine residues were used for fuel. Six percent was chipped for fiber use, but only the coarse residue was employed for this purpose. The fiber went into paper pulp, hardboard, and roofing felt.

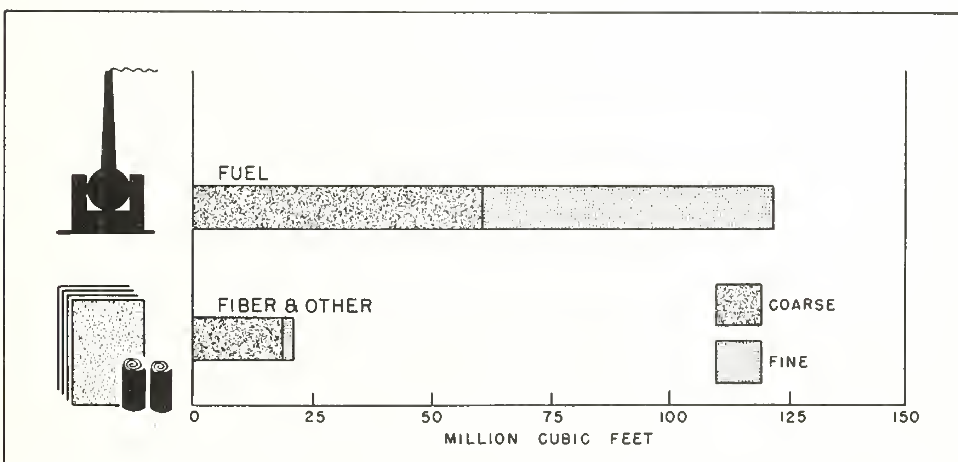



Figure 2.--Uses of wood residues, California, 1952.

Miscellaneous other products accounted for 8 percent of the volume used, taking primarily coarse material. Some coarse residues went into such varied products as lath, moulding, shade rollers, toy stock, and mine-timber blocking. Cores from veneer bolts were sawed into lumber, mainly studs. Also, veneer cores and clippings were manufactured into particle board. Fine residues were sold for livestock bedding, soil conditioning, sawdust for packing purposes, and for resale.

Sawmills were the source of 97 percent of the residues developed in the State. Veneer plants furnished most of the remainder. Large mills[1/] produced 40 percent of the total volume of the sawmill residues, and medium and small mills about equally divided the remainder (fig. 3). Seventy percent of the residue produced by the large mills was used, as compared with 24 percent for medium mills and 7 percent for small mills.

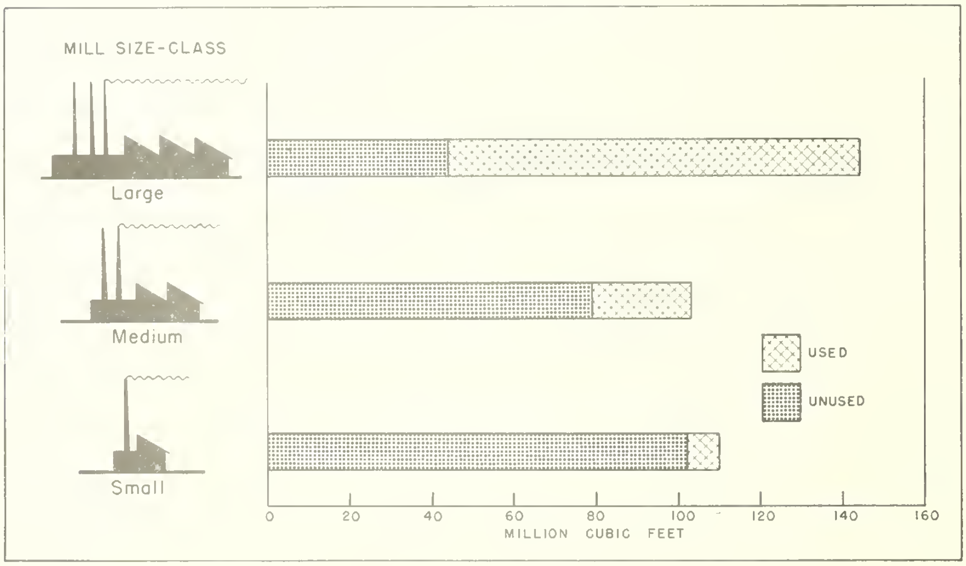



Figure 3.--Production and use of wood residues, by size of sawmill, California, 1952.

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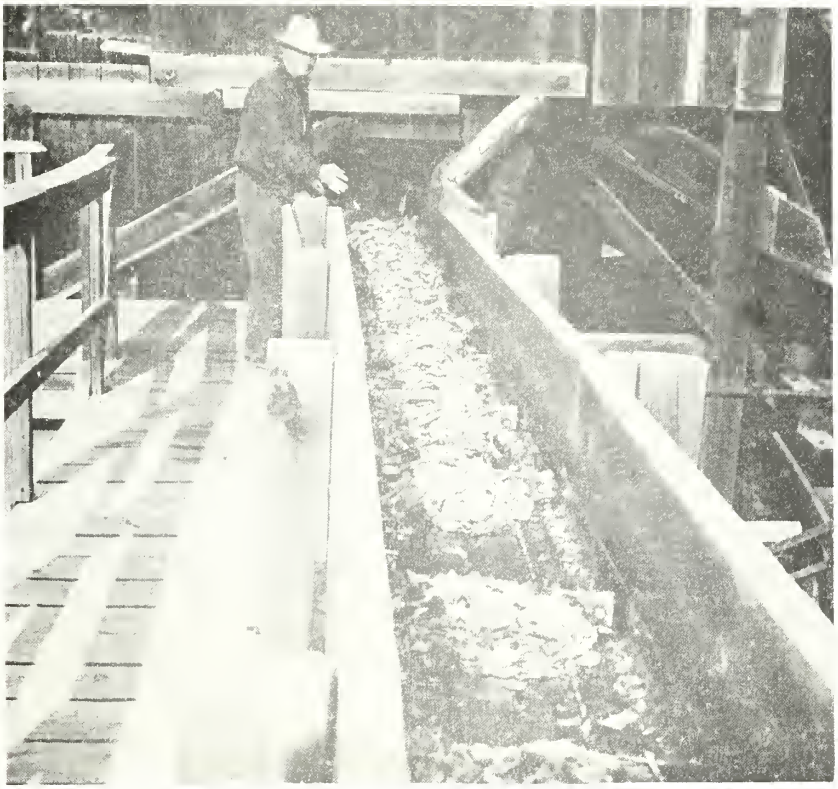
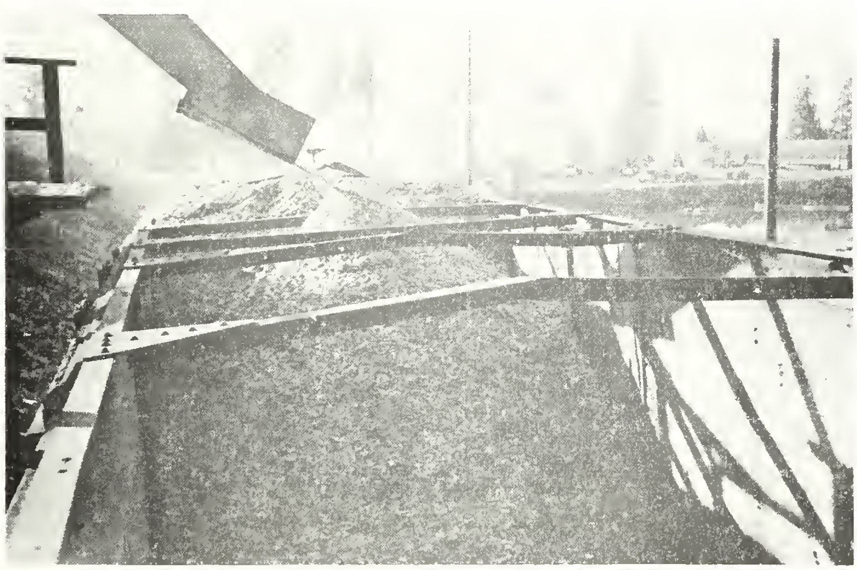
1/ Sawmill size classes are defined as follows: Large - mills producing 25.0 and more million board-feet of lumber annually. Medium - mills producing 10.0 to 24.9 million board-feet of lumber annually. Small - mills producing 9.9 and less million board-feet of lumber annually.



Transferring chips from sawmill chipper for loading in railroad cars or trucks.



Loading car of chips at sawmill for shipment to pulpmill.

The greater use of residue from large mills was chiefly due to fuel use, because these mills included most of those burning wood to produce steam for power. One advantage of the large mills as a source of raw material is that they have a greater volume and concentration of available residue than other mills. In the aggregate small sawmills produce the greatest volume of unused residue, but they are scattered and their individual production is small, so that collecting their residue may be more costly than collecting from the large mills.

## PRINCIPAL CONCENTRATION AREAS

Primary wood-using industries are scattered over much of northern California. Four areas, however, have a concentration of mills and a transportation network that offer good possibilities for development of secondary industries using wood residue. These areas (see map preceding page 1) are:

(1) The Humboldt area, consisting of Humboldt and western Trinity Counties;

(2) The Mendocino area, consisting of Mendocino, Lake, and northern Sonoma Counties;

(3) The upper Sacramento Valley, within a 75-mile radius from Redding; and

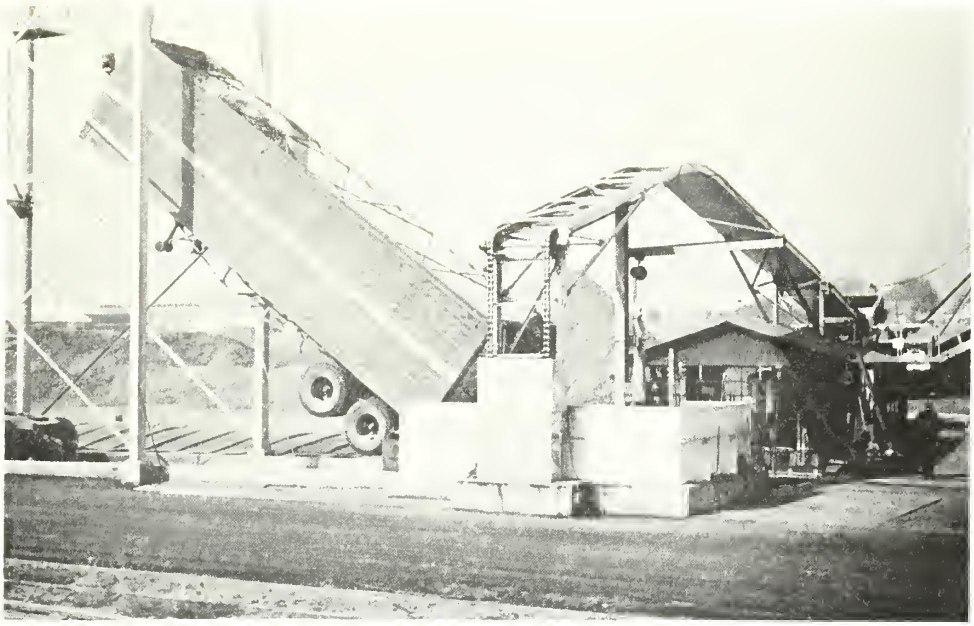
(4) The lower Sacramento Valley, within a 75-mile radius from Sacramento.

The mills in these areas together produced 78 percent of the total millwood residue in the State.

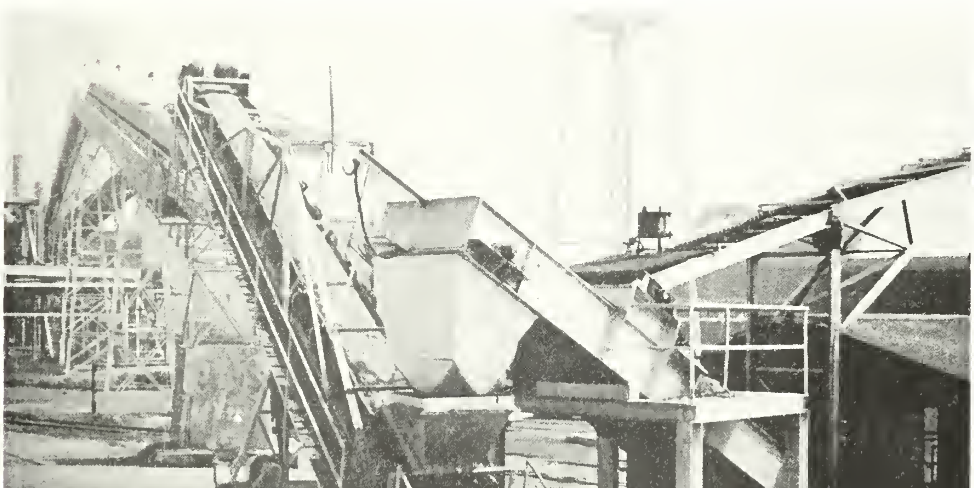
Nearly one-third of the total residue produced in California was developed in the Humboldt area, and about one-sixth came from each of the other three principal areas (fig. 4 and table 3). Use of residue was proportionately the greatest in the two Sacramento Valley areas, where nearly half the total volume produced was used, chiefly for fuel (table 4).

About one-third of the coarse residue in all four areas combined was used. The greatest use (44 percent) was in the lower Sacramento Valley, and the least (24 percent) in the Mendocino area.

The Humboldt area was the greatest producer of chips for fiber. Even here the 2.9 million cubic feet of coarse material used for fiber was only 4 percent of the total volume of coarse residue produced, and only 14 percent of the volume used.



Dumping chips from trailer into pit at fiber-using plant. Chips may go direct to mill or to storage piles in background.



Chip handling by conveyors, from pit to movable transfer section, then either to plant as shown or to storage piles.

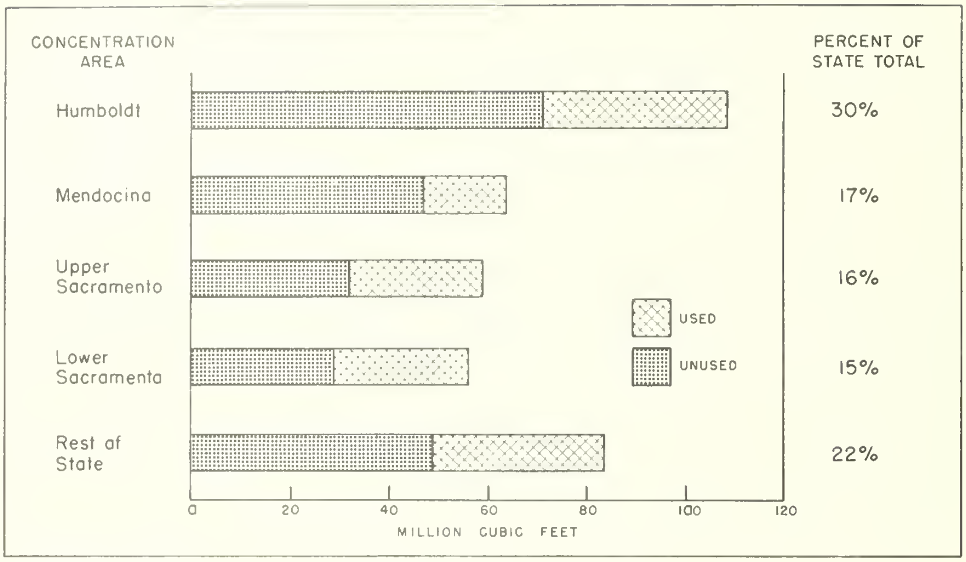



Figure 4.--Production and use of wood residue by areas of concentration, California, 1952.

The large volume of unused residue, especially coarse material, in the four principal areas of concentration, offers opportunity for a great expansion in fiber utilization. Wood residues for fuel will probably continue to give ground to petroleum products and electricity. Agricultural and miscellaneous uses may be expected to expand but will probably not consume a large share of the total volume of residue. The use of coarse residue for fiber, however, seems limited only by the availability of a market within economical distance once the problems of water supply and pollution are overcome. Solving the water problems in a manner compatible with other water-use requirements is recognized as a major factor in wood-fiber utilization. Where an industrial demand for fiber has existed, as in Washington and Oregon, the volume of mill residue chips used by pulp and hardboard plants has increased markedly since World War II.

The 48 million cubic feet (530,000 cords equivalent) of unused coarse residue in the Humboldt County area alone could supply 3 pulp mills each of 250 tons daily capacity. The 162 million cubic feet of unused coarse residue in the entire State could produce 900,000 tons of pulp annually if fully utilized.

By more complete and effective utilization of mill residues, wood-processing industries could be greatly expanded, and employment, income, and community stability increased without additional drain on the standing timber in California.

## PROCEDURE AND ACCURACY

### Basis of Estimate

Survey forms were mailed to all primary wood-using plants of record in California--sawmills, plywood and veneer plants, shingle and shake mills, and cooperage plants. The forms requested information for 1952 on quantity of logs consumed, the volume of coarse and fine residue produced, and the percentage of residue used by type of use.

Information was received from 191 sawmills representing 54 percent of total 1952 production. By size classes, returns represented 78 percent of production by large mills, 63 percent by medium mills, and 22 percent by small mills.[2] In the veneer and plywood industry, returns from 17 plants represented 73 percent of total log consumption. For sawmills and veneer plants combined, the mills replying accounted for 56 percent of total log consumption.

### Residue Factors

#### Sawmills

The reported volumes of residue developed at sawmills were extremely variable. A number of companies omitted these figures entirely, and some indicated that the figures shown were "guesses." Apparently, few operators had any information on which to base an estimate. Therefore, residue volumes produced in lumber manufacture were estimated from the results of 15 mill-scale studies made by the U. S. Forest Service in California.

These studies showed that the end products of pine and fir logs on a cubic volume basis were as follows:

| | |
|---|---|
| Dressed lumber | 47 percent |
| Residue | 53 percent |
| Slabs, edgings, trim | 29 percent |
| Sawdust | 12 percent |
| Shavings | 12 percent |

---

2/ See footnote 1, page 4, for definitions of mill-size classes.

Corresponding figures for redwood were:

| | |
|---|---|
| Dressed lumber | 37 percent |
| Residue | 63 percent |
| Slabs, edgings, trim | 41 percent |
| Sawdust | 13 percent |
| Shavings | 9 percent |

These percentages were applied to each reporting company's figure of log consumption. Adjustment was made for lack of shavings at mills cutting rough lumber only. This procedure gave an estimated volume of residue per plant.

The percentages of use or non-use reported by each company were then applied to the estimate of total residue for each plant to give estimates of volume of residue used or not used for each plant. These volumes were totalled to give volumes of residue for the reporting plants by strata based on mill-size, class of residue, and region.

Total volumes of residue for all strata were then expanded on the basis of the ratio between the reported 1952 lumber production of the reporting plants in a stratum and the 1952 lumber production of all plants in the same stratum.

Veneer and Plywood Plants

Volumes of residues reported by veneer and plywood plants were extremely variable; some plants did not report. The volumes of residue developed were therefore computed from factors derived from other sources. From industry figures on the ratio between plywood and log volumes, and from information on veneer and plywood yields, it was estimated that the plywood yield was 61 percent of the cubic volume of logs. The remaining 39 percent was divided into cores and solid wood 8 percent, veneer waste 25 percent, and sander dust 6 percent.

The disposition of plant residues was computed from information shown on returns from individual veneer and plywood plants. The residue volumes computed for the reporting plants were expanded to an estimated total for all plants by applying the ratio between production of reporting plants and production of all plants.

Other Industries

Returns were received from the one cooperage plant in California and from 14 of the 36 active shingle and shake plants.

Volumes of residue produced by these industries were based on earlier studies, and the proportions used were derived from their 1952 reports.

Estimates of residues produced at pulp mills were compiled in the Washington office of the Forest Service. Such residues consist only of wood losses in storage and in preparing wood for pulping.

## Accuracy

The sampling error of the total volume of residue could not readily be computed. But the sampling error of the percentage of residue used in relation to total volume produced was computed as 6 percent (within one standard deviation) for the sawmill industry and 11 percent for the plywood-veneer industry. The sampling error of this ratio for these industries combined was 5.5 percent. These two segments of industry represent 97 percent of the total log consumption by primary wood-using plants in the State, and produce 99 percent of the total residues.

Other types of error were more important than sampling error in this survey. These include, first, errors in the factors for volume of residue per unit of production. These factors were based on earlier mill-scale studies, but several independent checks indicated these mill-scale studies to be reliable in 1952. Another possible source of error is the company estimates of percentage of residue used. We believe the final results are reasonably close to a true figure.

Table 1.--Estimated volume of residues from primary wood-using plants by kind of plant, region, and utilization, California, 1952

| Origin by kind of plant and region | Used: Coarse | Used: Fine | Used: Total | Unused: Coarse | Unused: Fine | Unused: Total | All residue: Coarse | All residue: Fine | All residue: Total Vol. | All residue: Total Pct. |
|---|---|---|---|---|---|---|---|---|---|---|
| | - - - | - - - | - - - | - - - | Million cubic feet[1] | - - - | - - - | - - - | - - - | |
| Sawmills[2] | | | | | | | | | | |
| Pine region | 42.1 | 38.3 | 80.4 | 72.5 | 27.8 | 100.3 | 114.6 | 66.1 | 180.7 | 49 |
| Redwood region | 29.7 | 23.2 | 52.9 | 86.6 | 37.6 | 124.2 | 116.3 | 60.8 | 177.1 | 48 |
| Total | 71.8 | 61.5 | 133.3 | 159.1 | 65.4 | 224.5 | 230.9 | 126.9 | 357.8 | 97 |
| Veneer plants[3] | | | | | | | | | | |
| Pine region | 2.6 | 0.3 | 2.9 | 0.3 | (4/) | 0.3 | 2.9 | 0.3 | 3.2 | 1 |
| Redwood region | 5.2 | 0.9 | 6.1 | 2.8 | 0.2 | 3.0 | 8.0 | 1.1 | 9.1 | 2 |
| Total | 7.8 | 1.2 | 9.0 | 3.1 | 0.2 | 3.3 | 10.9 | 1.4 | 12.3 | 3 |
| Other plants[5] | | | | | | | | | | |
| Pine region | (4/) | (4/) | (4/) | (4/) | (4/) | (4/) | (4/) | (4/) | (4/) | (4/) |
| Redwood region | 0.4 | 0.8 | 1.2 | 0.1 | 0.2 | 3.3 | 0.5 | 1.0 | 1.5 | - |
| All plants | | | | | | | | | | |
| Pine region | 44.7 | 38.6 | 83.3 | 72.8 | 27.8 | 100.6 | 117.5 | 66.4 | 183.9 | 50 |
| Redwood region | 35.3 | 24.9 | 60.2 | 89.5 | 38.0 | 127.5 | 124.8 | 62.9 | 187.7 | 50 |
| Total Volume | 80.0 | 63.5 | 143.5 | 162.3 | 65.8 | 228.1 | 242.3 | 129.3 | 371.6 | - |
| Pct. of total | 21 | 17 | 38 | 44 | 18 | 62 | 65 | 35 | - | 100 |

1/ Solid wood equivalent.
2/ Sawmills and integrated planing mills.
3/ Veneer plants, including integrated plywood plants.
4/ = less than 50,000 cubic feet.
5/ Shingle (including sawn shake), pulp and cooperage plants.

Table 2.--Wood residue used by originating plant, region, and type of use, California, 1952

| Origin by kind of plant and region | Used for fuel | | | Used for fiber | | | Used for other[1] | | | All uses | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Total | Coarse | Fine | Total | Coarse | Fine | Total | Coarse | Fine | Total Vol. | Total Pct. |
| | Million cubic feet[2] | | | | | | | | | | | | |
| Sawmills | | | | | | | | | | | | | |
| Pine region | 35.7 | 37.8 | 73.5 | 1.6 | -- | 1.6 | 4.8 | 0.5 | 5.3 | 42.1 | 38.3 | 80.4 | 57 |
| Redwood region | 21.2 | 22.2 | 43.4 | 5.2 | -- | 5.2 | 3.3 | 1.0 | 4.3 | 29.7 | 23.2 | 52.9 | 37 |
| Total | 56.9 | 60.0 | 116.9 | 6.8 | -- | 6.8 | 8.1 | 1.5 | 9.6 | 71.8 | 61.5 | 133.3 | 94 |
| Veneer plants | | | | | | | | | | | | | |
| Pine region | 1.4 | 0.2 | 1.6 | 0.2 | -- | 0.2 | 1.0 | 0.1 | 1.1 | 2.6 | 0.3 | 2.9 | 2 |
| Redwood region | 2.9 | 0.8 | 3.7 | 1.0 | -- | 1.0 | 1.3 | 0.1 | 1.4 | 5.2 | 0.9 | 6.1 | 4 |
| Total | 4.3 | 1.0 | 5.3 | 1.2 | -- | 1.2 | 2.3 | 0.2 | 2.5 | 7.8 | 1.2 | 9.0 | 6 |
| Other plants[3] | | | | | | | | | | | | | |
| Pine region | (4/) | -- | (4/) | -- | -- | -- | -- | (4/) | (4/) | (4/) | (4/) | (4/) | -- |
| Redwood region | 0.4 | 0.7 | 1.1 | -- | -- | -- | -- | 0.1 | 0.1 | 0.4 | 0.8 | 1.2 | -- |
| Total | 0.4 | 0.7 | 1.1 | -- | -- | -- | -- | 0.1 | 0.1 | 0.4 | 0.8 | 1.2 | -- |
| All plants | | | | | | | | | | | | | |
| Pine region | 37.1 | 38.0 | 75.1 | 1.8 | -- | 1.8 | 5.8 | 0.6 | 6.4 | 44.7 | 38.6 | 83.3 | 59 |
| Redwood region | 24.5 | 23.7 | 48.2 | 6.2 | -- | 6.2 | 4.6 | 1.2 | 5.8 | 34.9 | 24.4 | 59.3 | 41 |
| Total used Volume | 61.6 | 61.7 | 123.3 | 8.0 | -- | 8.0 | 10.4 | 1.8 | 12.2 | 80.0 | 63.5 | 143.5 | |
| Percent | 43 | 43 | 86 | 6 | -- | 6 | 7 | 1 | 8 | 56 | 44 | -- | 100 |

1/ Agricultural and miscellaneous uses.
2/ Solid wood equivalent.
3/ Cooperage, pulp, and shingle mills.
4/ Less than 50,000 cubic feet.

Table 3.--Estimated volume of residue from primary wood-using plants in four major concentration areas of California, 1952

| Origin by area and kind of plant | Used | | | Unused | | | All residue | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Total | Coarse | Fine | Total | Coarse | Fine | Total |
| | Million cubic feet[1] | | | | | | | | |
| Humboldt Area | | | | | | | | | |
| Lumber | 17.0 | 16.3 | 33.3 | 47.4 | 23.1 | 70.5 | 64.4 | 34.4 | 103.8 |
| Veneer | 3.8 | 0.4 | 4.2 | 0.5 | 0.1 | 0.6 | 4.3 | 0.5 | 4.8 |
| Other | (2/) | 0.4 | 0.4 | 0.1 | 0.1 | 0.2 | 0.1 | 0.5 | 0.6 |
| Total | 20.8 | 17.1 | 37.9 | 48.0 | 23.3 | 71.3 | 68.8 | 40.4 | 109.2 |
| Mendocino Area | | | | | | | | | |
| Lumber | 8.9 | 7.0 | 15.9 | 29.7 | 16.7 | 46.4 | 38.6 | 23.7 | 62.3 |
| Veneer | 0.8 | 0.1 | 0.9 | 0.6 | (2/) | 0.6 | 1.4 | 0.1 | 1.5 |
| Other | (2/) | 0.2 | 0.2 | (2/) | 0.1 | 0.1 | (2/) | 0.3 | 0.3 |
| Total | 9.7 | 7.3 | 17.0 | 30.3 | 16.8 | 47.1 | 40.0 | 24.1 | 64.1 |
| Upper Sacramento Valley | | | | | | | | | |
| Lumber | 11.4 | 13.4 | 24.8 | 24.6 | 7.6 | 32.2 | 36.0 | 21.0 | 57.0 |
| Veneer | 1.8 | 0.2 | 2.0 | (2/) | (2/) | (2/) | 1.8 | 0.2 | 2.0 |
| Total | 13.2 | 13.6 | 26.8 | 24.6 | 7.6 | 32.2 | 37.8 | 21.2 | 59.0 |
| Lower Sacramento Valley | | | | | | | | | |
| Lumber | 15.8 | 10.7 | 26.5 | 19.7 | 9.3 | 29.0 | 35.5 | 20.0 | 55.5 |
| Veneer | 0.1 | (2/) | 0.1 | 0.1 | (2/) | 0.1 | 0.2 | (2/) | 0.2 |
| Total | 15.9 | 10.7 | 26.6 | 19.8 | 9.3 | 29.1 | 35.7 | 20.0 | 55.7 |
| Rest of State | 20.4 | 14.8 | 35.2 | 39.6 | 8.8 | 48.4 | 60.0 | 23.6 | 83.6 |
| Total | 80.0 | 63.5 | 143.5 | 162.3 | 65.8 | 228.1 | 242.3 | 129.3 | 371.6 |

1/ Solid wood equivalent.
2/ Less than 50,000 cubic f[illegible]

Table 4.--Wood residue used, by originating areas, kind of originating plant and type of use, California, 1952

| Origin by area and kind of plant | Used for fuel | | | Used for fiber | | | Other[1] | | | All used | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Total | Coarse | Fine | Total | Coarse | Fine | Total | Coarse | Fine | Total |
| | Million cubic feet[2] | | | | | | | | | | | |
| Humboldt Area | | | | | | | | | | | | |
| Lumber | 14.0 | 15.4 | 29.4 | 2.3 | -- | 2.3 | 0.7 | 0.9 | 1.6 | 17.0 | 16.3 | 33.3 |
| Veneer | 2.5 | 0.3 | 2.8 | 0.6 | -- | 0.6 | 0.7 | 0.1 | 0.8 | 3.8 | 0.4 | 4.2 |
| Other[3] | (4/) | 0.3 | 0.3 | -- | -- | -- | -- | 0.1 | 0.1 | (4/) | 0.4 | 0.4 |
| Total | 16.5 | 16.0 | 32.5 | 2.9 | -- | 2.9 | 1.4 | 1.1 | 2.5 | 20.8 | 17.1 | 37.9 |
| Mendocino Area | | | | | | | | | | | | |
| Lumber | 6.0 | 6.9 | 12.9 | 1.7 | -- | 1.7 | 1.2 | 0.1 | 1.3 | 8.9 | 7.0 | 15.9 |
| Veneer | 0.2 | 0.1 | 0.3 | 0.2 | -- | 0.2 | 0.4 | -- | 0.4 | 0.8 | 0.1 | 0.9 |
| Other[3] | (4/) | 0.2 | 0.2 | -- | -- | -- | -- | (4/) | (4/) | (4/) | 0.2 | 0.2 |
| Total | 6.2 | 7.2 | 13.4 | 1.9 | -- | 1.9 | 1.6 | 0.1 | 1.7 | 9.7 | 7.3 | 17.0 |
| Upper Sacramento Valley | | | | | | | | | | | | |
| Lumber | 9.6 | 13.4 | 23.0 | 0.6 | -- | 0.6 | 1.2 | (4/) | 1.2 | 11.4 | 13.4 | 24.8 |
| Veneer | 0.6 | 0.1 | 0.7 | 0.2 | -- | 0.2 | 1.0 | 0.1 | 1.1 | 1.8 | 0.2 | 2.0 |
| Total | 10.2 | 13.5 | 23.7 | 0.8 | -- | 0.8 | 2.2 | 0.1 | 2.3 | 13.2 | 13.6 | 26.8 |
| Lower Sacramento Valley | | | | | | | | | | | | |
| Lumber | 11.9 | 10.7 | 22.6 | 0.6 | -- | 0.6 | 3.3 | (4/) | 3.3 | 15.8 | 10.7 | 26.5 |
| Veneer | 0.1 | (4/) | 0.1 | -- | -- | -- | (4/) | -- | (4/) | 0.1 | (4/) | 0.1 |
| Volume | 12.0 | 10.7 | 22.7 | 0.6 | -- | 0.6 | 3.3 | (4/) | 3.3 | 15.9 | 10.7 | 26.6 |

1/ Agricultural and miscellaneous.
2/ Solid wood equivalent.
3/ Cooperage, shingle, and pulp.
4/ Less than 50,000 cubic feet.

TECHNICAL PAPER NUMBER 14

# SILVICAL CHARACTERISTICS OF SUGAR PINE

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CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
GEORGE M. JEMISON, DIRECTOR
BERKELEY - DECEMBER 1956

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

## Preface

The Forest Service is engaged in assembling information on the silvical characteristics of important forest trees of the United States. Much material that is of value in silviculture and research is widely scattered and difficult to locate. This report presents, in preliminary form, the information that has been collected for one species of tree. Similar reports are being prepared for other species at the California Forest and Range Experiment Station and at other forest experiment stations. Readers are encouraged to notify the authors of omissions, errors, or new information affecting the silvical characteristics of the species.

The California Forest and Range Experiment Station is maintained by the Forest Service, U. S. Department of Agriculture, at Berkeley, California, in cooperation with the University of California.

Agriculture - Berkeley

# SILVICAL CHARACTERISTICS OF SUGAR PINE

By H. A. Fowells and Gilbert H. Schubert

Technical Paper No. 14 December 1956

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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The Experiment Station is maintained at Berkeley, California
in cooperation with the University of California

Agriculture--Forest Service, Berkeley, California

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# SILVICAL CHARACTERISTICS OF SUGAR PINE

By H. A. Fowells [1/] and Gilbert H. Schubert [2/]

Sugar pine (*Pinus lambertiana* Dougl.), the largest and most valuable of the western pines, is native to Oregon, California, and Lower California. Its range extends from the North Fork of the Santiam River on the west slope of the Cascade Ranges in Oregon, through the Sierra Nevada and North Coast Ranges in California, in scattered mountain ranges in southern California, and to Mount San Pedro Martir in Lower California (fig. 1).

## HABITAT CONDITIONS

### CLIMATIC

The climate in which sugar pine grows may generally be called humid, according to Thornthwaite's classification (41). More specifically it is characterized by:

. . . dry summers, with July and August precipitation usually less than 1 inch per month.

. . . annual temperature extremes of below -10° F. to above 100° F.

. . . annual precipitation of about 25 inches or more, part of which falls as snow.

The tree's lower limit of precipitation may be about 20 inches a year, for isolated sugar pines are found in the Pacific ponderosa pine type (37) where precipitation is 18 to 20 inches. Its lower temperature limit has not been determined but probably is below -30° F.

### EDAPHIC

Sugar pine grows on many different kinds of soils, from shallow stony or rocky alkaline clays to loose, deep, well-drained, moderately acid sandy loams. These soils may develop from weathering of a wide range of parent rocks: Rhyolite, andesite, diorite,

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1/ Formerly Forester, California Forest and Range Experiment Station; now with the Division of Forest Management Research, U. S. Forest Service, Washington, D. C.

2/ Forester, Division of Forest Management Research, California Forest and Range Experiment Station.

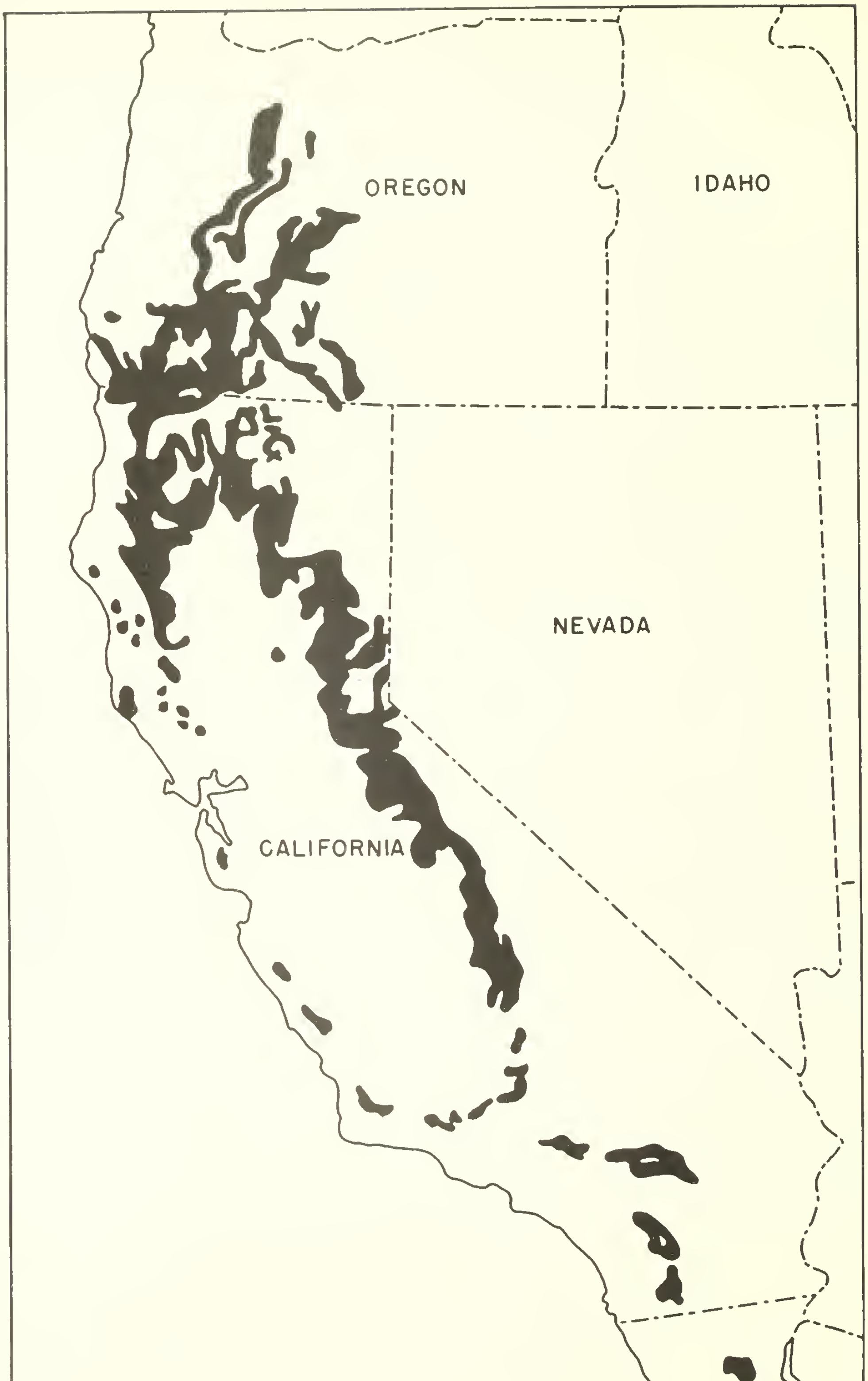


Figure 1.--The natural range of sugar pine.

sandstone, shale, basalt, and granitic or metamorphic equivalents. The Holland, Olympic, Aiken and Josephine soil series are the most common.

The best stands in the central Sierra Nevada grow on deep, sandy loam soils of the Holland series, developed from granitic rock. In the southern Cascade Range the best stands are on deep clay loams developed on basalt and rhyolite. In the northern Sierra Nevada and Cascade Mountains, sugar pine grows on loam to silty clay loam soils, brown to dark reddish-brown in color and slightly to moderately acid in reaction. Pumice soils here also support excellent stands, especially on benches and gentle slopes where the soils are deep, coarse textured, and well-drained.

In the Coast Range and Siskiyou Mountains in California and Oregon, the best stands are on light brown to reddish-brown, slightly to moderately acid, silt loams and clay loams derived from sandstone and shale. The poorest stands usually grow on red clay loam developed in place from weathering of peridotite and related ultrabasic rocks which in places are partially serpentinized.

PHYSIOGRAPHIC

At its northern limits, about latitude 44° 47' N., sugar pine grows between elevations of 1,700 and 3,700 feet (39); farther south in Oregon from about 1,100 feet to 5,400 feet. East of the Cascade summit it occurs up to 6,500 feet in Klamath County. In northern California it grows as high as 7,500 feet (latitude 41° 23' N.) and as low as 2,000 feet in the Sacramento canyon. In the central Sierra Nevada it ranges from 2,000 to 7,800 feet, as in Yosemite National Park (latitude 37° 44' N.). In southern California it occurs at from 4,000 to 10,500 feet in the San Bernardino Mountains (latitude 34° 15' N.), and in Lower California it is common at elevations of 8,000 to 10,000 feet in the San Pedro Martir Plateau (latitude 30° 30' N.).

The best stands of sugar pine occur in an elevational belt between 4,500 and 6,000 in the central Sierra, from the San Joaquin River north to the American River (latitudes 37° and 39° N.).

At the lower and middle elevations in the Sierra Nevada, sugar pine is most common on north and east facing slopes. In southern Oregon it grows on all aspects in equal abundance at lower elevations, but mostly on the warmer aspects at high ones.

BIOTIC

Sugar pine is one of the major timber species in the Transition Life Zone (26) in the Cascade-Sierra Range and Siskiyou Mountains. It is represented in nine cover types of western North

American (37), occurring as single trees or small groups but never in pure stands over extensive areas. It is one of the major components in the ponderosa pine-sugar pine-fir type (sometimes called the mixed conifer type) and as a minor component in the following cover types: California red fir, white fir, Pacific Douglas-fir, Port-Orford-cedar--Douglas-fir, Pacific ponderosa pine--Douglas-fir, Pacific ponderosa pine, California black oak, and Jeffrey pine.

In the northern part of its range it is commonly associated with Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), ponderosa pine (P. ponderosa Laws.), grand fir (Abies grandis (Dougl.) Lindl.), incense-cedar (Librocedrus decurrens Torr.), western hemlock (Tsuga heterophylla (Raf.) Sarg.), western redcedar (Thuja plicata Donn), and Port-Orford-cedar (Chamaecyparis lawsoniana (A. Murr.) Parl.).

In the central portions it is associated with ponderosa pine, Jeffrey pine (P. jeffreyi Grev. & Balf.), white fir (A. concolor (Gord. & Glend.) Lindl.), incense-cedar, California red fir (A. magnifica A. Murr.), and giant sequoia (Sequoia gigantea (Lindl.) Decne.) (fig. 2).

Farther south, common associates are: Jeffrey pine, ponderosa pine, Coulter pine (P. coulteri D. Don) and bigcone Douglas-fir (Pseudotsuga macrocarpa (Vasey) Mayr). As elevation increases, white fir and giant sequoia are added and at the upper limits, Jeffrey pine, western white pine (P. monticola Dougl.), California red fir, and lodgepole pine (P. contorta Dougl.).

Common brush species in the sugar pine range include greenleaf manzanita (Arctostaphylos patula Greene), deerbrush (Ceanothus integerrimus H. & A.), snowbrush (C. velutinus Dougl.), whitethorn (C. cordulatus Kell.), bearmat (Chamaebatia foliolosa Benth.), chinkapin (Castanopsis sempervirens Dudley), salal (Gaultheria shallon Pursh.), and coast rhododendron (Rhododendron californicum Hook.) (21).

## LIFE HISTORY

### SEEDING HABITS

#### Flowering and fruiting

Sugar pine flower buds are formed during July and August, but are not discernible until early the next summer (16). On the Stanislaus National Forest at about 6,000 feet, staminate strobili are visible about the middle of June; pistillate strobili a week or two later. Pollen shedding occurs after the middle of May at elevations below 3,000 feet and about the first week in July at 6,000 feet (5). The conelets are from 1 to 2 inches long at the time of pollen dissemination, and they grow to 2 or 3 inches by the

Figure 2.--Sugar pine (far left and third from the left) growing with ponderosa pine. White fir reproduction and manzanita in the understory.

end of the first growing season. The cones reach mature size--average approximately 12 inches with some exceptional cones measuring more than 22 inches--by late August of the second year and contain, on the average, 210 developed seeds per cone.

Time of ripening of cones differs a great deal in different parts of the range. In Oregon, at 1,000 feet elevation in the Rogue River Valley the cones usually open between August 15 and 20. From 2,000 to 3,000 feet in the Umpqua River drainage, cones open 2 to 4 weeks later. 3/ In California at 5,000 to 6,000 feet on the Stanislaus National Forest, the cones usually do not open until late in September or early in October.

Seed production

Seed production of sugar pine varies with tree size and dominance class. Some trees begin to bear a few cones when they are about 8 inches d.b.h.; however, they do not become good producers until they are about 30 inches in diameter, or about 150 years of age (16).

Almost all sugar pine cones, 98 percent in one study, are produced on the larger dominant trees. Trees less than 14 inches in diameter averaged less than 8 cones per tree per crop (16). Those over 50 inches averaged 100 or more cones. The most cones reported on a single tree was 848 on a 48-inch tree, equivalent to about 170,000 seeds, or 85 pounds.

Individual trees do not produce cones every year and relatively few have cones every other year. Heavy cone crops are borne at intervals of 2 to 7 years--the average being about 4 years. There is some evidence that the size of sugar pine cone crops can be increased by applications of ammonium phosphate fertilizer (34).

Many of the cones which appear on the trees during the spring of the second year fail to survive to maturity. Squirrels, particularly the Douglas pine squirrel (*Tamiasciurus douglasii*), at times cut down as many as half of the cones before they mature (16, 40). Birds, particularly the white-headed woodpecker (*Dendrocopos albolarvatus*), may completely riddle a third or more of the immature cones (40). Sugar pine cone beetles (*Conophthorus lambertianae* Hopk.) destroy many sugar pine cones (16, 17, 27), and their attacks are believed to be one of the major reasons for the lack of successive heavy cone crops (16). Subfreezing weather during the late spring of the second year can injure sugar pine conelets (32).

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3/ Unpublished data, Pacific Northwest Forest and Range Experiment Station.

## Seed dissemination

Natural seed dissemination begins in late August at the lowest elevations and in September at higher levels. It continues through October, and some seeds fall during the winter months. Most of the sound seed is shed by the end of October; after this most seeds are undeveloped. The cones begin to open when their specific gravity has dropped to 0.62 or lower (33).

Practically all sugar pine seeds are disseminated by wind. Rodents and birds are minor factors in seed dispersal. Some seeds are buried by rodents at considerable distances from the seed tree, but many are consumed during the winter and early spring. A few of the seeds buried by rodents remain in the soil and germinate, but the seedlings usually come up in dense clumps.

Sugar pine seeds are large (about 2,000 per pound) and have a relatively small wing for their weight. Consequently they are not carried great distances by air currents. In still air, the seed falls at the rate of 8.7 feet per second (36). In one study 80 percent of the seeds fell within 100 feet of the seed trees, but some were carried as much as 200 feet (13).

The number of seed shed per acre, of course, varies with the number and size of seed trees. The largest number observed in California was 180,000 sound seeds per acre in a cutover stand which had 5 cone-bearing trees per acre, each of which bore an average of 167 cones (16).

## VEGETATIVE REPRODUCTION

Sugar pine does not reproduce itself naturally by sprouts. Moreover, sugar pine cuttings do not root easily; in one test (29) only 2 percent of the cuttings rooted although calluses formed on the stems of others. But the cuttings were from a 12-year-old tree--younger material might root more readily.

Sugar pine can be grafted onto stocks of other pines. For example, successful grafts were made on stock of ponderosa pine and Monterey pine (*pinus radiata* D. Don), which are not closely related to the white pines (28).

## SEEDLING DEVELOPMENT

## Establishment

The germination of sugar pine is epigeous (cotyledons appear above the ground). The rate of germination is as high as or higher than that of its associated species (42). In one field test the germination rates were: Sugar pine 70 percent; ponderosa pine, 53; incense-cedar, 32; and white fir, 21 (15). Germination of sugar pine in seedspots in southern Oregon was equal to or higher than that of ponderosa pine and higher than Douglas-fir (38).

Sugar pine seeds are eagerly sought after by forest rodents, so little seed may germinate. Early reports that the viability of sugar pine seed was low and that sugar pine seedlings were not vigorous probably arose from the observed relative scarcity of reproduction. But destruction of the seed may have been another reason for the scarcity.

Although it is almost axiomatic that pine seeds germinate better on mineral soil, several field tests show that mineral soil is not necessarily superior for sugar pine. In one test of surface conditions, 70 percent of the sugar pine seed germinated on a mineral soil surface, compared to 54 percent on a litter-covered surface (15). In another test germination was little different on bare and on litter covered surfaces--62 percent on bare compared to 65 percent on litter one year, and 42 percent on bare against 50 percent on litter another year.

During their first year sugar pine seedlings are exceptionally vigorous, compared to their natural associates. In an 8-year study of establishment of seedlings, the first year survival of sugar pine seedlings was 42 percent--compared to 27 percent for ponderosa pine, 11 percent for white fir, and 12 percent for incense-cedar. In southwestern Oregon seed-spotting tests, first year stocking of sugar pine seedlings was 59 percent, of ponderosa pine 49 percent, and of Douglas-fir 16 percent (38).

Brush hinders the establishment and growth of sugar pine seedlings. In 18 to 24 years only 18 percent of the 1-year-old seedlings starting under brush survived (14). At the end of 10 years the tallest were barely over a foot high and still overtopped by the brush. Where sugar pine had an even start with brush, however, it has been able to compete successfully (12).

One reason for the better survival of sugar pine seedlings during their first year is that the seedlings are only slightly attacked by cutworms (Noctuidae). The California Station found that only 8 percent of the sugar pine seedlings were killed by cutworms, whereas 28 percent of the ponderosa pine, 34 percent of the white fir, and 53 percent of the incense-cedar seedlings were killed by these insects (10).

Sugar pine seedlings are more susceptible to freezing injury than ponderosa pine, Jeffrey pine, and incense-cedar seedlings, but they are slightly less damaged by freezing than white fir (31).

Drought may cause high mortality of sugar pine seedlings. In one 8-year study about half of the losses were attributed to drought. However, losses from low soil moisture were no greater for sugar pine than for ponderosa pine and white fir.

Rodents destroy many seedlings during the first 2 months after germination.

Records of seedling mortality in Oregon show no losses from heat injury even where seedlings grew through beds of charcoal on south exposures. 4/

Seedling mortality is greatest during the first 2 years (14). About 55 percent of the sugar pine seedlings on a series of natural reproduction plots were lost during the first year and 66 percent failed to survive 2 growing seasons. The mortality rate decreased after the second year and had almost leveled off by the tenth year.

The seed-to-seedling ratio is one measure of the effectiveness of different methods used to secure natural regeneration. This ratio was found to vary greatly, depending mainly on the condition of the seedbed and the amount of seed destroyed by animals. On three different areas the ratios were: 38 seeds per seedling when the ground surface was scarified and the rodents were poisoned; 70 when the area was only scarified; and more than 480 when no preparatory measures were taken (16).

On the basis of these data, it appears that natural sugar pine regeneration would be favored by a group selection type of regeneration cut. Past experience in California has indicated the desirability of even-aged management by clear-cutting small homogeneous units (18, 19). Small openings with soil disturbed by logging present satisfactory conditions for germination and offer more frost protection than large clear cuttings. Natural regeneration is sought when harvesting occurs during a good sugar pine seed year.

In non-seed years, the clear-cut areas should be planted or seed spotted the next spring. In southwest Oregon, the recommended practice for sugar pine management is to clear-cut and then spot seed or plant.

### Early growth

First-year root development of sugar pine seedlings is rapid. The primary root, which develops as a tap root with a few short lateral branches, penetrated bare sandy soils to as much as 24 inches in 2 to 3 months after germination on the Stanislaus plots. The tap roots averaged 17 inches long. In the same time, seedlings which germinated on duff-covered soil had roots mostly 7 to 9 inches long, and a maximum of 12 inches.

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4/ Unpublished data, Pacific Northwest Forest and Range Experiment Station.

Height growth is relatively slow during the first 5 years even on the best sites; however, after the fifth year growth is usually rapid. On high quality sites with little competition the first year's shoot grew to a length of 4 to 5 inches on the Stanislaus plots. Average 5-year-old seedlings were 10 inches and the tallest seedlings were about 15 inches. Average 8-year-old seedlings were 35 inches and the tallest was 73. By comparison, 8-year-old Jeffrey pines growing in the same location averaged 52 inches high and the tallest was 98 inches (35).

## SEASONAL GROWTH

Seasonal height growth usually starts later than that of the associated species, except white fir (11). The average date for start of height growth at an elevation of 5,200 feet on the Stanislaus Experimental Forest was May 26. Ponderosa pine started growing about 2 weeks earlier and white fir about a month later. Sugar pine completed its seasonal growth quickly, on the average in only 51 days, and was faster than the other associated species with the exception of white fir. Half of the total height growth of sugar pine was completed within 15 days.

Seasonal radial growth starts before height growth. At the Stanislaus Experimental Forest the average date of beginning of radial growth was April 17. Also, radial growth continued for a longer period than height growth. The average was 129 days. The time and period of radial growth of sugar pine was essentially the same as that of ponderosa pine.

The new needles of sugar pine do not appear until about 80 percent of the terminal growth is completed. At the Stanislaus Experimental Forest new needles usually appear early in July.

## SAPLING STAGE TO MATURITY

### Growth and yield

Described by its discoverer, Douglas, as "the most princely of the genus," sugar pine grows up to 121 inches in diameter and 246 feet tall (1, 20). A tree 250 feet tall was recently reported in southern Oregon. The larger sugar pines contain 20,000 to 25,000 board-feet, Scribner rule, and the largest scale recorded was 40,710 board-feet, gross. With the exception of the giant sequoia, sugar pines on high quality sites are usually the largest trees, both in height and diameter, in the old-growth stands of the Sierra Nevada and the southern Cascade Range.

Sugar pine is long-lived; large sugar pines often are more than 500 years old. One tree 92 inches d.b.h., had approximately 600 rings outside a rotten core at least a foot across.

Sugar pine maintains its growth rate to larger sizes than do its associates, giant sequoia possibly excepted. On site II or better it will grow at the rate of 2.5 percent in basal area annually to a diameter of 30 inches (7). On the best sites, some trees may continue to make good growth up to a diameter of more than 50 inches.

In young stands, the average dominant trees 5/ attain the following sizes on medium (Dunning Site II-150) and on high sites (Dunning Site A-200) (8):

| | Medium site | | High site | |
|---|---|---|---|---|
| | Height (Feet) | Diameter (Inches) | Height (Feet) | Diameter (Inches) |
| Age, years: | | | | |
| 20 | 28 | 3 | 45 | 5 |
| 40 | 55 | 9 | 82 | 13 |
| 60 | 75 | 14 | 110 | 20 |
| 80 | 90 | 18 | 127 | 25 |
| 100 | 102 | 21 | 140 | 29 |
| 120 | 112 | 24 | 152 | 34 |
| 140 | 118 | 26 | 160 | 38 |

Yield table data by Dunning and Reineke (9) for young sugar pines vary considerable from these values and are believed to be too high.

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5/ Average diameters are based on data compiled by Duncan Dunning, Calif. Forest and Range Expt. Sta.

In virgin central Sierra forests, dominant trees on low to high sites reached the following average heights and diameters in eight localities in California (25):

| Age, years: | Height (Feet) | D.b.h. (Inches) |
|---|---|---|
| 20 | 8 | 0.2 |
| 40 | 23 | 2.5 |
| 60 | 45 | 7.5 |
| 80 | 72 | 13.0 |
| 100 | 92 | 18.1 |
| 140 | 118 | 26.8 |
| 200 | 142 | 37.0 |

Sugar pine is rarely found in pure stands, except in scattered small areas, so that estimates of yields are meaningful only in relation to the whole stand. In the ponderosa pine-sugar pine type, sugar pine made up 37 percent of the total basal area of second-growth stands (9). In the virgin forest the board-foot volume of sugar pine in this type amounted to 40 percent or more of the total. One of the heaviest stands of record contained 192,000 board-feet of sugar pine on an acre plot.

On the best sites, yields of 130,000 to 180,000 board-feet per acre have been predicted for second-growth stands containing sugar pine at 100 years (9), the age at which mean annual growth culminates. However, yields of this magnitude are unrealistic. Because of the mixed species composition of stands containing sugar pine, yields of sugar pine seldom exceed 50,000 board-feet per acre. Under good management, sugar pine yields of 85,000 may be attained in 100 years on the best sites and up to 46,000 on medium sites in 120 years.

Since sugar pine does not prune itself early, even in dense stands, the many small dead branches would need to be removed in order to produce high-quality clear lumber in rotations of 80 to 120 years (fig. 3).

Figure 3.--Sugar pine does not prune itself early. These 60-year-old trees in a dense stand still have many small dead limbs.

## Reaction to Competition

Sugar pine is usually rated as intermediate in tolerance (2). It is more tolerant than ponderosa pine and Jeffrey pine and less tolerant than white fir and incense-cedar. Douglas-fir is judged to be of the same level of tolerance as sugar pine where the two grow together.

Sugar pine shows good response to release. In fact, much of what is called reproduction on cut-over land actually is advance reproduction, some of which may have been 30 to 40 years old and only a few feet tall at the time of logging. After being released, the advance reproduction begins vigorous growth and subsequently is considered to have come in after logging.

In southwestern Oregon sugar pine is unable to hold the site in competition with Douglas-fir that can grow faster than 150 feet tall in 100 years.

Once behind in the competition for dominance, particularly with white fir, sugar pine declines unless released. The dominant sugar pines in the old stands undoubtedly were always dominant or were released naturally while still relatively young. Sugar pine is not a climax species but is found in the white fir climax because of its greater fire and disease resistance.

Principal enemies

Only a few of the many insects that attack sugar pine are of economic importance (22). The chief insect enemies are the mountain pine beetle (*Dendroctonus monticolae* Hopk.), the five-spined engraver beetle (*Ips confusus* Lec.), and the pine flat-headed borer (*Melanophila gentilis* Lec.). They are capable of killing young and old trees, especially those weakened by logging and fire damage. The mountain pine beetle may cause severe losses in very dense young sugar pine stands (4). The red turpentine beetles (*Dendroctonus valens* Lec.) seldom kill vigorous trees but are capable of killing weakened ones.

Relatively few diseases cause serious losses among living sugar pines. White pine blister rust (*Cronartium ribicola* Fisch.) is the most destructive disease of trees of all ages. Sugar pine is particularly susceptible to blister rust, but spread and intensification of the disease have been slow in the southern part of the range. Wind direction, summer dryness, or other factors may hinder spread of the rust. Heart rots are not a serious factor in the management of sugar pine. Losses due to rot are estimated at 3.7 to 6.7 percent for mature trees in the Sierra Nevada and from 5.6 to 11.4 percent for mature trees in the Coast Range Mountains (23, 24).

In southern Oregon 3 percent of trees 24 to 50 inches in diameter were cull and 10 percent were partly defective; 4 percent of trees larger than 50 inches were cull, and 29 percent were partly defective.[6] *Fomes pini* (Thore) Lloyd and *Fomes laricis* (Jacq.) Murr. are the most destructive of the wood-rotting fungi attacking sugar pine. In many localities, dwarfmistletoe (*Arceuthobium campylopodum* f. Engelm. *blumeri* (A. Nelson) Gill) is a serious parasite on both young and old trees.

Saplings and poles of sugar pine are readily killed by fire. However, mature and older trees have some measure of resistance, as attested by the fire scars prevalent in the old-growth forests.

## SPECIAL FEATURES

The very large seeds of sugar pine were a source of food for the Indians. They ate seeds as nuts or ground them into a paste, called lopa. Lopa was used especially in feasts (3).

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6/ Hammond, H. L. Report on the work of the South Umpqua combined disease survey and timber cruising party. Umpqua National Forest office report. 1942.

This pine got its name from the sugary material, pinitol (monomethyl-D-inositol), found as exudations on the bark of the tree. This sugar alcohol was used by the Indians as a food and in solution as an eye wash. It also has cathartic properties.

The oleoresin of sugar pine was found to contain 65 percent l-alpha pinene, 13 percent l-beta pinene, 10 percent of a bicyclic sesquiterpene of cadalene type, 2 percent of a sesquiterpene alcohol, provisionally named lambertol, and 2 percent unidentified polyterpenes (30).

## RACES AND HYBRIDS

There is no evidence so far to show the presence of races of sugar pine. But it would not be surprising to find that races do occur, in view of the 15-degree spread of latitude over which the tree grows and of the discontinuous distribution in the southern part of its range. No natural hybrids are known to exist, but sugar pines have been crossed with Armand's pine (*P. armandi* Franch.) and with Korean pine (*P. koraiensis* Sieb. & Zucc.) (6).

## LITERATURE CITED


(1) American Forestry Association.
1951. American tree monarchs. Separate. 6 pp., illus.

(2) Baker, F. S.
1949. A revised tolerance table. Jour. Forestry 47: 179-181.

(3) Barrett, S. A. and Gifford, E. W.
1933. Sugar pine (Pinus lambertiana Dougl.) seed used by Indians as food. City of Milwaukee Public Museum Bul. 2: 150-151.

(4) Clements, V. A.
1953. Possible means of reducing mountain pine beetle attacks in young sugar pine. Calif. Forest and Range Expt. Sta. Res. Note 89, 5 pp.

(5) Duffield, J. W.
1953. Pine pollen collection dates--annual and geographic variation. Calif. Forest and Range Expt. Sta. Res. Note 85, 9 pp., illus.

(6) ______________, and Righter, F. I.
1953. Annotated list of pine hybrids made at the Institute of Forest Genetics. Calif. Forest and Range Expt. Sta. Res. Note 86, 9 pp.

(7) Dunning, Duncan
1923. Some results of cutting in the Sierra Forests of California. U. S. Dept. Agr. Bul. 1176, 26 pp., illus.

(8) ______________
1942. A site classification for the mixed conifer selection forests of the Sierra Nevada. Calif. Forest and Range Expt. Sta. Res. Note 28, 21 pp., illus.

(9) ______________, and Reineke, L. H.
1933. Preliminary yield tables for second-growth stands in the California pine region. U. S. Dept. Agr. Tech. Bul. 354, 24 pp., illus.

(10) Fowells, H. A.
1940. Cutworm damage to seedlings in California pine stands. Jour. Forestry 38: 590-591.

(11) Fowells, H. A.
1941. The period of seasonal growth of ponderosa pine and associated species. Jour. Forestry 39: 601-8, illus.

(12) ______________
1944. Site preparation as an aid to sugar pine regeneration. Calif. Forest and Range Expt. Sta. Res. Note 41, 4 pp.

(13) ______________
1950. Some observations on the seedfall of sugar pine. Calif. Forest and Range Expt. Sta. Res. Note 70, 3 pp.

(14) ______________, and Schubert, G. H.
1951. Natural reproduction in certain cutover pine-fir stands of California. Jour. Forestry 49: 192-6, illus.

(15) ______________, and Schubert, G. H.
1951. Recent direct seeding trials in the pine region of California. Calif. Forest and Range Expt. Sta. Res. Note 78, 9 pp.

(16) ______________, and Schubert, G. H.
1956. Seed crops of forest trees in the pine region of California. U. S. Dept. Agr. Tech. Bul. 1150, 48 pp., illus.

(17) Hall, Ralph C.
1955. Insect damage to the 1954 crop of Douglas-fir and sugar pine cones and seeds in northern California. Calif. Forest and Range Expt. Sta. Misc. Paper 18, 4 pp.

(18) Hallin, William E.
1951. Unit area control in California forests. Calif. Forest and Range Expt. Sta. Res. Note 77, 8 pp., illus.

(19) ______________
1954. Unit area control--its development and application. Calif. Forest and Range Expt. Sta. Misc. Paper 16, 10 pp.

(20) Harlow, W. M., and Harrar, E. S.
1950. Textbook of Dendrology. Ed. 3, 555 pp., illus. New York, Toronto, London.

(21) Jepson, Willis L.
1923. Manual of the flowering plants of California. 1,238 pp., illus. Berkeley

(22) Keen, F. P.
1952. Insect enemies of western forests. U. S. Dept. Agr. Misc. Pub. 273, 280 pp., illus.

(23) Kimmey, James W.
1950. Cull factors for forest tree species in northwest California. Calif. Forest and Range Expt. Sta. Forest Survey Release 7, 30 pp., illus.

(24) ____________
1954. Cull and breakage factors for pines and incense-cedar in the Sierra Nevada. Calif. Forest and Range Expt. Sta. Res. Note 90, 4 pp.

(25) Larsen, L. T., and Woodbury, T. D.
1916. Sugar pine. U. S. Dept. Agr. Bul. 426, 40 pp., illus.

(26) Merriam, C. H.
1898. Life zones and crop zones of the United States. U. S. Dept. Agr. Biol. Surv. Bul. 10, 79 pp., illus.

(27) Miller, John M.
1914. Insect damage to the cones and seeds of Pacific Coast conifers. U. S. Dept. Agr. Bul. 95, 7 pp., illus.

(28) Mirov, N. T.
1940. Tested methods of grafting pine. Jour. Forestry 38: 768-777, illus.

(29) ____________
1944. Experiments in rooting pines in California. Jour. Forestry 42: 199-204.

(30) ____________, Haagen-Smit, A. J., and Thurlow, James
1949. Composition of gum turpentine of *Pinus lambertiana*. Jour. Amer. Pharmaceutical Assoc. 38: 407-408.

(31) Schubert, Gilbert H.
1955. Freezing injury to young sugar pine. Jour. Forestry 53: 732.

(32) ____________
1955. Freezing injury to sugar pine cones. Calif. Forest and Range Expt. Sta. Res. Note 96, 2 pp., illus.

(33) Schubert, Gilbert H.
1956. Effect of ripeness on the viability of sugar, Jeffrey, and ponderosa pine seed. Soc. Amer. Foresters Proc. 1955: 67-69, illus.

(34) ____________
1956. Effect of fertilizer on cone production of sugar pine. Calif. Forest and Range Expt. Sta. Res. Note 116, 5 pp., illus.

(35) ____________
1956. Early survival and growth of sugar pine and white fir in clear-cut openings. Calif. Forest and Range Expt. Sta. Res. Note 117, 6 pp., illus.

(36) Siggins, Howard W.
1933. Distribution and rate of fall of conifer seeds. Jour. Agr. Res. 47: 119-128, illus.

(37) Society of American Foresters, Committee on Forest Types.
1954. Forest cover types of North America (exclusive of Mexico). 67 pp., illus. Washington, D. C.

(38) Stein, William I.
1955. Some lessons in artificial regeneration from southwestern Oregon. Northwest Science 29: 10-22, illus.

(39) Sudworth, George B.
1908. Forest trees of the Pacific slope. U. S. Dept. Agr. Forest Service. 441 pp., illus.

(40) Tevis, Lloyd, Jr.
1953. Effect of vertebrate animals on seed crop of sugar pine. Jour. Wildlife Management 17: 128-131, illus.

(41) Thornthwaite, C. W.
1941. Atlas of the climatic types in the United States 1900-1939. U. S. Dept. Agr. Misc. Pub. 421, 7 pp., 96 plates.

(42) U. S. Forest Service
1948. Woody-plant seed manual. U. S. Dept. Agr. Misc. Pub. 654, 416 pp., illus.

TECHNICAL
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# SILVICAL CHARACTERISTICS OF CALIFORNIA RED FIR AND SHASTA RED FIR

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FOREST AND RANGE
EXPERIMENT STATION
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FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

# Preface

The Forest Service is engaged in assembling information on the silvical characteristics of important forest trees of the United States. Much material that is of value in silviculture and research is widely scattered and difficult to locate. This report presents, in preliminary form, the information that has been collected for one species of tree. Similar reports are being prepared for other species at the California Forest and Range Experiment Station and at other forest experiment stations. Readers are encouraged to notify the authors of omissions, errors, or new information affecting the silvical characteristics of the species.

# SILVICAL CHARACTERISTICS OF CALIFORNIA RED FIR AND SHASTA RED FIR

By William E. Hallin
Division of Forest Management Research

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CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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The Experiment Station is maintained at Berkeley, California in cooperation with the University of California.

Agriculture--Forest Service, Berkeley, California

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# SILVICAL CHARACTERISTICS OF CALIFORNIA RED FIR AND SHASTA RED FIR

By William E. Hallin, Forester,
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California red fir (Abies magnifica A. Murr.) and Shasta red fir (Abies magnifica var. shastensis Lemm.) are believed to be almost identical in silvical characteristics. The only known morphological differences are those in the cone structure by which the typical species and variety are distinguished. Their range extends from the Cascade Mountains in southwestern Oregon south to the North Coast Ranges of California and through the Sierra Nevada to central California and western Nevada (fig. 1). In the more northern parts of their range, especially in southern Oregon, the variety is more prevalent than the type species; southward the Shasta variety is less abundant. In this report no distinction will be made between them and they will be referred to collectively as red fir.

Red fir extends from latitude 43° 35' N. in the southern Cascades in Oregon down the coast ranges to Lake County in California and down the Sierra Nevada to the Kern River drainage, latitude 35° 40' N. It also is indigenous to Washoe County in western Nevada (10).

Although logging started only recently in red fir, the tree is destined to become of substantial economic importance. It produces wood of good quality, and the tops of red fir saplings bring premium prices as Christmas trees in the California markets. Its growth behavior and requirements are less well known than those of trees that have been commercially important for a long time, and experimental work is just getting underway in southern Oregon and northern California.

## HABITAT CONDITIONS

### CLIMATIC

Red fir grows in a habitat characterized by long winters with a heavy snowpack and short, dry summers. Where it is the predominant tree, the snowpack usually remains until late June or early July. Precipitation--about 80 percent snow--varies from 30 to 60 inches. The annual precipitation on areas with optimum development of red fir averages 40 to 50 inches. July and August precipitation is commonly less than 1 inch--usually from thundershowers and very spotty in character.

Maximum temperatures seldom exceed 80° F. and very rarely exceed 90° F. Minimum temperature may be -25° F. or lower.

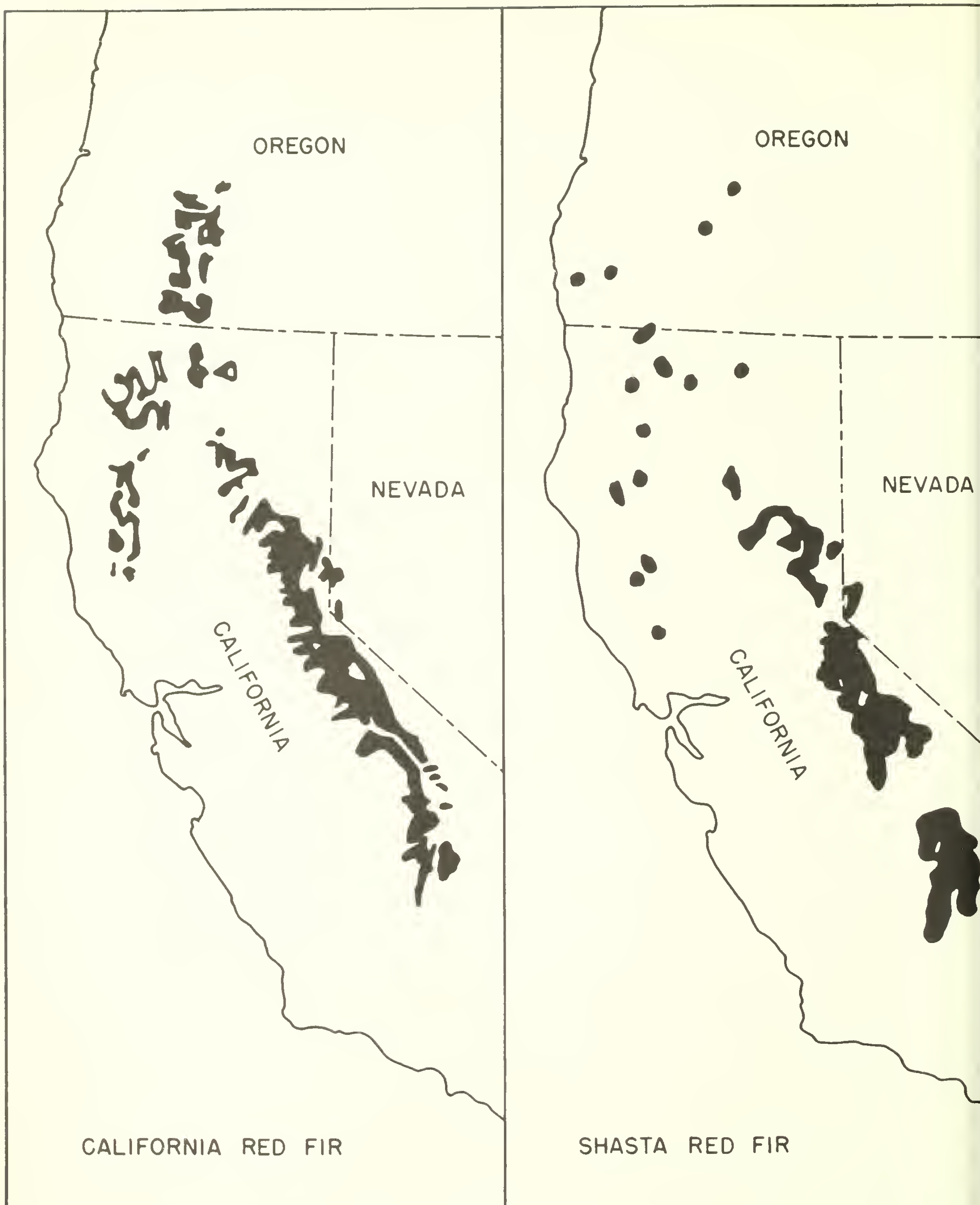


Figure 1.--The natural range of California red fir and Shasta red fir. (From Munns, E. N. 1938. The distribution of important forest trees of the United States. U. S. Dept. Agr. Misc. Pub. 287, 176 pp.)

Red fir forests occur in the Canadian life zone. Individual trees also are found in the Transition and Hudsonian zones.

## EDAPHIC

Red fir grows on soils derived from a variety of parent materials. In the Sierra Nevada of California, its best development apparently is on glacial moraines or on unglaciated areas with a deep soil (5). Well drained soils on gentle slopes are particularly favorable. It is also found on protected steep slopes and on level areas where water from melting snow does not stand. On windswept slopes and shallow, rocky soils the trees are small and unthrifty. In southern Oregon red fir is commonly found on clay loams and pumice soil.

At 5 locations in the central Sierra Nevada within red fir stands, the soil pH varied from 5.0 to 6.1 in the surface inorganic layer and 4.6 to 6.0 in the organic layer (5). The loss on ignition at these 5 stations varied from 6.8 to 19.4 percent in the inorganic surface mineral soil and from 64.9 to 81.8 percent in the organic layer. This sharp contrast indicates a mor humus type of soil. However the dry summers prevent development of a true mor humus and accompanying podzol.

## PHYSIOGRPHIC

Red fir occurs chiefly between elevations of 6,000 and 9,000 feet over its range. However, on the west slopes of the Cascades in southern Oregon and in northern California it occasionally is found at 5,000 feet and infrequently at 4,500 feet.

Pure stands typically occur at relatively high altitudes within a narrow belt of about 1,000 feet difference in elevation.

## BIOTIC

Red fir is most prevalent in its central altitudinal zone, either in pure stands or in mixture with white fir (*Abies concolor* (Gord. and Glend.) Lindl.). In these mixed stands the proportion of red fir increases with altitude. In the northern part of its range it also grows in mixture with noble fir (*Abies procera* Rehd.). At its upper altitudinal range it appears with lodgepole pine (*Pinus contorta* Dougl.), western white pine (*P. monticola* Dougl.), whitebark pine (*P. albicaulis* Engelm.), and mountain hemlock (*Tsuga mertensiana* (Bong.) Carr). At its lower elevation it mixes with sugar pine (*P. lambertiana* Dougl.), Jeffrey pine (*P. jeffreyi* (Grev. and Balf.), ponderosa pine (*P. ponderosa* Laws.), lodgepole pine, incense-cedar (*Libocedrus decurrens* Torr.), white fir, and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco).

In its zone of optimum development red fir stands often are very dense. Fully stocked stands are even-aged and crown closure is complete. Few herbs, shrubs, or young trees are present. In many places the ground is completely bare and has a surprisingly shallow duff layer above the mineral soil. Duff layers up to 2 inches thick have been reported.

Where openings have been created by insects, disease, wind, or fire, and where restocking with trees is not yet complete, a variety of herbs and shrubs will be found. They may include any of the common plants of the Canadian, Transition, and Hudsonian zones, such as: pine-mat manzanita (*Arctostaphylos nevadensis* Gray), bitter cherry (*Prunus emarginata* Dougl.), sticky current (*Ribes viscosissimum* Pursh.), round leaf snowberry (*Symphoricarpos rotundifolia* Gray), whitethorn (*Ceanothus cordulatus* Kell.), and bush chinkapin (*Castanopsis sempervirens* Dudley).

Large brush fields may reseed to trees very slowly, but the evidence is that red fir eventually will reclaim them.

Red fir is rated as intermediate in tolerance when compared with other conifers (2). It commonly will recapture the ground occupied by intermingled patches of lodgepole pine. Many examples of various stages of conversion from lodgepole to red fir--red fir seedlings, saplings, and poles in lodgepole stands and young red fir stands containing lodgepole windfalls--can be seen on the Swain Mountain Experimental Forest.

Virgin red fir forest is regarded by Oosting as a true climatic climax plant association (5).

## LIFE HISTORY

### SEEDING HABITS

Pollination is believed to occur in June, cones ripen in August, and seed is dispersed in September and October.

Good seed crops appear at 2- or 3-year intervals. For example, on a clear-cut area in southern Oregon, the Pacific Northwest Forest and Range Experiment Station recorded nearly 140,000 red fir seeds per acre fell in 1951 (8), and 164,000 in 1953.

Insects at times severely reduce the quantity of good seed produced.

Red fir seeds are disseminated primarily by wind. They fall at the rate of 5.3 feet per second (7). A 10-mile-per-hour wind would carry seed 405 feet from a height of 150 feet.

## VEGETATIVE REPRODUCTION

Red fir does not reproduce naturally by sprouting from the root collar or by rooting (layering). Like many other conifers, red fir saplings when topped for Christmas trees will generally send up a new top from a bud on the stem or branch below. Limbs in the whorl of branches just below the cut will sometimes turn up and form a new top, particularly on open-grown thrifty trees.

## SEEDLING DEVELOPMENT

Red fir seeds have medium to low viability. In a clear-cut area in southern Oregon only 2.2 percent of the natural seedfall germinated in 1952, and 3.7 percent of the natural seedfall germinated in 1954, according to the Pacific Northwest Forest and Range Experiment Station. Rodent depredations may have affected the results of this test. Despite the low germination, this area had a total of 3,800 red fir seedlings per acre, and 59 percent of the mil-acres were stocked in the fall of 1955. The red fir seedlings were hardy and survival during the first few years was good. Red fir seedlings may become established either in clearings or partially cut areas. Red fir seeds frequently germinate in the snow above the ground.

Seedling losses are commonly caused by insects, drouth, and gophers (8). The seedlings appear to be intermediate in frost resistance between white fir and sugar pine (6). Some frost injury to new growth on seedlings in clearings has been observed, but development was not severely retarded.

Red fir commonly restocks small openings created by fire, cutting, or other causes. Even-aged stands of saplings and poles from 1 or 2 acres to 15 to 20 acres in size are common in the red fir type in northeastern California. The Pacific Northwest Forest and Range Experiment Station reports that in a sample of 10 clear-cut patches 8 to 35 acres in size in the red fir type in southern Oregon, 6 were well stocked, 2 medium stocked, and 2 poorly stocked 2 to 5 years after logging.

Red fir grows very slowly during the seedling and sapling stages--much more slowly than Jeffrey pine, for example. Under natural conditions in openings in the forest, average seedlings are likely to require 5 to 10 years to attain a height of 1 foot. Until they reach about 12 to 15 feet in height, terminal shoots generally grow only 2 to 6 inches each year under typical wild stand conditions. This may be an adaptation to the exceedingly deep snowpack which covers them each winter until they attain heights of 10 to 20 feet. In partial shade, height growth is equally slow or slower.

Precise information regarding optimum size of openings for establishment and growth of red fir seedlings is not available. However, the openings must be small enough to permit adequate seed dispersal and large enough to permit satisfactory growth without excessive competition from border trees.

## SAPLING STAGE TO MATURITY

Red fir commonly grows in dense stands until maturity. A 4-acre sample of a mature stand (age 200 years) on the Swain Mountain Experimental Forest in Lassen County, California, had a gross volume of 140,000 board-feet per acre, with an average of 90 trees 12 inches and larger d.b.h. per acre. The largest tree on record is 100 inches d.b.h. and 177 feet tall (1). A tree 66 inches d.b.h. and 186 feet tall was measured on the Swain Mountain Experimental Forest. Considerably taller trees may have gone unreported or may still be discovered.

Heart rots which enter through scars--especially basal fire scars--cause extensive losses in mature stands (4). Cull in mature stands commonly ranges from 30 to 50 percent of the gross volume. The common heart rots are yellow cap fungus (*Pholiota adiposa* Fr.), fomes butt rot (*Fomes annosus* (Fr.) Cke.), shoe-string fungus (*Armillaria mellea* Vahl.) Quel.), sulfur fungus (*Polyporus sulphureus* (Bull.) Fr.), and Indian paint fungus (*Echinodontium tinctorium* E. and E.).

Dwarfmistletoe (*Arceuthobium campylopodum* Engelm. f. *abietinum* Gill) causes extensive damage in stands from sapling size through maturity (3). Dwarfmistletoe is rarely found on trees under 3 or 4 feet in height. Dwarfmistletoe either directly or indirectly causes mortality, and it also leads to much damage by lowering the vigor of trees, deforming them, serving as entrance courts for decay organisms, and weakening the trunk at bole cankers.

Insects frequently cause serious mortality. The common tree-killing insects are the fir engraver (*Scolytus ventralis* Lec.) (9), the flatheaded fir borer (*Melanophila drummondi* (Kby.)), and the roundheaded fir borer (*Tetropium abietis* Fall).

Saplings and small poles frequently are broken or deformed by the crushing action of deep snow. Once the young trees have emerged above the level of the deepest snow, much less snow injury occurs because the stem and branches are exceptionally well adapted to resisting it. Sweep in butt logs of mature trees is common as a result of the trees being bent by snow movement while they were young.

Windthrow losses are commonly very severe after selection cutting in mature stands. However, if selection cuts are light, windthrow losses may be low. The intensity of selection cutting which can be made without incurring excessive windthrow has not been determined.

Even-aged management by clear cutting is recommended because of windthrow losses following selection cutting, heart rot entrance through logging scars, prevalence of dwarfmistletoe in mature stands, and slow growth rate of understory trees. The predominantly even-aged character of wild stands seems further to indicate that attempts at uneven-aged management would violate natural principles.

## LITERATURE CITED

(1) American Forestry Association
1956. These are the champs. American Forests, April 1956.

(2) Baker, Frederick S.
1950. Principles of silviculture. 414 pp., illus. New York, Toronto, (etc.)

(3) California Forest Pest Control Action Council
1956. Forest pest conditions in California--1955. Calif. State Div. Forestry, Sacramento, 21 pp., illus.

(4) Kimmey, James W.
1950. Cull factors for forest tree species in northwestern California. U. S. Forest Serv., Calif. Forest and Range Expt. Sta. Forest Survey Release 7. 30 pp., illus.

(5) Oosting, H. J. and Billings, W. D.
1943. The red fir forest of the Sierra Nevada: Abietum magnificae. Ecol. Monog. 13(3) 260-274, illus.

(6) Schubert, Gilbert H.
1956. Early survival of sugar pine and white fir in clear-cut openings. California Forest and Range Expt. Sta. Res. Note 117. 6 pp., illus.

(7) Siggins, Howard W.
1933. Distribution and rate of fall of conifer seeds. Jour. Agr. Res. 47: 119-128.

(8) Stein, William I.
1954. Natural reproduction of Shasta red fir from a single cone crop. U. S. Forest Serv. Pacific Northwest Forest and Range Expt. Sta. Res. Note 100. 5 pp., illus.

(9) Struble, G. R.
1937. The fir engraver beetle, a serious enemy of white fir and red fir. U. S. Dept. Agr. Cir. 419. 16 pp., illus.

(10) Sudworth, George B.
1908. Forest trees of the Pacific slope. U. S. Dept. Agr., Forest Serv. 441 pp., illus.

TECHNICAL
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# SILVICAL CHARACTERISTICS OF JEFFREY PINE

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FOREST AND RANGE
EXPERIMENT STATION
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BERKELEY - APRIL 1957

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

# Preface

The Forest Service is engaged in assembling information on the silvical characteristics of important forest trees of the United States. Much material that is of value in silviculture and research is widely scattered and difficult to locate. This report presents, in preliminary form, the information that has been collected for one species of tree. Similar reports are being prepared for other species at the California Forest and Range Experiment Station and at other forest experiment stations. Readers are encouraged to notify the authors of omissions, errors, or new information affecting the silvical characteristics of the species.

# SILVICAL CHARACTERISTICS OF JEFFREY PINE

By William E. Hallin
Division of Forest Management Research

Technical Paper No. 17 April 1957

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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The Experiment Station is maintained at Berkeley, California in cooperation with the University of California.

Agriculture--Forest Service, Berkeley, California

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# SILVICAL CHARACTERISTICS OF JEFFREY PINE

By William E. Hallin, Forester,
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The most noteworthy feature of Jeffrey pine (Pinus jeffreyi Grev. & Balf.) is its similarity in appearance and behavior to ponderosa pine (Pinus ponderosa Laws.)--a much more widespread and better known species. At one time Jeffrey pine was considered to be a variety of ponderosa pine, and lumber markets make no distinction between the two species because their wood differs little in structure and properties. Because of the apparent similarity of silvical characteristics and wood, usually no distinction has been made between the two species in either management or research records.

Jeffrey pine is found in southwestern Oregon, the Coast Range of California, the Sierra Nevada--including the eastern slopes a short distance into Nevada, southern California, and northern Lower California (Fig. 1).

Jeffrey pine is believed to be an old stable species, whereas ponderosa pine is a young, vigorous, and variable species (12). The relative youthfulness of ponderosa pine as a species probably accounts for its more widespread distribution.

## HABITAT CONDITIONS

### CLIMATIC

With but few exceptions the climate of Jeffrey pine habitats is characterized by dry summers and cold winters. Minimum temperatures are $-25^{o}$ F. or lower, and maximum temperatures are near or above $100^{o}$ F. Most of the precipitation falls as snow. In some years summer thundershowers may add appreciably to the precipitation. Contrary to some reports (19), Jeffrey pine probably does not require more moisture than ponderosa pine. Good nearly pure stands are present where the average annual precipitation is only 18 inches. However, Jeffrey pine, like ponderosa pine, grows most rapidly where the annual precipitation averages greater than 30 inches.

Jeffrey pine appears to be more frost resistant than ponderosa pine. In northeastern California on timbered flats and around the borders of non-timbered flats, which probably are frost pockets, Jeffrey pine is more prevalent than ponderosa pine. In these places, the stands are frequently nearly pure Jeffrey pine. On the slopes, however, the stands commonly are pure ponderosa


Figure 1.--The natural range of Jeffrey pine. (From Munns, E. N. 1938. The distribution of important forest trees of the United States. U. S. Dept. Agr. Misc. Pub. 287, 176 pp.)

pine. On the west side of the Sierra Nevada Jeffrey pine is more prevalent than ponderosa pine on the colder flats, but seldom grows on the slopes above. On high cold ridges in almost pure true-fir forests, Jeffrey pine is frequently present while ponderosa pine is not.

Nevertheless, Jeffrey pine may have a much more sharply defined low temperature limit than ponderosa pine, according to unpublished observations by Willis W. Wagener of the California Forest and Range Experiment Station. During the winter of 1936-1937, cold weather injured pines the entire length of the east slope of the Sierra Nevada. Foliage of both species was severely injured; twigs, bark, and buds of ponderosa pine were not seriously injured, but Jeffrey pine branches were often completely killed. Evidently a sharply delineated temperature inversion occurred within the cold air layer. Many saplings or small poles of Jeffrey pine were frozen back at the base but remained alive at the top until the trees died later because of the killing below. This type of killing indicates that the margin between little or no injury and mortality from cold is very narrow for Jeffrey pine.

Jeffrey pine commonly occurs in the Canadian life zone and the upper elevation of the Transition zone.

### EDAPHIC

In its range Jeffrey pine grows on much the same wide variety of soil as ponderosa pine. It is most common on soils developed from lava flows and granite. In addition it is rather commonly found on soils developed from serpentine rock and is more capable of growth on such soils than ponderosa pine. The occurrence of Jeffrey pine on serpentine soils indicates it can tolerate low levels of calcium, available molybdenum, and major nutrients, and high levels of nickel, chromium, and magnesium (21). Although Jeffrey pine reaches its best development on deep, well-drained soils, it also is found in stunted form on very shallow soils and in crevices in rocks. Lindsay claims that nowhere is Jeffrey pine found on poorly drained soils (10).

### PHYSIOGRAPHIC

Except in southern and Lower California and a few places in southwestern Oregon, Jeffrey pine generally grows above 5,000 feet (10). It is found down to 3,500 feet in southern California and down to 4,000 feet in Lower California. In interior northern California it occasionally is found down to 3,500 feet. The lowest known incidence in California is at 1,000 feet above sea level in the Coast Range near Garberville, latitude 40° 13' N., longitude 123° 55' W. (reported by R. E. Nelson, California Forest and Range Experiment Station); in Oregon, at 600 feet above sea level near Myrtle Creek, latitude 43° 2' N., longitude 123° 19' W. (reported by W. I. Stein, Pacific Northwest Forest and Range Experiment Station). The best commercial stands are between 5,000 and 6,500 feet (19). Individual trees may be found up to 10,000 feet.

## BIOTIC

Jeffrey pine is commonly associated with ponderosa pine, both with and without other species, such as sugar pine (Pinus lambertiana Doug.), California red fir (Abies magnifica A. Murr.), Shasta red fir (Abies magnifica var. shastensis Lemm.), white fir (Abies concolor (Gord. & Glend.) Lindl.), Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), incense-cedar (Libocedrus decurrens Torr.) and western juniper (Juniperus occidentalis Hook.). Pure Jeffrey pine stands, however, are common in a narrow belt on the east slopes of the central and southern Sierra Nevada and in the mountains of southern California. The common forest types in which Jeffrey pine is found are: Interior ponderosa pine, ponderosa pine-sugar pine-fir, Jeffrey pine, red fir, and western juniper (18).

Jeffrey pine is reported to occur between the upper limits of ponderosa pine and the lower limits of white fir (19). However, it frequently grows outside this belt--both in patches at lower elevations with ponderosa pine and as scattered trees at higher elevations with white or red fir.

In southern California Jeffrey pine is associated with California live oak (Quercus agrifolia Nee) and Coulter pine (Pinus coulteri D. Don).

In northeastern California common sagebrush (Artemisia tridentata Nutt.), bitterbrush (Purshia tridentata DC.), squaw-carpet (Ceanothus prostratus Benth.), and greenleaf manzanita (Arctostaphylos patula Greene), are the most common shrubs associated with Jeffrey pine. In other parts of its range some of the common shrubs are whitethorn (Ceanothus cordulatus Kell.), greenleaf manzanita, bearmat (Chamaebatia foliolosa Benth.), and bush chinkapin (Castanopsis sempervirens Dudley).

## LIFE HISTORY

### SEEDING HABITS

Pollination occurs in May and June, and cones ripen in August or early September the following year. Most of the seeds are dispersed in September and October. At the Blacks Mountain Experimental Forest in Lassen County, northeastern California, approximately two-thirds of the seeds fall before November 1.

Although some cones are produced almost every year, abundant seed crops are produced at irregular intervals of 4 to 8 years. Cone production starts at 8 years and reaches an optimum at 150 years (3).

Jeffrey pine seed are disseminated by wind and rodents. They fall at the rate of 7.25 feet per second (17). On level ground, a 10-mile per hour wind will carry seed 300 feet as it falls from a height of 150 feet.

Insects attacking the cones and seed often seriously reduce the quantity of good seed produced. The more common pests are a cone-beetle (*Conopthorus ponderosae* Hopk.) and two pine cone moths, *Laspeyresia piperana* Kearf. and *Eucosma babana* Kearf. (9).

## VEGETATIVE REPRODUCTION

Jeffrey pine does not reproduce naturally by sprouting or rooting.

## SEEDLING DEVELOPMENT

### Establishment

Jeffrey pine seeds are usually highly viable. Germination is generally better than that of ponderosa pine (3). In a seed-storage test, the germination capacity of Jeffrey pine seed was 93 percent; of ponderosa pine, 86 percent (15). In two direct-seeding tests with seed protected with screens, the germination was: First test, Jeffrey pine 98 percent and ponderosa pine 91 percent; second test, Jeffrey pine 86 percent and ponderosa pine 69 percent (8).

Jeffrey pine seeds are about twice as heavy as ponderosa pine, and they usually produce larger seedlings the first year. In one study the dry weight of Jeffrey pine 1-year-old seedlings was about 50 percent greater than that of ponderosa pine (7). However, the larger size of Jeffrey pine seedlings probably does not promote much better survival. Available data do not clearly show an advantage for either species.

The seeds of Jeffrey pine, like those of ponderosa pine, are readily eaten by rodents. Consequently natural regeneration or direct seeding generally are unsuccessful unless rodent populations are at a low level (from natural causes or control measures) or the seeds are protected as by screening. Except on a few small plots, direct seeding of Jeffrey pine without seed protection has failed.

Neither Jeffrey pine nor ponderosa pine can successfully be regenerated on areas occupied by competing vegetation. At the

Blacks Mountain Experimental Forest, the need for removal of competing vegetation was shown in tests of natural regeneration and of planted nursery stock. In a year of an excellent seed crop, rodents were poisoned in and around openings in a mixed ponderosa-Jeffrey pine stand. On bare ground, 33,329 ponderosa and Jeffrey pine seedlings per acre germinated, and 33 percent survived at the end of 4 years (20); on areas with heavy vegetation, 2,914 seedlings germinated, and 4 percent survived at the end of 4 years (20). In the planting test, second-year survival on bare ground was 62 percent for 1-1 Jeffrey pine and 71 percent for ponderosa pine, whereas on areas with heavy vegetation it was 0 for Jeffrey pine and 7 percent for ponderosa pine (13).

Cutworms and other insects frequently cause serious mortality among young seedlings.

Because of irregular seed crops and rapid invasion of cutover areas by other vegetation, artificial regeneration will be needed much of the time.

Early Growth

Jeffrey pine and ponderosa pine grow at about the same rate when present together under natural conditions. Compared with such associates as Douglas-fir, white fir, incense-cedar, and sugar pine, they have a rapid early growth if free from an overstory and other plant competition. On clear-cut areas which were free of vegetation after cutting, the average heights of Jeffrey pine, sugar pine, and white fir were 4.3 feet, 2.9 feet, and 0.6 feet, respectively, at the end of 8 years (16). In a plantation study in Plumas County, California, the average height of Jeffrey pine was 4.2 feet 9 years after planting (7). As is true of most fast-growing trees, several years after establishment are required before a maximum rate of height growth is reached. In stands free of competition and not overly dense, the period before maximum height growth is believed to be between 5 and 10 years for Jeffrey pine.

Seasonal height growth starts at about the same time as for ponderosa pine but earlier than for white fir and sugar pine (6). The average date was May 16 at an elevation of 5,200 feet at the Stanislaus Experimental Forest in the central Sierra Nevada. The average duration of height growth was 78 days at this locality. In Lassen County in northeastern California at an elevation of 5,000 feet, the average starting date of height growth was May 15.

Jeffrey pine frequently becomes established under open, overmature overstories. Under these conditions, however, its growth is very slow. Both Jeffrey and ponderosa pine seedlings 40 years or more in age and less than 3 feet tall are common in California stands. When released by removal of the overstory, Jeffrey pine begins rapid height growth after 3 to 7 years.

The pine reproduction weevil (*Cylindrocopturus eatoni* Buch.) frequently causes serious mortality in Jeffrey pine plantations (4).

## SAPLING STAGE TO MATURITY

Comparative growth data for Jeffrey pine and ponderosa pine are not available. Jeffrey pine trees commonly look as though they were more vigorous than ponderosa pine and retain youthful appearance to greater ages where the two species grow together. Yet their growth rate, maximum size, and age appear to be similar. We believe that ponderosa pine growth and yield data can be used for both Jeffrey pine stands and mixed stands of Jeffrey and ponderosa pine.

The largest tree reported is 57 inches d.b.h. and 157 feet tall (1). However trees larger than 60 inches d.b.h. have been measured on the Blacks Mountain and the Stanislaus Experimental Forests. A Jeffrey pine 83 inches d.b.h. has been measured on the Inyo National Forest. Undoubtedly there are Jeffrey pine trees over 200 feet tall. A number of "yellow pine" trees taller than 200 feet are recorded in early volume table measurements. As ponderosa and Jeffrey pine were lumped together as yellow pine in early records, some of these trees probably were Jeffrey pine.

Jeffrey pine is long lived. Ages of 400 to 500 years are common.

Jeffrey pine usually occurs in both pure and mixed stands as even-aged groups of trees. The groups are from a fraction of an acre to 5 or 10 acres in size--rarely larger. Commonly a younger even-aged understory of seedlings, saplings, or poles is also present.

Jeffrey pine is rated as an intolerant tree in its light requirements--being similar to ponderosa pine in this respect (2).

On large areas with low precipitation (15 to 20 inches) on the east side of the Sierra Nevada, Jeffrey pine occurs as a climatic climax association either as pure stands or mixed with ponderosa pine. Where precipitation is higher and the more tolerant white fir occurs, Jeffrey pine probably is present only in subclimax stages of plant succession.

Even-aged management by small groups is indicated by the even-aged character of natural stands and by the more rapid growth of young stands without an overstory. We believe that for management purposes the optimum size of group is between 5 and 10 acres although this has not been definitely determined. The groups must be small enough to permit adequate seed dispersion from border trees after a reproduction cutting, and large enough to minimize competition from larger border trees.

## COMMON PESTS

Porcupines cause extensive damage in sapling and pole stands by girdling the tops of young trees. Although they kill some trees, their usual damage is reduction in growth resulting from loss of crown and cull resulting from tree deformation. Occasionally they girdle and kill seedlings.

Dwarfmistletoe (*Arceuthobium campylopodum* Engelm. f. *typicum* Gill) causes extensive damage by reducing growth, especially in young age classes. It also is a contributing cause of mortality in mature trees. Dwarfmistletoe is more prevalent and destructive on the poorer sites.

A root rot (*Fomes annosus* (Fr.) Cke.) and a stain fungus (*Leptographium* spp.) cause considerable mortality in all age classes by killing the roots of Jeffrey pine.

A limb rust (*Cronartium filamentosum* (?) Peck) is common on Jeffrey pine in the central and southern Sierra. In the remainder of the range of Jeffrey pine the rust is restricted to an occasional tree. The rust attacks large saplings and older trees. Although the rust develops slowly it eventually kills the trees it infects.

The Jeffrey pine beetle (*Dendroctonus jeffreyi* Hopk.)--the principal insect enemy of Jeffrey pine--causes heavy losses in old-growth stands on the east side of the Sierra Nevada (5). Before the final harvest cut, losses in old-growth Jeffrey pine stands can be kept to a minimum by a sanitation-salvage cut in which the high risk trees--the ones most likely to be infested--are removed.

The California flatheaded borer (*Melanophila californica* Van Dyke) frequently attacks mature Jeffrey pine and may occasionally kill the tree. Usually it only weakens the tree before it is killed by bark beetles. The Oregon pine engraver (*Ips oregoni* Eichh.) attacks and kills the tops of mature Jeffrey pine.

## SPECIAL FEATURES

An unusual feature of Jeffrey pine is that its turpentine is not composed of terpenes, as is that of most pines, but is composed of normal heptane, one of the paraffin hydrocarbons, with a small admixture of fragrant aliphatic aldehydes (14). This composition of Jeffrey pine turpentine may have a bearing on silviculture. For example, heptane may be extracted commercially, it affects rosin impregnation, and it may affect the resistance of this pine to some species of bark beetles.

## RACES AND HYBRIDS

Jeffrey pine hybridizes naturally with both Coulter pine [1/] and ponderosa pine (11).

## LITERATURE CITED

(1) American Forestry Association
1956. These are the champs - part II. American Forests 62(4): 33-40.

(2) Baker, Frederick S.
1950. Principles of silviculture. 414 pp., illus. New York, Toronto (etc.).

(3) Forest Service
1948. Woody plant seed manual. U. S. Dept. Agr. Misc. Pub. 654. 416 pp., illus.

(4) Eaton, C. B.
1942. Biology of the weevil *Cylindrocopturus eatoni* Buchanan, injurious to ponderosa and Jeffrey pine reproduction. Jour. Econ. Ent. 35(1): 20-25, illus.

(5) Eaton, Charles B.
1956. Jeffrey pine beetle. U. S. Dept. Agr. Forest Pest Leaflet 11. 7 pp., illus.

(6) Fowells, H. A.
1941. The period of seasonal growth of ponderosa pine and associated species. Jour. Forestry 39: 601-607, illus.

(7) ____________
1953. The effect of seed and stock size on survival and early growth of ponderosa and Jeffrey pine. Jour. Forestry 51: 504-507, illus.

(8) ____________ and Schubert, G. H.
1951. Recent direct seeding trials in the pine region of California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 78. 9 pp., illus.

---

1/ Zobel, Bruce J. The natural hybrid between Coulter and Jeffrey pine. Ph.D. thesis, Univ. Calif., Berkeley, 114 pp. 1951. (Typewritten.)

(9) Keen, F. P.
1952. Insect enemies of western forests. U. S. Dept. Agr. Misc. Pub. 273. 280 pp., illus.

(10) Lindsay, A. D.
1932. Jeffrey pine. Commonwealth (Australia) Forestry Bureau Leaflet 7. 5 pp.

(11) Mirov, N. T.
1932. A note on Jeffrey pine and western yellow pine. Jour. Forestry 30: 93-94.

(12) Mirov, Nicholas Tiho
1938. Phylogenetic relations of *Pinus jeffreyi* and *Pinus ponderosa*. Madrono IV(6): 169-171.

(13) Roy, D. F.
1953. Effects of ground cover and class of planting stock on survival of transplants in the east-side pine type of California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 87. 6 pp., illus.

(14) Schorger, A. W.
1919. The oleoresin of Jeffrey pine (*Pinus jeffreyi*). Wis. Acad. Sci. Arts, Letters, Trans. 19, Part 2: 739-740.

(15) Schubert, Gilbert H.
1955. Effect of storage and temperature on viability of sugar, Jeffrey, and ponderosa pine seed. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 100. 3 pp.

(16) ______
1956. Early survival and growth of sugar pine and white fir in clear-cut openings. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 117. 6 pp., illus.

(17) Siggins, Howard W.
1933. Distribution and rate of fall of conifer seeds. Jour. Agr. Res. 47: 119-128.

(18) Society of American Foresters.
1954. Forest cover types of North America. 67 pp.

(19) Sudworth, George B.
1908. Forest trees of the Pacific slope. U. S. Dept. Agr., Forest Serv. 441 pp., illus.

(20) Tackle, D. and Roy, D. F.
1953. Site preparation as related to ground cover density in natural regeneration of ponderosa pine. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Tech. Paper 4. 13 pp., illus.

(21) Walker, Richard B.
1954. The ecology of serpentine soils. II. Factors affecting plant growth on serpentine soils. Ecology 35: 259-266. Illus.

TECHNICAL PAPER NUMBER 18

# SILVICAL CHARACTERISTICS OF INCENSE-CEDAR

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GEORGE M. JEMISON, DIRECTOR
BERKELEY — AUGUST 1957

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

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By Gilbert H. Schubert

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Agriculture--Forest Service, California

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# SILVICAL CHARACTERISTICS OF INCENSE-CEDAR

By Gilbert H. Schubert, Forester,
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Incense-cedar (Libocedrus decurrens Torr.) is one of the most distinctive trees in the mixed conifer stands of western United States. Its range extends from the southern slope of Mt. Hood in Oregon southward in the mountains to Lower California (26, 32, 35) (fig. 1). It occurs in the Cascade Ranges and Siskiyou Mountains in Oregon, the Coast Ranges and the Sierra Nevada in California, where it extends into western Nevada near Lake Tahoe, and in the Hanson Laguna Range and Sierra de San Pedro Martir in Lower California.

The total net volume of live incense-cedar sawtimber on commercial forest land in the United States was estimated at 13,296 million board-feet in 1952--9,725 million of it in California (7, 37). The rest was in Oregon (3,557 million) and Nevada (12 million). The value of incense-cedar in virgin stands is relatively low because of extensive decay in overmature trees. However, in managed, second-growth stands properly protected from fire and logging injury, incense-cedar should be sound. It will probably increase in commercial importance because of its suitability for soft, easily-worked lumber.

## HABITAT CONDITIONS

### CLIMATIC

The climate in which incense-cedar grows is characterized by: dry summers, usually less than 1 inch of precipitation per month; annual temperature extremes of below -10°F. to above 100°F.; and annual precipitation of about 20 inches or more, part of which falls as snow. The lower limit of precipitation may be about 15 inches a year, for incense-cedars are found on the east side of the Cascades and in the Warner Mountains in Oregon and California (34). Its lower temperature limit has not been determined but it probably is below -20°F.

### EDAPHIC

Incense-cedar grows on many kinds of soils developed from weathering of a wide variety of parent rocks--rhyolite, andesite, diorite, sandstone, shale, basalt, serpentine, and granitic or metamorphic equivalents.

Soils of the western and eastern slopes of the Cascades and in the Siskiyou Mountains in Oregon are quite variable (33).


Figure 1.--The natural range of incense-cedar. (From Munns, E. N. 1938. The distribution of important forest trees of the United States. U. S. Dept. Agr. Misc. Pub. 287, 176 pp.)

The acidity varies from nearly neutral to strongly acid. Textures range from very coarse soils to very fine clays. Incense-cedar grows on most of these soils, but the best stands are generally found on three kinds: Deep, well-drained, sandy loam soils developed on granitic rocks and sandstone; deep clay loams developed on basalt and rhyolite; and deep, coarse-textured, well-drained soils developed from pumice.

In California the best stands are found on deep, slightly to moderately acid, sandy loam soils of the Holland series developed from granitic rocks and the Olympic series derived from basalt and andesite. These soils are common in the central Sierra Nevada.

In the southern Cascades, soils developed from pumice also support excellent stands, especially on benches and gentle slopes where the soils are deep, coarse-textured and well-drained.

In the Coast Ranges and Siskiyou Mountains in California, the best stands occur on deep, slightly to moderately acid, silt loams and clay loams derived from sandstone.

Incense-cedar is also found in isolated spots in the Coast Ranges growing on soils developed from serpentine. Though they make better growth than other conifers on these soils, their growth is considerably less than on the other soil types.

PHYSIOGRAPHIC

Incense-cedar is more common on west- than on east-facing mountain slopes. It grows at increasingly higher elevations toward the southern part of its range and on the east slopes, chiefly because of insufficient moisture at the lower altitudes. In the Cascades it generally occurs at 2,000 to 5,000 feet on the west side and 5,000 to 6,600 feet on the east side. In the Coast Ranges it grows between 1,200 to 6,000 feet. In the central Sierra Nevada, where the best stands occur, it is found between 2,000 and 7,000 feet. On San Jacinto Mountain in southern California, it occurs at 3,000 to 8,000 feet; and in the Sierra de San Pedro Martir, above 7,500 feet (18, 24, 25, 26, 32, 35).

BIOTIC

Incense-cedar seldom grows in pure stands except over very small areas. Under the more favorable conditions for its development, it may form up to 50 percent of the stand (8, 17, 35); however, it generally averages less than 30 percent of the total stems in the stand.

Incense-cedar is rarely a major component of any of the six forest cover types of western North America (31) in which it occurs. It is most abundant in the ponderosa pine-sugar pine-fir type (referred to by some as the mixed-conifer type) and a minor component in the following cover types: Pacific Douglas-fir, Pacific ponderosa pine--Douglas-fir, Pacific ponderosa pine, California black oak, and Jeffrey pine.

In the northern part of its range it is commonly associated with these trees:

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)
ponderosa pine (*Pinus ponderosa* Laws.)
sugar pine (*P. lambertiana* Dougl.)
western white pine (*P. monticola* Dougl.)
white fir (*Abies concolor* (Gord. & Glend.) Lindl.)
grand fir (*A. grandis* (Dougl.) Lindl.)
western hemlock (*Tsuga heterophylla* (Raf.) Sarg.)
western redcedar (*Thuja plicata* Donn)
Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.)
California black oak (*Quercus kelloggii* (Newb.)
tanoak (*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.)
golden chinkapin (*Castanopsis chrysophylla* (Dougl.) A. DC.)
Pacific madrone (*Arbutus menziesii* Pursh).

In the central part it is associated with:

ponderosa pine
sugar pine
Jeffrey pine (*P. jeffreyi* Grev. and Balf.)
lodgepole pine (*P. contorta* Dougl.)
white fir
California red fir (*A. magnifica* A. Murr.)
giant sequoia (*Sequoia gigantea* (Lindl.) Decne.)
California black oak
tanoak
golden chinkapin
Pacific madrone

In the southern part common associates are:

Jeffrey pine
ponderosa pine
sugar pine
Coulter pine (*P. coulteri* D. Don)
bigcone Douglas-fir (*Pseudotsuga macrocarpa* (Vasey) Mayr).

Common brush species occurring with incense-cedar are:

greenleaf manzanita (*Arctostaphylos patula* Greene)
mountain whitethorn (*Caenothus cordulatus* Kell.)
deerbrush (*C. integerrimus* H. & A.)
snowbrush (*C. velutinus* Dougl.)
littleleaf ceanothus (*C. parvifolius* Trel.)
bearmat (*Chamaebatia foliolosa* Benth.)
bush chinkapin (*Castanopsis sempervirens* Dudley)
salal (*Gaultheria shallon* Pursh.)
coast rhododendron (*Rhododendron californicum* Hook.)

## LIFE HISTORY

### SEEDING HABITS

#### Flowering and Fruiting

Male and female flowers occur separately (on the same tree or occasionally on separate trees) on the ends of short lateral branchlets of the previous year's growth throughout the entire crown ( 8, 24, 26, 36). The pollen-bearing strobili are about one-fourth inch long in early spring at the time of pollen shedding. The conelets are usually small and not noticeable until sometime later. By late summer the pendant cones are from 3/4 to 1-1/2 inches long. The cones--consisting of two seed-bearing scales with two seeds each--mature in one season and shed their seeds during late summer and fall.

#### Seed Production

Incense-cedars are prolific seed bearers; however, they do not produce seeds every year (16). During a period of 28 years, incense-cedars on the Stanislaus National Forest (Tuolumne County, California) had 6 cone crops rated as heavy or very heavy, 8 medium-size crops, and 14 rated as none or light. During this period the interval between medium or heavier cone crops varied from 1 to 5 years, with an average of 2 years. The interval between heavy or very heavy crops varied from 3 to 6 years.

The best seed year on record occurred in 1934 when seed trap counts on 5 Stanislaus plots indicated an estimated per acre seedfall of 186,210 seeds (16). The highest on an individual plot was 389,100 seeds per acre.

The percent of sound seed in seed trap collections varied from 14 to 65 percent (16). The highest proportion of sound seed occurred during heavy seed years and the lowest during light seed years.

Little information is available on the seed production of individual incense-cedars. The relationship between seed production and stand volume in immature and mature dominants indicates that relatively small volumes in cutover stands--as little as 500 board feet--will produce approximately 100,000 seeds per acre (16). Full-crowned dominant trees in the immature age class have been observed to bear tremendous quantities of seeds.

Destruction of seed is not particularly serious in incense-cedar. Some losses are caused by sawflies (*Augomonoctenus libocedri* Rohw.) which attack the cones (19, 23); however, the exact extent of the damage has not been determined. Squirrels, particularly the Douglas squirrel (*Tamiasciurus douglasii* Backman) at times cut down incense-cedar cones; however, they usually destroy few cones (16). During poor seed years for pines, firs, or brush, rodents eat greater quantities of incense-cedar seeds.

## Seed Dissemination

Natural seed dissemination begins in late August at the lowest elevations and in October at the higher levels. Some seeds may fall during the winter months. During a period of hot, dry, windy weather, seeds are released earlier than when the weather is cool, moist, and calm. The percentage of the total seed crop that fell at different observation dates on the Stanislaus National Forest at 6,000 feet elevation was (16):

| Year and date: | Percent of seed caught in seed traps | |
|---|---|---|
| | All seed | Sound seed |
| 1937 | | |
| October 6 | 11 | 3 |
| " 27 | 36 | 37 |
| November 11 | 53 | 60 |
| 1940 | | |
| October 11 | 32 | 54 |
| " 29 | 34 | 38 |
| November 13 | 34 | 8 |

Incense-cedar seeds vary in size and weight. The number of seeds per pound averages 15,000 and ranges from 6,400 to 29,000 (36). The seeds have a relatively large wing for their weight. Consequently they are carried great distances by air currents. In still air, the seeds fall at the rate of 5.9 feet per second (30). However, the seed flight patterns under actual forest conditions are unknown.

## VEGETATIVE REPRODUCTION

Incense-cedar does not reproduce naturally by sprouting or rooting.

## SEEDLING DEVELOPMENT

### Establishment

Incense-cedar seeds germinate in the field under a wide variety of conditions. The seeds will germinate in both organic and mineral soil. Although they will also germinate on compact roadbeds and skidroads and on the top of snow, the resulting seedlings seldom get their roots into the soil before the advent of the dry summer season.

Viability tests in the greenhouse indicate that up to 98 percent of the sound seeds can germinate (27, 28). However, germination of seed sown in the field usually varies from 20 to 40 percent (15, 24). Since a moist seedbed is required for germination, field germination will seldom approach the maximum--especially on exposed sites where soil moisture in the upper half-inch of soil is rapidly depleted through evaporation.

In the first stages of development, seedlings may require partial shade. During a period of 18 to 24 years after logging, 10,092 seedlings per acre started on a series of cutover plots on the Stanislaus National Forest (14); 84 percent were incense-cedar. Of the 2,749 seedlings that were alive at the end of the period, 78 percent were incense-cedar. Ground surface conditions and incense-cedar seedling incidence on these plots were:

| Ground surface condition: | Seedling incidence (Percent) |
|---|---|
| Bare ground | 1 |
| Brush | 51 |
| Litter | 41 |
| Logs, rocks, and other debris | 7 |

Seedling mortality is frequently high. Cutworms and drought destroy many seedlings; rodents generally are of minor importance. During a 5-year period, 53 percent of the 1- to 2-month-old incense-cedar seedlings on the Stanislaus plots were destroyed by cutworms (Noctuidae larvae) (12). The seed to seedling ratio on 4 cutover plots varied from 20:1 to 355:1 (16). Drought may cause high mortality of incense-cedar seedlings during the first growing season, but these losses are usually less than those caused by insects (12). Losses from low soil moisture are most noticeable on dry sites and on compacted landings and skid roads.

## Early Growth

First-year development of incense-cedar seedlings is usually slow in comparison to that of the associated pines. The primary root grows to a depth of about 12 inches during the first growing season--about half to two-thirds the length of ponderosa or sugar pine of the same age. Lateral roots begin development early in the first season and continue at a greater rate than the taproot. Incense-cedar seedlings may take 3 to 5 years to grow the first 6 inches in height. Pines of the same age are normally 2 to 3 times as tall. After the fifth year the rate of height growth increases, but at no time does it approach that of its associates.

## Seasonal Growth

Seasonal height growth of incense-cedar on the Stanislaus Experimental Forest starts earlier than for sugar pine and white fir, but later than for ponderosa or Jeffrey pine (13). The average date growth started at an elevation of 5,200 feet was May 24. Growth was completed in an average of 91 days--a longer period than for any of the associated species.

Seasonal radial growth starts before height growth. At the Stanislaus Experimental Forest the average date of beginning of radial growth was April 15. This was about the same as ponderosa pine, but earlier than sugar pine and white fir. The average period of radial growth was 136 days. Half of the total radial growth was completed in 39 days (13).

# SAPLING STAGE TO MATURITY

## Growth and Yield

Incense-cedar varies greatly in size in different parts of its range (18, 24, 32, 35). In the coast ranges and in southern California the largest trees are generally from 60 to 80 feet high and 3 to 4 feet in diameter. In the Sierra Nevada, incense-cedars frequently grow to a height of 150 feet with diameters up to 7 feet. The probability exists that considerably taller trees may have occurred or may still be discovered. The largest tree measured had a circumference of 36 feet (1)--about 11.5 feet in diameter. A tree 225 feet tall was recently reported in southern Oregon. At high elevations, especially on dry exposed sites, the trees are small and scrubby.

Incense-cedar is long-lived; large trees often are more than 500 years old (24). The oldest recorded age was 542 years. This tree was only 51 inches d.b.h., therefore larger trees may be older. It has an extensive, well-developed lateral root system and is quite wind-firm.

Incense-cedar ordinarily makes its most rapid height growth between the 50th and 75th years (24). On good sites--Dunning Sites A-200 and I-175 (10)--height growth continues to be rapid up to 150 years. Beyond 150 years, height growth is very slow.

Basal area growth of incense-cedar is usually slower than that of the associated species (9, 29). On medium or poorer sites it has a lower basal-area growth rate than white fir, Douglas-fir, sugar pine or ponderosa pine. However, on some poorer sites under the most favorable conditions, the basal area growth of incense-cedars up to about 24 inches in diameter may exceed all other species except white fir (9).

Since incense-cedar is seldom found in pure stands, yields are of practical significance only in relation to the entire stand. Although the stand may contain many incense-cedars, particularly in the younger age classes, they rarely make up more than 5 to 10 percent of the stand volume (11).

Average total stand volumes in trees larger than 12 inches d.b.h. range from 20,000 to 90,000 board-feet in the Sierra Nevada. On the Stanislaus Experimental Forest the average gross volume of a cutover plot of 200 acres was 79,100 board-feet per acre; 10,100 board-feet, or 13.4 percent, was incense-cedar. The average volume per incense-cedar over 12 inches was 897 board-feet.

Incense-cedar does not readily shed its lower branches even in dense stands. Many dead branches must be removed if high quality clear lumber is to be produced in rotations of 80 to 120 years.

## Reaction to Competition

Incense-cedar is usually rated as tolerant (3). It is more shade tolerant than the associated pines and Douglas-fir and less tolerant than white fir and grand fir. In the seedling stage incense-cedar can endure dense shade, but for full development from sapling stage through maturity it requires more light (24).

Incense-cedar shows good response to release. Much of the extremely slow growth of young reproduction is caused by suppression. When released, these seedlings make rapid height growth; however, since height growth is slower than that of the associated species of comparable age, incense-cedar will always be a secondary species in the final stand (9).

Principal Enemies

Incense-cedar is noted for the durability of its heartwood in timber products. Yet standing overmature trees are rated as the most defective of all associated conifers. The amount of cull has been found to increase with age of the trees and to vary between stands (20, 21). Average cull percents based on gross volume were: 4 to 6 percent for immature dominants, 21 percent for mature dominants, and 68 to 77 percent for overmature dominants.

The most important single destructive agent affecting mature incense-cedar is the pocket dry-rot fungus (Polyporus amarus Hedge.), which causes practically all of the decay in this species (5, 6, 22). In parts of the Sierra Nevada, 75 to 100 percent of the mature trees have dry-rot (22).

The spores of pocket dry-rot must be deposited on an open wound to infest trees because the mycelium is unable to penetrate through the bark into the heartwood (22). The most prevalent port of entry was found to be through fire scars (84 percent). Knots (10 percent) were next in frequency, and injuries caused by lightning and frost (6 percent) were least (5).

In the management of second-growth incense-cedar, the age at which dry-rot causes the greatest losses is of primary importance. Suppressed trees are subject to severe dry-rot infection after they reach the age of 165 years; dominant trees are generally safe up to an age of 210 (5). Since the rotation age for second-growth stands will probably be considerably less than these critical ages, dry-rot should not cause severe cull in future managed stands.

Two other diseases of incense-cedar have been reported. One is incense-cedar leaf rust (Gymnosporangium libocedri (P. Henn) Kern), which commonly kills small sprays of foliage and causes witches-brooms and swellings on the branches (6). Extensive infections of leaf rust retard growth and may kill the tree. The second is incense-cedar mistletoe (Phoradendron libocedri Howell), which commonly causes spindle shaped swellings on the branches and occasionally on the trunk (6, 38). The mistletoe occurs throughout the range of incense-cedar. Severe infections suppress growth, but there is no evidence that it kills large trees.

Many kinds of insects are found on incense-cedar, but relatively few cause serious losses (19). Some of the more damaging ones are: The cedar flatheaded borer (Chrysobothris nixa Horn), which is a common enemy of incense-cedar in the coast region; the western cedar bark beetle (Phloeosinus punctatus Lec.), which is not generally serious but occasionally kills apparently healthy trees; the western cedar borer (Trachykele blondeli Mars.) and the flatheaded borer (T. opulenta Fall), which mine in the sapwood and heartwood of living trees and are very destructive to timber where sound wood is required; and the amethyst cedar borer (Semanotus amethystinus Lec.), which usually attacks injured or dying trees but which may occasionally kill apparently healthy trees.

Young trees are readily killed by fire. The thick bark of mature trees offers considerable protection from fire, but intense fires indirectly cause a great deal of damage by exposing trunks to infection by the pocket dry-rot fungus.

## SPECIAL FEATURES

Incense-cedar and Jeffrey pines are found on serpentine soils, while ponderosa pines are not. Where these three species occur, a stand of incense-cedar and Jeffrey pine can be used as an aid in delineating this soil type.

## RACES AND HYBRIDS

There are no known hybrids of incense-cedar. A few horticultural varieties are recognized in Standardized Plant Names (2). The probability exists that search and study would reveal the occurrence of local races. For example, the incense-cedars of southern California are conspicuously narrower-crowned and more spire-like in silhouette than those of the Sierra Nevada.

## LITERATURE CITED

(1) American Forestry Association
1955. These are the champs. American Forests 61 (9): 31-40, illus.

(2) American Joint Committee on Horticultural Nomenclature
1942. Standardized plant names. Ed. 2. 675 pp. Harrisburg, Pa.

(3) Baker, Frederick S.
1949. A revised tolerance table. Jour. Forestry 47: 179-81.

(4) Betts, H. S.
1955. Incense-cedar (Libocedrus decurrens). Amer. Woods. U. S. Dept. Agr. 4 pp., illus.

(5) Boyce, J. S.
1920. The dry-rot of incense-cedar. U. S. Dept. Agr. Bul. 871, 58 pp., illus.

(6) Boyce, John Shaw
1948. Forest Pathology, Ed. 2, 550 pp., illus. New York, Toronto, London.

(7) California Forest and Range Experiment Station
1954. Forest statistics for California. Forest Survey Release 25. 66 pp., illus.

(8) Collingwood, G. H. and Brush, Warren D.
1955. Knowing your trees. Amer. Forestry Assoc. 328 pp., illus.

(9) Dunning, Duncan
1923. Some results of cutting in the Sierra forests of California. U. S. Dept. Agr. Bul. 1176. 26 pp., illus.

(10) ______________
1942. A site classification for the mixed-conifer selection forests of the Sierra Nevada. Calif. Forest and Range Expt. Sta. Forest Res. Note 28. 21 pp., illus.

(11) ______________ and Reineke, L. H.
1933. Preliminary yield tables for second-growth stands in the California pine region. U. S. Dept. Agr. Tech. Bul. 354. 23 pp., illus.

(12) Fowells, H. A.
1940. Cutworm damage to seedlings in California pine stands. Jour. Forestry 38: 590-1.

(13) ____________
1941. The period of seasonal growth of ponderosa pine and associated species. Jour. Forestry 39: 601-8, illus.

(14) ____________ and Schubert, G. H.
1951. Natural reproduction in certain cutover pine-fir stands of California. Jour. Forestry 49: 192-6, illus.

(15) ______________________________
1951. Recent direct seeding trials in the pine region. California Forest and Range Expt. Sta., Forest Res. Note 78, 9 pp.

(16) Fowells, H. A. and Schubert, G. H.
1956. Seed crops of forest trees in the pine region of California. U. S. Dept. Agr. Bul. 1150 48 pp., illus.

(17) Harlow, William M. and Harrar, Ellwood S.
1950. Textbook of dendrology. Ed. 3, 555 pp., illus. New York, Toronto, London.

(18) Jepson, Willis Linn
1909. The trees of California. 228 pp., illus... San Francisco.

(19) Keen, F. P.
1952. Insect enemies of western forests. U. S. Dept. Agr. Misc. Publ. 273. 280 pp., illus.

(20) Kimmey, James W.
1950 Cull factors for forest-tree species in northwestern California. Calif. Forest and Range Expt. Sta. Forest Survey Release 7. 30 pp., illus.

(21) ______
1954. Cull and breakage factors for pines and incense-cedar in the Sierra Nevada. California Forest and Range Expt. Sta. Forest Res. Note 90. 4 pp.

(22) Meinecke, E. P.
1914. Forest tree diseases common in California and Nevada. A manual for field use. U. S. Dept. Agr. Forest Service Pub. 67 pp., illus.

(23) Miller, John M.
1914. Insect damage to the cones and seeds of Pacific Coast conifers. U. S. Dept., Agr. Bul. 95. 7 pp., illus.

(24) Mitchell, Alfred J.
1918. Incense-cedar. U. S. Dept. Agr. Bul. 604. 40 pp., illus.

(25) Peattie, Donald Culross
1953. A natural history of western trees. 751 pp., illus., Boston.

(26) Sargent, Charles Sprague
1922. Manual of the trees of North America (exclusive of Mexico). Ed. 2. 910 pp., illus. Boston, New York.

(27) Schubert, G. H.
1952. Germination of various coniferous seeds after cold storage. Calif. Forest & Range Expt. Sta. Forest Res. Note 83. 7 pp.

(28) ______
1954. Viability of various coniferous seeds after cold Storage. Jour. Forestry 52: 446-7.

(29) Show, S. B.
1926. Timber growing and logging practice in the California pine region. U. S. Dept. Agr. Dept. Bul. 1402. 75 pp., illus.

(30) Siggins, Howard W.
1933. Distribution and rate of fall of conifer seeds. Jour. Agr. Res. 47: 119-28, illus.

(31) Society of American Foresters, Committee on Forest Types
1954. Forest cover types of North America (exclusive of Mexico). 67 pp., illus. Washington, D.C.

(32) Sudworth, George B.
1908. Forest trees of the Pacific slope. U. S. Dept. Agr., Forest Service. 441 pp., illus.

(33) Tarrant, Robert F.
1956. Forest soils of the Pacific Northwest. Soc. Amer. Foresters Proc. 1955: 73-6, illus.

(( (34) U. S. Department of Agriculture
1941. Climate and Man. Agr. Yearbook 1941. 1248 pp., illus.

(35) U. S. Forest Service
1907. Incense-cedar. U. S. Dept. Agr. Silvical Leaflet 9. 4 pp.

(36) U. S. Forest Service
1948. Woody-plant seed manual. U. S. Dept. Agr. Misc. Pub. 654. 416 pp., illus.

(37) U. S. Forest Service
1955. Timber Resource Review. Chap. IX, (Summary of basic statistics). U. S. Dept. Agr. 116 pp.

(38) Wagener, W. W.
1925. Mistletoe in the lower bole of incense-cedar. Phytopathology 15: 614-6.

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# DWARFMISTLETOES OF CALIFORNIA AND THEIR CONTROL

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CALIFORNIA
FOREST AND RANGE
EXPERIMENT STATION
KEITH ARNOLD, DIRECTOR
BERKELEY - OCTOBER 1957

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

# THE DWARFMISTLETOES OF CALIFORNIA AND THEIR CONTROL

By James W. Kimmey

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Agriculture--Forest Service, Berkeley, California

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# THE DWARFMISTLETOES OF CALIFORNIA AND THEIR CONTROL

By James W. Kimmey [1]

Losses caused by the dwarfmistletoes in California's coniferous forests rank next to losses from heart rots. In the future when the overmature virgin stands have been largely cut over, these parasitic plants, if not controlled, may be far more damaging than fungi. Although damage from dwarfmistletoes has long been recognized here, the extent and magnitude of the losses have not been generally known until recent years. It is now recognized that the reduction of damage caused by these parasites is the most important problem in applied forest pathology in the State.

Because foresters have not appreciated the potential threat of dwarfmistletoes, little has been done to work out a concerted control program for young coniferous stands. To provide impetus to a control program, foresters should have a general understanding of the parasites, how they function, and how they may be controlled.

The purpose of this paper is to provide a summary of essential facts regarding the dwarfmistletoes and their control.

## SPECIES AND FORMS

The dwarfmistletoes are seed-bearing plants belonging to the genus *Arceuthobium* that are parasitic on most western conifers. Based on anatomical characteristics, there are three species in California; one of them includes seven forms, with different host susceptibility relationships. In general the various species and forms are confined to a definite host or group of hosts, but transfers from one host species or genus to another occur now and then.

The species and forms occurring in California and their tree hosts are:

1. Lodgepole pine dwarfmistletoe: *A. americanum*, common on the mountain form of lodgepole pine but seldom attacking the coast form. Occasionally it may occur on other pines when these are associated with infected lodgepole pines.

2. Douglas-fir dwarfmistletoe: *A. douglasii*, confined to and common on Douglas-fir.

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3. Western dwarfmistletoe: *A. campylopodum*, divided into a number of host forms:

   a. forma *campylopodum* (figs. 1, 2, 3, and 4) occurs on Coulter, digger, Jeffrey, Monterey, and ponderosa pines but is rare on knobcone and lodgepole pines;

   b. forma *divaricatum* occurs on pinyons;

   c. forma *cyanocarpum* on bristlecone, foxtail, limber, and whitebark pines;

   d. forma *blumeri* on sugar and western white pines;

   e. forma *abietinum* on lowland white, red, and white firs;

   f. forma *tsugensis* on mountain and western hemlocks;

   g. forma *microcarpum* on weeping spruce.

## THE PARASITE PLANT

The plants of the dwarfmistletoes are quite similar in all species except those of *A. douglasii*, which are especially small, usually being 1/4 to 3/4 inch in length. Even in the largest species, however, the shoots rarely attain a length of 8 inches.

### Aerial Shoots

The aerial parts appear as perennial shoots, either simple or branched (figs. 1 and 2). Usually they occur in tufts, but the aerial parts of *A. douglasii* and occasionally those of other species are scattered along the young twigs of the host. They are jointed, with opposite pairs of scale-like leaves at the top of each segment. The segments are four-sided at the base and are usually angular throughout but may be round at the upper end. The color varies from yellowish to brownish green or olive green in many shades.

### Seed Production

The male and female flowers are produced on separate plants (figs. 1 and 2). *A. americanum* and *A. douglasii* bloom in the spring; *A. campylopodum* in late summer. The berries (fig. 2) mature the second autumn after pollination. After flowering, the male shoots die as do the female shoots after the seeds are discharged.

Birds and animals do not eat the seeds; therefore they are of no significance in the spread of the dwarfmistletoe plants.

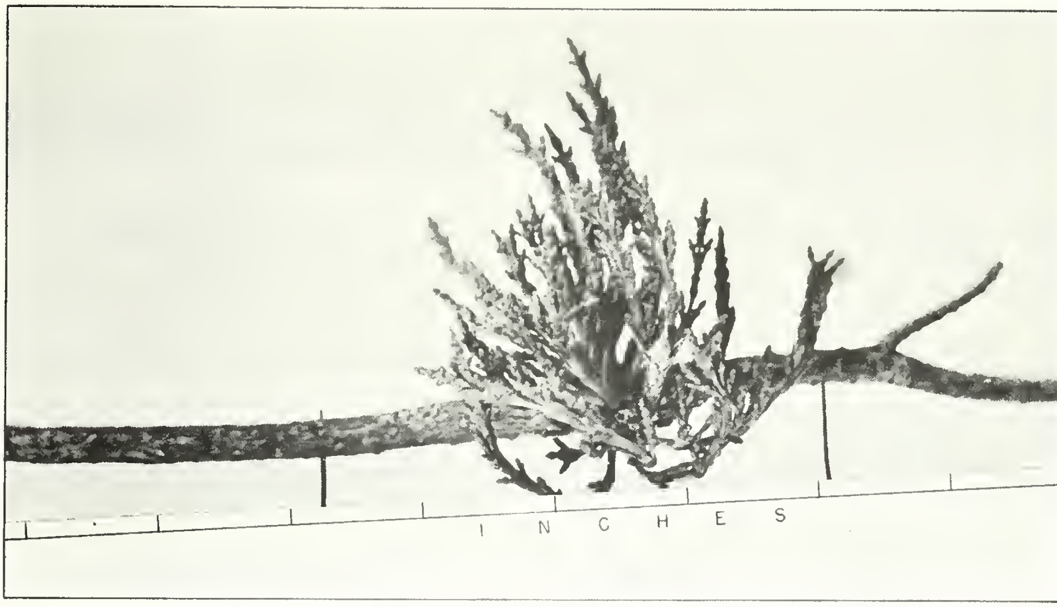


Figure 1.--Typical young male plant of western dwarfmistletoe on a pine branch.


Figure 2.--Female plant of western dwarfmistletoe producing berries. Pine branch shows typical spindle-shaped swelling or canker.
A. Basal "cups" from which shoots of the parasite have dropped.

Seed Dissemination

On ripening, the berries develop a considerable internal pressure, which increases until any slight disturbance causes them to explode and eject the seed with some force. This explosive ejection of the seed is the means by which the parasite is spread. Because of the position of the berries, the seeds are usually shot upward and arch outward. The maximum lateral distance travelled by seed of lodgepole pine dwarfmistletoe in a laboratory test was 33 feet.

Wind during the berry ripening period affects the distance and pattern of spread. Wind is one of the principal sources of the mechanical jarring that triggers seed ejection. Wind is responsible for the oval pattern of seed distribution below a tall tree, the axis of the oval being in the direction of the prevailing wind during the dissemination period. The wind does not "carry" the seeds in the ordinary sense. It reduces the distance to which the seeds are shot against the wind by the ejective force and increases the distance with the wind.

Because of their mucilaginous covering, the seeds stick to whatever they strike. A good many may stick to twigs of the surrounding tree crown.

Germination and Growth

To start a new infection the seed must become attached to the bark of a young branch on a susceptible host. On germination the germ tube (radicle) grows along the bark surface until it is obstructed by a bud or leaf base. At this point the radicle produces an irregular mound of tissue which functions as an anchor. From the under side of this mound of tissue the primary root-like haustorium develops. If the bark is not more than 3 years old, the haustorium can penetrate it to the cambium. Sometimes the haustorium penetrates thin older bark. From this primary haustorium other haustoria develop in the bark, constituting a new infection from which the aerial parts develop.

Any individual seed can produce a plant of only one sex, depending upon the genes it possesses. Male and female plants occur in about a 50-50 ratio. Development of a new plant of seed-bearing age from time of seed germination takes from 4 to 6 years, depending on site and host species.

## SYMPTOMS OF INFECTION

Plants.--The presence of dwarfmistletoe plants is the surest sign of infection, but if the shoots have dropped off, the small basal "cups" from which they came remain on the bark (fig. 2).

Cankers.--Slight to definite, more or less fusiform swellings or cankers usually develop on infected twigs and branches (figs. 1 and 2). A cut through an infected branch will show, especially under a hand magnifier, the yellowish wedge-shaped sinkers of the subsurface (endophytic) part of the plants (fig. 3).

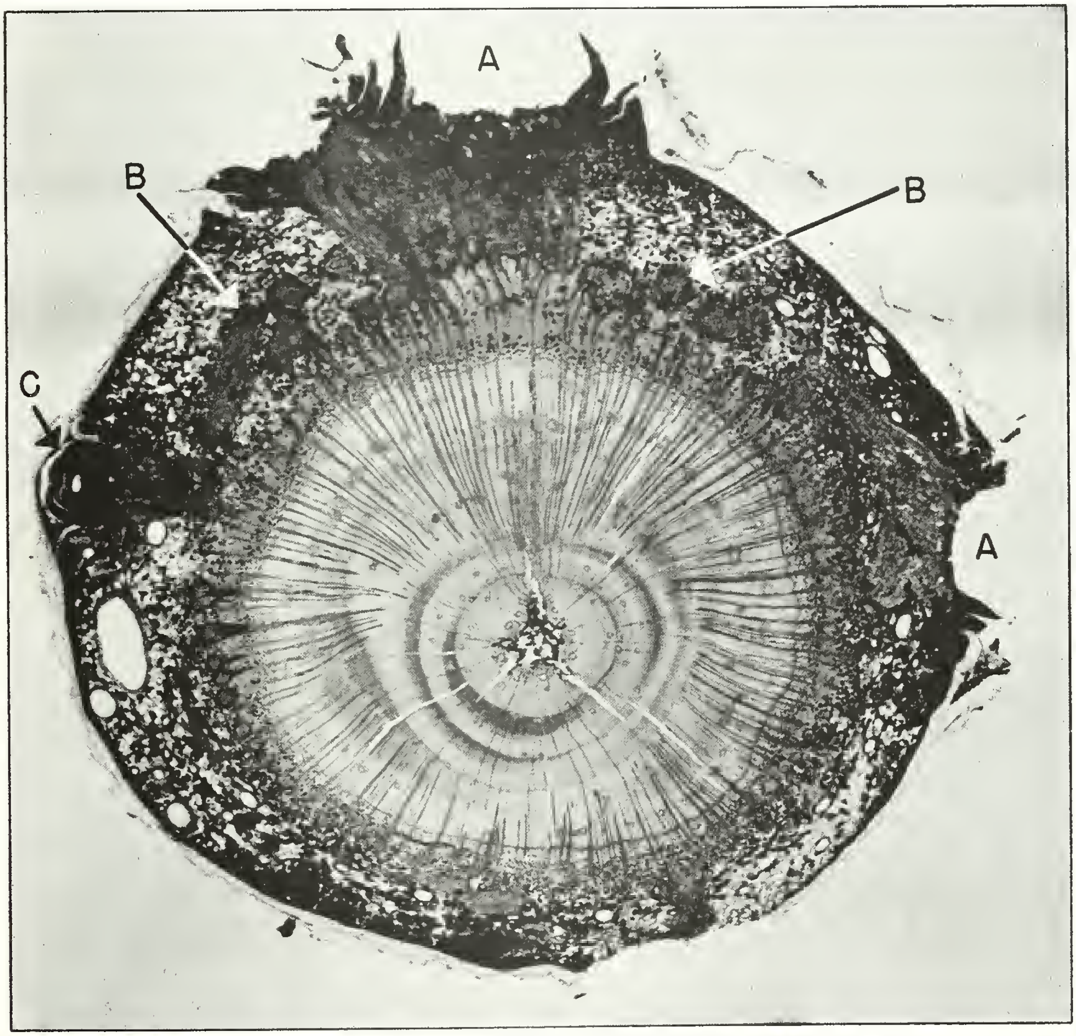


Figure 3.--Enlarged cross section of a pine branch infected with western dwarfmistletoe. A. Basal "cups" from which aerial parts of the parasite have dropped. B. Root-like haustoria in the bark from which dark, wedge-shaped sinkers originate and extend into the wood. C. A new dwarfmistletoe bud breaking through the surface of the host bark.

Witches' brooms.--Witches' brooms, which are proliferous growths of branches (fig. 4), are common in infected trees of Douglas-fir, western hemlock, ponderosa, sugar, and lodgepole pines. Brooms are less common on other tree species. Abnormally enlarged or swollen branches usually occur even where brooms are lacking.

Flags.--Large numbers of dwarfmistletoe-infected branches in red fir stands are killed each spring by a fungus (*Cytospora abietis*) which invades the dwarfmistletoe swellings. The foliage of these dead branches turns brick red, making conspicuous "flags" which persist throughout the year. This branch killing is much more common on red fir than on other tree species.

Trunk swellings.--Large spindle shaped or fusiform swellings, or flattened cankers, commonly occur on infected trunks of red and white firs and may occasionally be found on other species. Such swellings or cankers are rare on Douglas-fir.

Other symptoms.--When the lower crown is heavily broomed, spike tops may occur in older trees, especially in Douglas-fir and western hemlock. The foliage of infected trees is reduced except in broomed portions. Thin crowns and shortened and lighter colored needles are often symptoms of dwarfmistletoe infection.

Light to moderately infected stands are not readily distinguished from healthy stands except by the presence of such symptoms as cankers, brooms, or flags. Heavily infected stands on the other hand give the appearance of poor site conditions. They contain deformed, stunted or dying, and dead trees. Many white and red fir trees in heavily infected stands are broken off at bole cankers (fig. 5), and the stands have many small to large openings caused by the breaking up of the crown canopy by dead and broken trees.

## DAMAGE

Dwarfmistletoes cause extensive, although not always spectacular, damage in California coniferous forests. Trees of any age may be retarded, deformed, or killed. Mortality is particularly heavy in Jeffrey pine seedlings and saplings and in red fir of all ages. Some young stands of Jeffrey pine may be so heavily infected as to be practically worthless, and in some areas red fir may be eliminated as a stand component. Many red and white firs break off at bole infections where decay has developed in dwarfmistletoe cankers and weakened the trunk (fig. 5).

In surveys of lodgepole pine dwarfmistletoe in the Rocky Mountains, the intensity of infection is classed as light when less than one-third, moderate when one-third to two-thirds, and heavy when more than two-thirds of the trees in the predominant size class are infected.

Figure 4.--Witches' brooms, caused by dwarfmistletoe, in the lower crown of a ponderosa pine.

Growth reduction.--Dwarfmistletoe reduces tree vigor. Height growth of Douglas-fir may be reduced as much as 49 percent and diameter growth of ponderosa pine as much as 72 percent in some heavily infected stands. In Arizona cubic-foot increment was reduced by 89 percent in a heavily infected stand of ponderosa pine, while a moderately infected stand was reduced 75 percent, and a lightly infected stand by 41 percent.

Quality reduction.--Dwarfmistletoe affects both quantity and quality of merchantable timber. Quality is reduced by numerous large knots and by abnormally grained, spongy wood that is frequently stained, pitchy, or decayed.

Seed reduction.--Seed production may be drastically reduced in heavily infected stands. Studies in Arizona have shown seed reductions as great as 75 percent in ponderosa stands. Quality of the seed is also affected. Jeffrey pine seed from dwarfmistletoe-infected trees was 20 percent lower in germination and produced less vigorous seedlings than seed from uninfected trees.

Other hazards.--Heavy dwarfmistletoe infection predisposes trees to attack by bark beetles, wood decay, and root diseases, as well as windthrow and breakage (fig. 5). Large dwarfmistletoe brooms, especially the dead ones, are a fire hazard, particularly promoting crown fires.

## CONTROL POSSIBILITIES

There is nothing complicated about the control of dwarfmistletoe. The parasite can be eliminated from a stand by cutting or pruning all infected trees from seedlings to mature trees. In some pure stands this may necessitate clear cutting in blocks, and if the resulting blocks are too large, artificial regeneration may be required. However, in the mixed-conifer type it usually means at the most cutting all trees of one or two species. Subsequent artificial regeneration would not be necessary unless it is desired to reproduce the species removed. Manipulations of the tree species in a stand may at times be the most practical means of control. Since opening up a stand stimulates growth of dwarfmistletoe on the remaining infected trees, it is necessary to eradicate the parasite completely to effect control.

Dwarfmistletoe may be controlled on relatively small areas because its distance of spread is so limited. This means that the spread of the parasite into uninfected stands can be prevented, for all practical purposes, by maintaining a protective zone free of the parasite between the diseased stand and the stand to be protected. This zone may be cleared of all trees; it may be an area already free of all trees, such as an established right-of-way or a stream; or it may be a strip in which only the susceptible tree species have been removed. To maintain a protective zone in which susceptible trees

Figure 5.--Old-growth stand of red fir breaking up from heavy infection of dwarfmistletoe. Note many dead and broken trees.

occur would require constant vigilance for and eradication of new dwarfmistletoe plants. Therefore all protective zones should be completely free of the host tree that is being protected.

Only actively growing female dwarfmistletoe plants produce seed and are able to spread the disease. Male plants or old inactive infections need not be removed to prevent spread. Other than the capacity to spread the disease, however, all plants are equally able to damage the host trees.

Dwarfmistletoe often is eliminated where large forest fires have killed extensive timber stands. When natural regeneration in such burns comes from a distance rather than from an overhead seed source, or when the burned area is artificially regenerated, the resulting stands are usually free of the parasite. Conversely, when stands have been protected from fire for long periods, dwarfmistletoe becomes more abundant and damage more prevalent.

Biological agents sometimes affect dwarfmistletoe to a minor extent. Rodent chewing of cankered branches and parasitism by insects and fungi, although frequent, are of no practical significance in controlling dwarfmistletoe.

Control of the parasite by chemical spray or tree injection has possibilities, but research now being conducted has not yet revealed a satisfactory means of control.

Resistance to dwarfmistletoe is occasionally indicated by individual trees. There is a definite possibility that resistant strains could be genetically produced for many of our commercial conifers.

## RECOMMENDED CONTROL PROCEDURES

After a control area has been delineated on the ground, the first step should be to eliminate the overhead source of infection. All infected trees of sawlog size should be removed unless it is desirable to retain those from which the infections can be removed by pruning. In recreation areas it may even be desirable to leave non-seed-bearing mistletoe infections.

After the overstory has been cleaned, all dwarfmistletoe infections in the pole stands and advanced reproduction should be eliminated in commercial timber areas and at least the seed-bearing dwarfmistletoe plants in other areas. Witches' brooms, although much more conspicuous than ordinary infections, are usually less important as seed sources than the less conspicuous thrifty, younger infections.

Three years after the first cutting and pruning the area should be carefully reworked to remove dwarfmistletoe plants that have subsequently appeared. After that, examinations should be made periodically at about 5-year intervals to detect and remove any new infections in order to prevent dwarfmistletoe from again spreading into or building up in the area.

Protective zones should never be less than 50 feet wide, even on level ground. If the host trees in the diseased area are more than 50 feet tall, the zone should be at least as wide as the height of the tallest host tree. On a slope where the diseased trees are above the protective zone, one foot should be added to the zone width for each degree of slope.

Dwarfmistletoe control in immature stands may often be incorporated in thinning and crop-tree pruning operations. Branch infections that have not yet grown into the main bole may be removed from a tree by cutting off the branch. If the distance from the swelling (or other indication of infection) to the base of the branch is greater than twice the branch diameter, the infection may be pruned out by cutting off the branch flush with the tree bole.

Bole infections cannot be satisfactorily cut out; therefore, trees thus affected must usually be removed.

The best time for control is in the late summer just before the berries mature, and when the maximum number of young shoots can be detected. Timber felling should be avoided during the seed dissemination period, if possible, to prevent unnecessary spreading of the seeds.

## CONTROL COSTS

Costs of control measures now recommended vary with the intensity of infection, the age and composition of the stand, and the size of the infected areas involved.

In sawtimber stands the costs will depend largely upon the amount of dwarfmistletoe infection remaining after the harvest cut and the extent of artificial regeneration required. Costs will be less in lightly infected stands and in pure stands of even-aged old-growth timber where clear cutting in blocks is practical.

Control costs will be greater in pole stands and other immature stands where trees to be cut are not merchantable. Should a market be developed for material from immature stands, control costs would be reduced significantly.

To minimize costs, stand units to be clear cut should have a low ratio of perimeter to area. Large compact areas approaching a circle or square are most desirable. Narrow strips should be avoided to minimize reinfestation of the sanitized area from the uncut perimeter. This will reduce costs of obtaining and maintaining infection-free reproduction.

Forest managers are urged to keep cost records on all their dwarfmistletoe control projects so that cost data may be accumulated for California conditions. We especially need more information on the practicability and cost of control on areas of varying size.

## REFERENCES


Boyce, John Shaw
1948. Forest pathology. Ed. 2, 550 pp., illus. New York.

Gill, Lake S.
1954. Dwarfmistletoe of ponderosa pine in the southwest. U. S. Forest Service, Rocky Mountain Forest and Range Experiment Station. Sta. Paper No. 14. 9 pp.

Gill, Lake S., and Frank G. Hawksworth
1954. Dwarfmistletoe control in southwestern ponderosa pine forests under management. Jour. Forestry 52:347-353.

Hawksworth, Frank G., and Arthur A. Lusher
1956. Dwarfmistletoe survey and control on the Mescalero-Apache Reservation, New Mexico. Jour. Forestry 54:384-390.

Korstian, C. F., and W. H. Long
1922. The western yellow pine mistletoe--effects on growth and suggestions for control. U. S. Dept. Agr. Bul. 1112. 35 pp.

Scharpf, Robert Fred
1957. Growth and extension of the endophytic system of the dwarfmistletoe (Arceuthobium campylopodum Dougl.). Master's Thesis, typewritten. University of California, School of Forestry Library. 43 pp.

Weir, James R.
1916. Mistletoe injury to conifers in the Northwest. U. S. Dept. Agr. Bul. 360. 38 pp.

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# SILVICAL CHARACTERISTICS OF GIANT SEQUOIA

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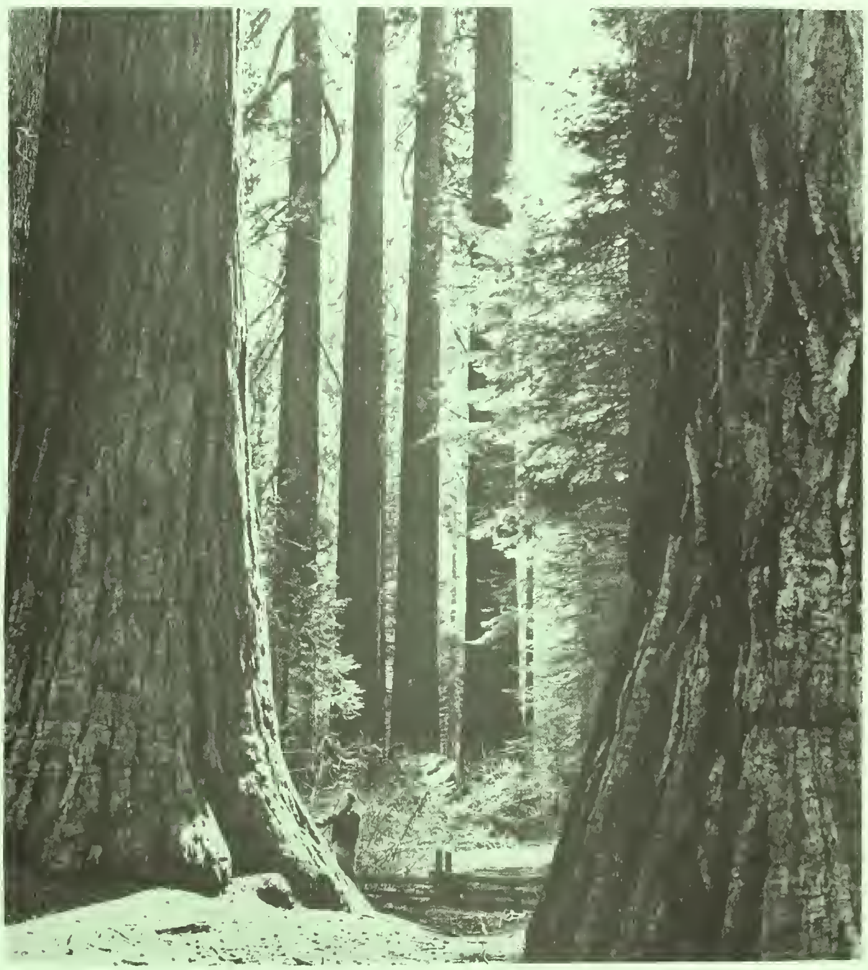

CALIFORNIA
FOREST AND RANGE
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KEITH ARNOLD, DIRECTOR
BERKELEY - NOVEMBER 1957

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

## Preface

The Forest Service is engaged in assembling information on the silvical characteristics of important forest trees of the United States. Much material that is of value in silviculture and research is widely scattered and difficult to locate. This report presents, in preliminary form, the information that has been collected for one species of tree. Similar reports are being prepared for other species at the California Forest and Range Experiment Station and at other forest experiment stations. Readers are encouraged to notify the authors of omissions, errors, or new information affecting the silvical characteristics of the species.

# SILVICAL CHARACTERISTICS OF GIANT SEQUOIA

By Gilbert H. Schubert, Forester
Division of Forest Management Research

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CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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The Experiment Station is maintained at Berkeley, California in cooperation with the University of California.

Agriculture--Forest Service, Berkeley, California

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# SILVICULTURAL CHARACTERISTICS OF GIANT SEQUOIA

By Gilbert H. Schubert, Forester,
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Giant sequoia (Sequoia gigantea (Lindl.) Decne) is the world's largest tree in terms of volume (23). Within its natural range it occurs in more or less isolated groves on the western slopes of the Sierra Nevadas in central California. These groves, variously listed at 25 to 72 by different authorities (6, 8, 10, 11, 13, 14, 20, 23, 26, 28), lie in a narrow belt approximately 260 miles long (fig. 1). The northernmost grove, consisting of six trees, is along the Middle Fork of the American River in Placer County. The southernmost grove with 100 trees in it, is near Deer Creek in Tulare County.

## HABITAT CONDITIONS

### CLIMATIC

The climate in the areas where giant sequoia grows is cooler and drier than where the redwoods (Sequoia sempervirens (D. Don) Endl.) occur (26, 28). Annual precipitation, which varies with altitude and from year to year, ranges from 18 inches to more than 60 inches (23, 26, 28). The best stands grow in protected locations where the average annual precipitation is from 45 to 60 inches (23).

Most of the precipitation occurs in form of snow during the months of September through May. Summer storms are infrequent. Snow falls throughout the range of giant sequoia and accumulates in places up to 10 or more feet. During the winter of 1905-1906, snow in the Giant Forest (Sequoia National Park) was 29 feet deep; in protected spots, snow was still 12 feet deep by mid-summer (10).

The temperature occasionally drops to -12°F. and seldom exceeds 100°F. In the Giant Forest, one of the largest and best developed groves, the minimum temperature is -5°F. and the maximum is 94°F. The average growing season in this grove is 124 days--June 2 to October 4 (27).

### EDAPHIC

Giant sequoia grows on a wide variety of soils from shallow rocky, to deep sandy loams (28). Although it grows on shallow moderately dry soils, it does best on moist, deep, well-drained soils slightly to moderately acid in reaction. These soils are generally developed from granitic, dioritic, and andesitic rocks. The most common soil series are: Holland, Olympic, and Sierra.

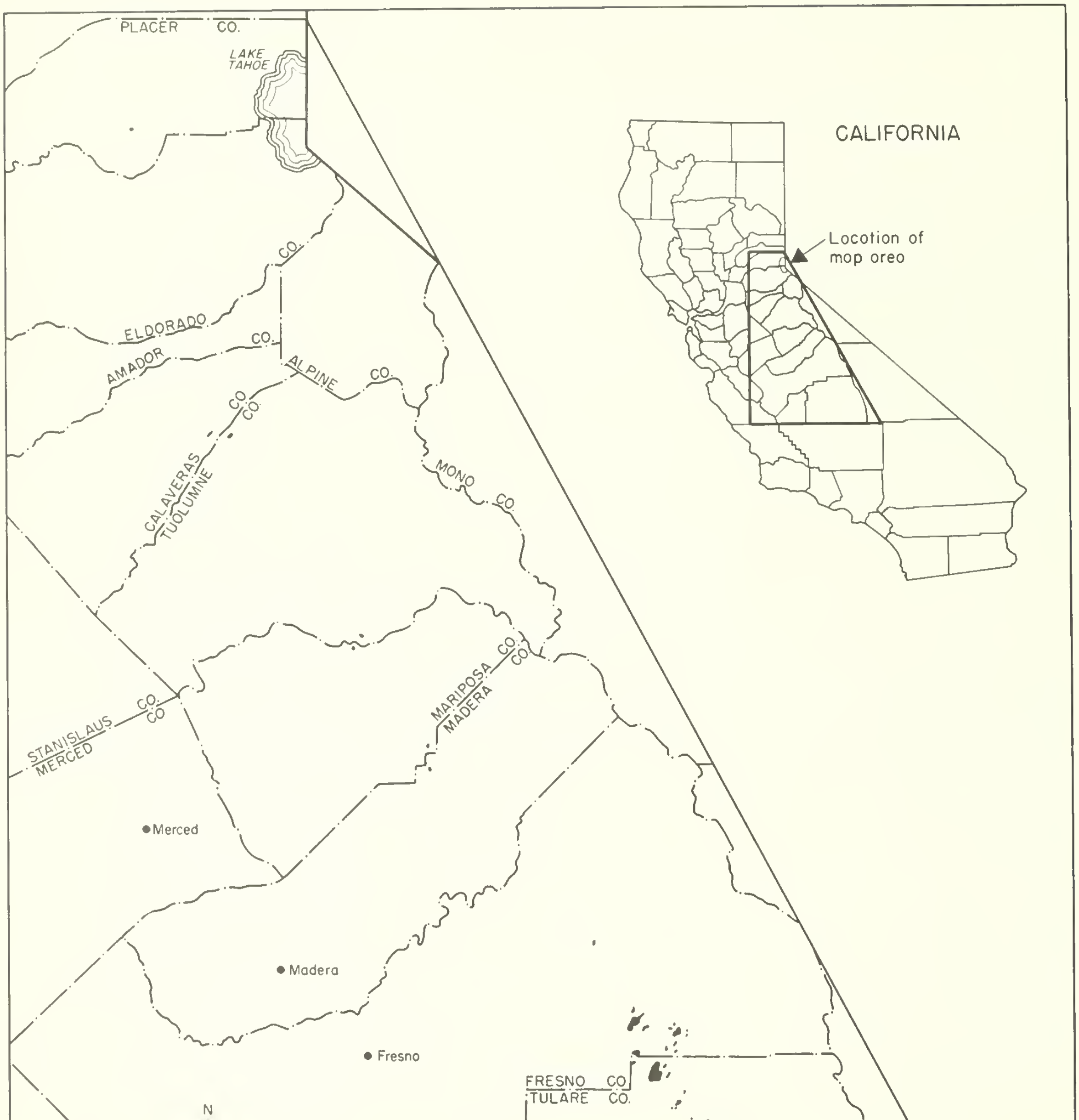


Figure 1.--The natural range of giant sequoia. (Adapted from California Department of Natural Resources (6).)

## PHYSIOGRAPHIC

Most of the groves are at elevations between 4,500 and 7,500 feet (6, 23). Some occur as low as 3,000 feet and a few grow at 8,900 feet. At the northern part of its range the trees occur at 4,500 to 5,500 feet; in the central part, at 5,400 to 7,000 feet; and at the southern end, at 6,000 to 8,000 feet.

Giant sequoias grow on slopes of all aspects. The groves are generally found in canyons where soil moisture is always adequate but also occur on or near the tops of high exposed ridges where underground water is available (6, 11, 28).

## BIOTIC

Giant sequoias occur in small groves within the ponderosa pine-sugar pine-fir type (25). They never make up pure stands except over small areas.

Trees commonly associated with giant sequoia are:

White fir (Abies concolor (Gord. & Glend.) Lindl.)
Sugar pine (Pinus lambertiana Dougl.)
Ponderosa pine (P. ponderosa Laws.)
Incense-cedar (Libocedrus decurrens Torr.)
California black oak (Quercus kelloggii Newb.)

Other trees found growing with giant sequoia are:

Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco)
California red fir (A. magnifica A. Murr.)
Jeffrey pine (P. jeffreyi Grev. & Balf.)
Pacific dogwood (Cornus nuttallii Audubon)
Bigleaf maple (Acer macrophylum Pursh)
Canyon live oak (Q. chrysolepis Liebm.)
White alder (Alnus rhombifolia Nutt.)
Bitter cherry (Prunus emarginata Dougl.)

Common brush species occurring with giant sequoia are:

Greenleaf manzanita (Arctostaphylos patula Green)
Mountain whitethorn (Caenothus cordulatus Kell.)
Deerbrush (C. integerrimus H. & A.)
Snowbrush (C. velutinus Dougl.)
Littleleaf ceanothus (C. parvifolius Trel.)
Bearmat (Chamaebatia foliolosa Benth.)
Bush chinkapin (Castanopsis sempervirens Dudley)
Scouler willow (Salix scouleriana Barr.)
Western azalea (Rhododendron occidentale Gray)

## LIFE HISTORY

### SEEDING HABITS

#### Flowering and Fruiting

Male and female flower buds are formed on the same tree during late summer, but are not discernible until the following spring when they begin to swell and open (4). The ovule-bearing strobili originate on the larger twigs near the tips of branches but rarely on the leaders. The pollen-bearing strobili are formed on the smaller twigs.

Pollination usually occurs between the middle of April and the first of May when the conelets are only 2 to 3 times as large in diameter as the twigs on which they are borne (4). By the end of the first growing season the conelets are about one-third mature size. They reach mature size of 2 to 3.5 inches in length at the end of the second growing season (5).

In one study the number of seeds per cone varied from 97 to 306, and averaged about 230 (10). The greatest number of seeds reported from a single cone was 329 (10).

#### Seed Production

Giant sequoias usually begin to produce large numbers of cones only after they have reached an age of 150 to 200 years (11). Cones have been observed on 18- to 24-year-old saplings, but they usually contain only infertile seeds (11, 23, 28). Heavy cone crops with viable seeds have been reported on some trees 50 to 75 years old (17).

Cones are generally produced each year and enormous quantities are borne on the largest trees (28). The immense size of the tree and the relatively small size of the cones make it impossible to count accurately all the cones on a tree.

Not all cones which first appear on the tree survive to maturity. One instance was reported when all 1-year-old cones were frozen in the early summer of 1906 (10). None of the 2-year-old cones on the same trees were affected. Some immature cones may have been destroyed by freezing during other years, but no other report on freezing injury was located.

Squirrels, particularly the Douglas squirrel (*Tamiasciurus douglasii* Backman) cut down and cache vast numbers of mature cones for their winter food supply (10). These cone caches provide a convenient seed source for seed collectors.

No seed or cone insects or diseases of economic importance have been reported for giant sequoia.

### Seed Dissemination

In contrast with the habit of most conifers, giant sequoia seeds are not usually released the first year after the cones mature (4, 10). Viable seeds may be retained in the cones for more than 14 years (10). One cone, on a branch broken off a large tree during a wind storm, was 19 years old (4). This cone still contained 137 seeds--more than half the average number of seeds normally found in cones at maturity.

The tissue in the peduncle of mature cones that remain closed on the tree produce annual rings (4). Cones with only 2 growth rings in the peduncle are immature, whereas those having 3 or more rings are mature. Annual rings continue to form in cones that have not shed all their seeds and therefore can be used to determine the age and maturity of the cones. Cones which open and release all of their seeds die, turn brown, and do not form annual rings thereafter.

Giant sequoia seeds are very light and may be carried for great distances by air currents. The number of seeds varies from 54,000 to 132,000 per pound; the average is 91,000 (19, 28). Exact distances that wind will carry these light seeds are not known; however, it is believed to be several hundred yards (11). In one instance seeds were carried by wind for 580 feet (10).

## VEGETATIVE REPRODUCTION

Giant sequoia does not produce sprouts from roots or stumps as is common in redwood, but tall broken stubs and crowns sprout vigorously (26) and form new tops if sufficient live foliage remains below the point of breakage.

## SEEDLING DEVELOPMENT

### Establishment

Giant sequoia seeds germinate best on exposed mineral soil and in loose ashes on a freshly burned area (23, 28, 29). Very few seedlings are found in the northern groves where the litter is deep and dry. In the central and southern groves reproduction is abundant only where the soil has been disturbed following logging, fire, erosion, windthrow, or road construction (fig. 2).


Figure 2.--Dense giant sequoia reproduction along road.

Field germination and survival, even on the better sites, are low. Although exact records have never been made, probably only one seed in a million germinates under natural conditions and only a small percentage of these survive (10). One of the main reasons for poor establishment has been an inadequate moisture supply, especially on areas covered with competing vegetation or dry litter.

Seeds stored in cones on the tree and in cold storage retain their viability for long periods (4, 10, 22). Two seed lots held in cold storage at 5°C. (41°F.) still had a viability of 41 to 43 percent after 16 and 17 years (22).

During the initial stages of seedling establishment some shade may be required. In a nursery study, none of the seedlings survived full exposure to sunlight, 16 percent survived under partial shade, and 68 percent survived in full shade (24). Since giant sequoia seedlings do survive in the open under natural conditions, other causes of mortality, such as excessive heat or drying, may have been the deciding factors in the nursery study.

Heavy losses of seedlings are frequently noted for giant sequoia. Sparrows (Zonotrichia spp.), the California purple finch (*Carpodacus purpureus californicus*), cutworms (*Noctuidae* spp.), ground squirrels (*Citellus* spp.), and chipmunks (*Eutamias* spp.) destroy many seedlings during the first few months after germination. Many seedlings also die in areas where the soil is too wet or too dry. Severe root competition for the limited soil-moisture supply is a factor in preventing the establishment of seedlings in old stands (17).

## Early Growth

Height growth of giant sequoia seedlings is slow during the first year but increases rapidly after the second or third year (23). One-year-old seedlings are from 1 to 3 inches tall. By the end of the second year they are 3 to 6 inches, and after 3 growing seasons 6 to 12 inches. Trees 35 years old average between 45 and 87 feet tall depending on site quality and competition with older trees (17). With an even start, giant sequoias are capable of outgrowing any of the associated species (17).

Exact root growth measurements have not been reported; but root elongation is probably rapid. During the first few years, the main root system consists of a taproot with few laterals (20). After 6 to 8 years lateral root growth is predominate, and elongation of the taproot practically stops. Later in the life of the giant sequoia, the lateral root system may spread over an area of 2 to 3 acres with none of the roots more than 6 to 8 feet deep (10, 20). This wide-spread root system provides excellent support for the trees throughout their life span.

## SEASONAL GROWTH

There are no published data on beginning dates or duration of seasonal radial or height growth of giant sequoia.

## SAPLING STAGE TO MATURITY

### Growth and Yield

Although giant sequoia is not the tallest species, and although occasional individuals of other species may surpass it in basal circumference, it is the most massive tree in the world (23). The highest volume of a single tree was estimated to be 600,120 board-feet; many trees have a gross volume of more than 500,000 board-feet (8).

The General Sherman tree in the Giant Forest has the greatest circumference of the measured trees. It has a basal circumference of 101.6 feet at 4.5 feet and a height of 272 feet (1). The tallest giant sequoia (California tree in the General Grant Grove, Kings Canyon National Park) is reported to be 310 feet high (23). Trees with an average basal diameter of 20 feet and a height of 275 feet are common in the southern groves where the best stands are found (21, 28).

Giant sequoias are long-lived (28). Trees in many groves range from 2,000 to 3,000 years old, and a few are over 3,000 years (23, 28). The maximum age has been reported to be over 4,000 years (28), but no authentic records are available to substantiate this claim. The actual age of the oldest living tree is a subject of much speculation and only crude estimates can be made. Ring counts on felled trees indicate ages up to 3,200 years (23). Huge old trees, which were too big to cut in early years and which are now protected, may be much older.

Giant sequoias grow rapidly during their youth; in old age growth is rather slow. Trees under 75 years of age increase in diameter at an average rate of 1 inch every 3 to 5 years, but ancient overmature trees may require more than 20 years to grow 1 inch in diameter (9).

Giant sequoias less than 100 years old retain most of their branches. In contrast, trunks of mature trees are generally free of branches to a height of 100 to 150 feet.

Most giant sequoia groves are on public lands withdrawn from cutting; only 12 percent of the total acreage is in private ownership (6). Very few trees are being cut. In 1952, the latest year of record, about 2,000,000 board-feet were harvested (7). One of the main reasons for the small volume cut is the strong public desire to preserve old-growth trees. Since most "specimen" or "museum" trees are in virgin stands of which 92 percent are publicly owned, the amount cut in the future will probably continue to be small (6)

Although giant sequoias are prized chiefly for their esthetic value, some of the stands could be placed under management for their timber products. In the northern part of the range, there are too few trees to be of economic importance. But in the southern part the trees are more numerous and the areas are better adapted to silvicultural treatments.

Mixed forests in which giant sequoia is an important component could be managed to increase the quality and quantity of this species. About 34 percent of the area growing giant sequoias has been cut-over and is in need of silvicultural treatment. Some cut-overs are poorly-stocked or non-stocked and should be brought up to acceptable stocking standards by planting or special site preparation measures to encourage natural regeneration. Other areas contain overdense thickets which should be thinned to prevent further stagnation and to increase the growth rate of crop trees. And still other areas require stand-improvement measures to release potential crop trees from competition and increase the proportion of giant sequoias in the final stand. In the young stands dominant large saplings and small poles will require pruning to produce clear lumber in rotations of less than 150 years.

Periodic annual growth rates of giant sequoia have not been determined. However, rotation ages for second-growth stands will probably be based mainly on the size of tree that can be harvested without serious loss due to breakage, which runs 45 to 50 percent in old trees. In general, breakage is not a serious factor in young trees.

## Reaction to Competition

The capacity of giant sequoia to develop and grow in close competition with other trees is still open to considerable debate. In the revised tolerance table, 25 percent of those receiving the questionnaire rated giant sequoia as tolerant, 50 percent as intermediate, and 25 percent as intolerant (3). Much depends on the period in the life span during which the trees were rated as to tolerance. For best development, giant sequoias require full overhead light (26, 28).

The trees are able to endure more shade during youth than in old age (11, 28). In dense thickets growth is very poor and when released the spindling trees recover slowly; however, after the crown has filled out, growth is rapid. During the first few years, adequate soil moisture is more critical than light for seedling establishment. Young reproduction is generally found only in openings where root competition for moisture has been reduced (17, 18). Small openings are preferable to large ones, mainly because of the lower evaporation rate of soil moisture and the partial shade in the smaller more protected areas. However, good reproduction has filled in some large areas when logging was followed by a good seed year and favorable climatic conditions.

### Principal Enemies

Giant sequoia has few important natural enemies other than fire (12, 28). Ground fires are especially destructive during the seedling and sapling stages (23, 28). Mature trees, protected by an asbestos-like bark up to 2 feet thick, are able to survive repeated fires without serious loss (23). However, after the bark has been burned off, repeated hot fires may hollow-out large trees. Few of the veterans have been destroyed by fire alone, but some have been windthrown where roots were destroyed by fire, road construction or were exposed by erosion following fires. Most of the trees larger than 10 feet in diameter have fire scars (9). Soil compaction by the thousands of tourists that visit the groves each year has seriously reduced the vigor of many large trees (16). Trampling around the base of these trees has destroyed the many feeder-roots necessary to supply the vast quantities of water required by the trees, reduced the water-holding capacity of the soil, and lowered the amount of water penetration into the soil around the trees.

Once established, giant sequoia is noted for its resistance to insect and disease attacks (9, 23, 28). None of the insects reported on giant sequoia has caused the death of a single tree (15). An unidentified brown heartrot has caused some decay in large trees where heartwood has been exposed but no trees have been killed by this disease (28). Old trees which fell centuries ago show very little evidence of decay in the heartwood (23). The 2- to 3-inch layer of sapwood rots away in a few years.

## SPECIAL FEATURES

A high content of tannin in the wood, bark, and cones of giant sequoia protects the tree from seed formation to maturity against attacks by insects or diseases.

The cones contain a highly-colored water-soluble pigment (73 percent tannin, 3 percent organic matter, 1.5 percent ash, and 22 percent water) which has been reported (10) to:

- Protect the cones from fungus
- Increase the germinative capacity of the seed
- Increase the retention of viability of the seeds
- Increase the vigor of seedlings
- Reduce the susceptibility of seedlings to insect and disease attacks.

## RACES AND HYBRIDS

There are no known races or hybrids of giant sequoia. Two horticultural clons--blue giant sequoia (*Sequoia glauca*) and columnar giant sequoia (*Sequoia pendula*)--are listed in Standardized Plant Names (2).

## LITERATURE CITED


(1) American Forestry Association
1956. These are the champs. American Forests 62(4): 33-40, illus.

(2) American Joint Committee on Horticultural Nomenclature
1942. Standardized plant names. Ed. 2, 675 pp. Harrisburg, Pa.

(3) Baker, Frederick S.
1949. A revised tolerance table. Jour. Forestry 47: 179-181.

(4) Buchholz, J. T.
1938. Cone formation in *Sequoia gigantea*. I. The relation of stem size and tissue development to cone production. II. The history of the seed cone. Amer. Jour. Bot. 25: 296-305, illus.

(5) ____________
1939. The morphology and embryogeny of *Sequoia gigantea*. Amer. Jour Bot. 26: 93-101, illus.

(6) California Department of Natural Resources
1952. The status of *Sequoia gigantea* in the Sierra Nevada. Report to the California Legislature. 75 pp., illus.

(7) California Forest and Range Experiment Station
1954. Forest statistics for California. Forest Survey Release 25. 6 pp., illus.

(8) Collingwood, G. H., and Brush, Warren D.
1955. Knowing your trees. Amer. Forestry Assoc. 328 pp., illus. Washington.

(9) Cook, Lawrence F.
1942. Giant sequoia of California. U. S. Dept. Int. 28 pp., illus.

(10) Fry, Walter, and White John R.
1938. Big Trees. Stanford University Press. 126 pp., illus.

(11) Green, George Rex
1933. Trees in North America (exclusive of Mexico) Vol. 1 The Conifers. 186 pp., illus. Ann Arbor.

(12) Harlow, William M., and Harrar, Ellwood S.
1950. Textbook of dendrology. Ed. 3. 555 pp., illus., New York, Toronto, London.

(13) Jepson, Willis Linn
1910. The silva of California. Vol. 2. 480 pp., illus., Berkeley.

(14) ____________
1923. The trees of California. Ed. 2. 240 pp., illus., Berkeley.

(15) Keen, F. P.
1952. Insect enemies of western forests. U. S. Dept. Agr. Pub. 273. 280 pp., illus.

(16) Meinecke, E. P.
1928. Tree giants in the Sequoia Groves are menaced by tourists. Agr. Yearbook 1927. 1234 pp., illus.

(17) Metcalf, Woodbridge
1948. Youthful years of the bigtree. Pacific Discovery 1(3): 4-10, illus.

(18) ____________
1949. Timber growth studies--tree growth in Whitaker's Forest, Tulare County, during 33-year period; 1915 to 1948. Calif. Agr. 3(8): 7, 14, illus.

(19) Mirov, N. T.
1940. Additional data on collecting and propagating the seeds of California wild plants. U. S. Forest Service, California Forest and Range Expt. Sta. Res. Note 21. 17 pp.

(20) Peattie, Donald Culross
1953. A natural history of western trees. 751 pp., illus., Boston.

(21) Sargent, Charles Sprague
1922. Manual of the trees of North America. (exclusive of Mexico). Ed. 2. 910 pp., illus. Boston.

(22) Schubert, G. H.
1952. Germination of various coniferous seeds after cold storage. U. S. Forest Serv., Calif. Forest and Range Expt. Sta. Res. Note 83, 7 pp.

(23) Shirley, James C.
1947. The redwoods of coast and Sierra. Ed. 4, 84 pp., illus. Berkeley, Los Angeles, Calif.

(24) Show, S. B.
1924. Some results of experimental forest planting in northern California. Ecology 5: 83-94.

(25) Society of American Foresters, Committee on Forest Types
1954. Forest cover types of North America (exclusive of Mexico). 67 pp., illus. Washington, D. C.

(26) Sudworth, George B.
1908. Forest trees of the Pacific slope. U. S. Dept. Agr., Forest Serv., 441 pp., illus.

(27) U. S. Department of Agriculture
1941. Climate and man. Agr. Yearbook 1941. 1248 pp., illus.

(28) U. S. Forest Service
1908. Bigtree. U. S. Dept. Agr. Silvical Leaflet 19. 5 pp.

(29) ____________
1948. Woody plant seed manual. U. S. Dept. Agr., Misc. Pub. 654. 416 pp., illus.

TECHNICAL
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# FIRE-WEATHER SURVEY CAN AID PRESCRIBED BURNING

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CALIFORNIA
FOREST AND RANGE
EXPERIMENT STATION
KEITH ARNOLD, DIRECTOR
BERKELEY - NOVEMBER 1957

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

# FIRE-WEATHER SURVEY CAN AID PRESCRIBED BURNING

By Mark J. Schroeder, Meteorologist, U. S. Weather Bureau
and Clive M. Countryman, Forester

Division of Forest Fire Research

Technical Paper No. 21 November 11, 1957

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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The Experiment Station is maintained at Berkeley, California in cooperation with the University of California.

Agriculture--Forest Service, Berkeley, Calif.

# FIRE-WEATHER SURVEY CAN AID PRESCRIBED BURNING

By Mark J. Schroeder, Meteorologist, U. S. Weather Bureau
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Foresters, particularly those concerned with type conversion, are using fire more and more each year as a tool to clear California brushland. Fire technicians are making this tool more efficient. They have developed area-ignition firing techniques to extend the range of fuel conditions under which safe and effective burns can be made. They have devised electrical firing systems that permit large areas of brush to be burned in a half hour or less. But how will the fire burn?

This question must be answered before a burn can be attempted. It points up the need for reliable information about local burning conditions. Weather, vegetation, and topography differ widely from area to area. Fires seldom burn in the same way. Knowledge of the detailed weather patterns is essential if the fire is to be set under conditions such that it will do the job and still not get away. Wind conditions are especially important. Area ignition requires low wind speeds, and even though electrical firing systems permit area ignition during relatively short periods of low wind speed, the fire boss must know when these lulls will occur. Established fire-weather stations and Weather Bureau climatological stations seldom provide weather data in enough detail and continuity.

A short-term survey of fire-weather, we reasoned, might supply the needed information. Summer weather conditions over much of California remain relatively unchanged for long periods of time. Furthermore, the same conditions tend to recur in a general way each year. A survey conducted for a few days before a scheduled burn seemed to promise a quick means of determining the most probable fire-weather pattern for the burn area.

A prescribed burn scheduled for August 29, 1956, at Iron Mountain, Magalia Ranger District of the Lassen National Forest, gave us the chance to test this hypothesis. Through cooperative efforts of the Lassen National Forest, the California Forest and Range Experiment Station, and the U. S. Weather Bureau, a fire-weather survey was organized and conducted in the proposed burn area.

Specifically, the objectives of the survey were to:

1. Provide the fire boss with a complete picture of the diurnal march of temperature, relative humidity, and wind over the fire site.

2. Explore the possibility of adapting this type of fire-weather survey method to use on going wildfires.

3. Develop sampling methods and instrumentation.

4. Measure the effect of fire on local winds.

The Area

The burn area is at the head of Beaver Creek drainage on the west slope of the Sierra Nevada, about 26 miles north and 7 miles east of Chico, California. The area of 1,000 acres varies in elevation from about 2,800 feet to 3,800 feet. Beaver Creek branches at the south end of the area, and the two branches extend nearly parallel northward; a long ridge separates the two. The rim of the drainage has a number of saddles, the lowest of which is about 3,150 feet on the east side. Beaver Creek valley opens into Deer Creek canyon about a mile and a half below the burn area. Deer Creek canyon in turn runs west-southwest from there and opens into the Sacramento Valley about 20 miles north of Chico.

Sampling Methods and Instrumentation

Over much of the west slope of the Sierra Nevada a west to southwest wind is common during the day, and east to northeast down-slope drainage winds during the night. Study of records of fire-weather stations near the area showed that this wind condition could be expected in late August for the general area. The records also indicated that temperatures in the mid-80's and relative humidities of 20 to 25 percent were likely.

From a topographic map we selected 10 places where weather measurements would be desirable. Five days before the scheduled burn, we went over the ground and asked the district ranger for his suggestions. He picked 3 spots where he felt wind information was desirable for fire-control purposes. They coincided with 3 of the 10 locations selected on the topographic map. One was at the bottom of the canyon (A, fig. 1), another on the large saddle on the east side of the drainage (C, fig. 1), and the third on a saddle on the northwest rim of the drainage (D, fig. 1).

We installed an anemometer and a wind vane at each of these places. Only 5 sets were available. The two most useful of the remaining sites, we decided, were near the top of the ridge on the south side of the drainage (B, fig. 1) and on the middle ridge near the center of the area (E, fig. 1).

Wind speed was measured with a Friez 3-cup totalizing anemometer, and wind direction with a nonrecording wind vane. The anemometer and wind vane were mounted on a cross arm atop a large aluminum tripod with adjustable legs (fig. 2). Adjustable legs permitted the instruments to be set up quickly on uneven ground. The instruments were mounted 10 feet above ground level. Electrically operated counters were used to register the 1/10-mile contacts made by the anemometer. A 6-volt dry battery supplied the power.

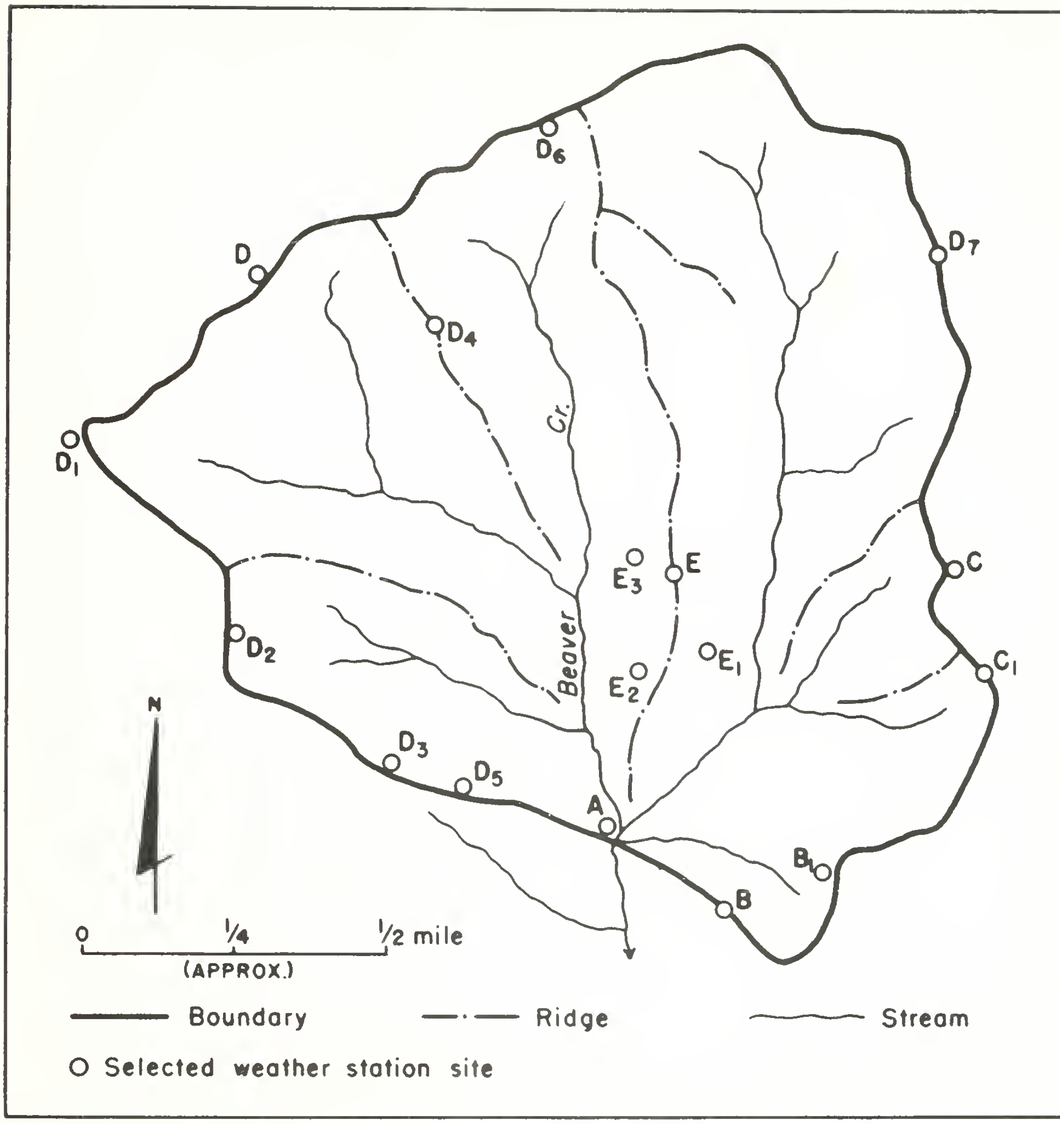


Figure 1.--Station locations, Iron Mountain fire-weather survey. Letters with subscripts indicate where supplementary observations were made with portable instruments.

Since the instruments were nonrecording, it was necessary to read them manually. A 10- to 20-minute sample of wind speed was taken each hour at each of the 5 stations, and as many spot samples of wind direction were taken at 5-minute intervals as was possible with the available manpower. Temperature and relative humidity were measured with sling psychrometers at stations B, C, D, and E. We continued the observations from about 0800 to 1800 or 1830 PST each day for 3 days before the fire and on the day of the fire.

Figure 2.--Wind vane and anemometer installation at station C.

Wind observations were also taken with portable wind-speed indicators at several other points (fig. 1) to obtain a more complete picture. Visual observations of eddies were also noted.

At station B an instrument shelter was installed containing maximum and minimum thermometers and a hygrothermograph. Also at that station a set of 1/2-inch fuel moisture sticks was exposed and measurements taken several times each day (fig. 3).

Analysis of Data

All observations for August 26, 27, and 28 were tabulated during the evening of August 28, the day before the burn. Wind directions and speeds were plotted on small maps of the area. The maps were drawn at about 3-hour intervals for August 26 and 27, and hourly for August 28.

As fate would have it, this 3-day period was one of changing general weather conditions, and the wind pattern was different each day. On the morning of August 26, three days before the burn, the wind flow was southwesterly in the canyon bottom, and southwest to west at higher locations. By afternoon the wind flow became northerly (down canyon) at the canyon bottom and west to northwest at higher locations (fig. 4). The strongest winds were recorded in the early morning hours. No observations were taken during the night. Next morning the winds were still northerly in the canyon bottom, but at higher locations they had set in from an easterly or east-northeasterly direction. A weak surface cold front passed through the area in the early afternoon of August 27. The wind at higher locations then set in from the west and northwest, but in the canyon bottom it remained northerly (fig. 5). The highest wind speeds were recorded at the first observations in the morning, though another peak was noted around mid-afternoon.

Figure 3.--Instrument shelter and fuel moisture sticks at station B. The burn area is in the background.

Early forenoon of August 28 the easterly downslope winds ceased and daytime west to southwest upslope winds began at the higher locations. The wind flow at the canyon bottom was already up-canyon at the time of our earliest observations. The wind pattern remained essentially the same all day (fig. 6). The wind speeds increased until mid-afternoon and then decreased.

Observations with portable instruments showed the presence of roll eddies on the lee side of ridges within the burn area. They also showed that winds in the canyon bottoms and on lower slopes were generally up-slope in direction and of low speed.

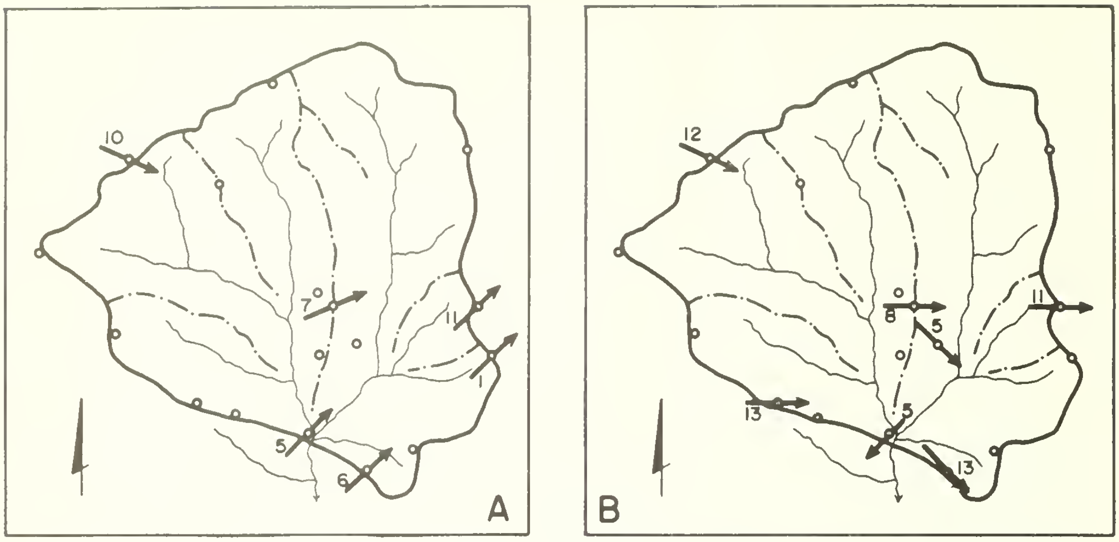


Figure 4.--Observed winds Sunday, August 26, 1956. A, 1100-1200 PST. B, 1500-1600 PST.

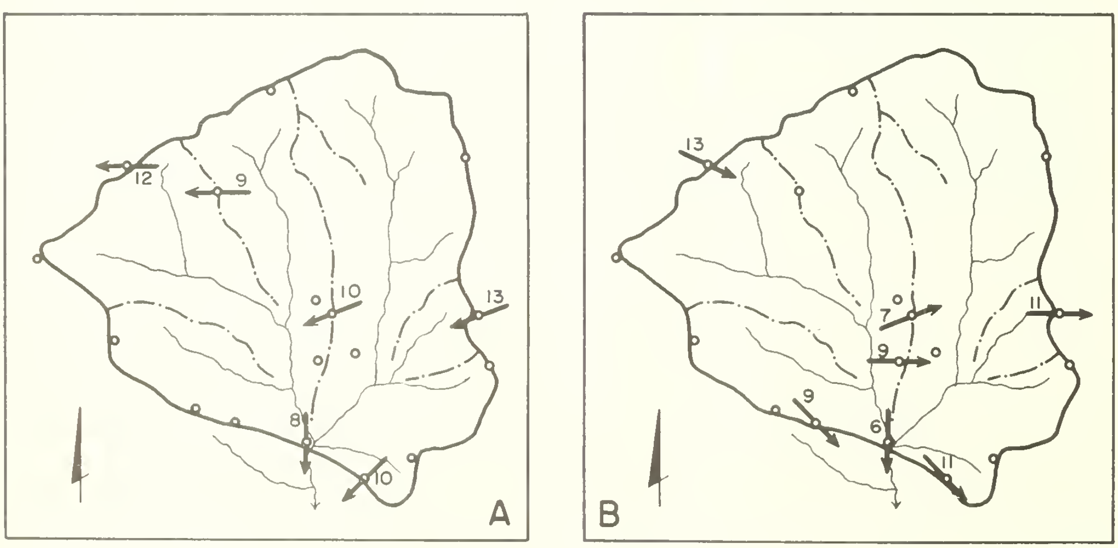


Figure 5.--Observed winds Monday, August 27, 1956. A, 0900-1000 PST. B, 1400-1500 PST.

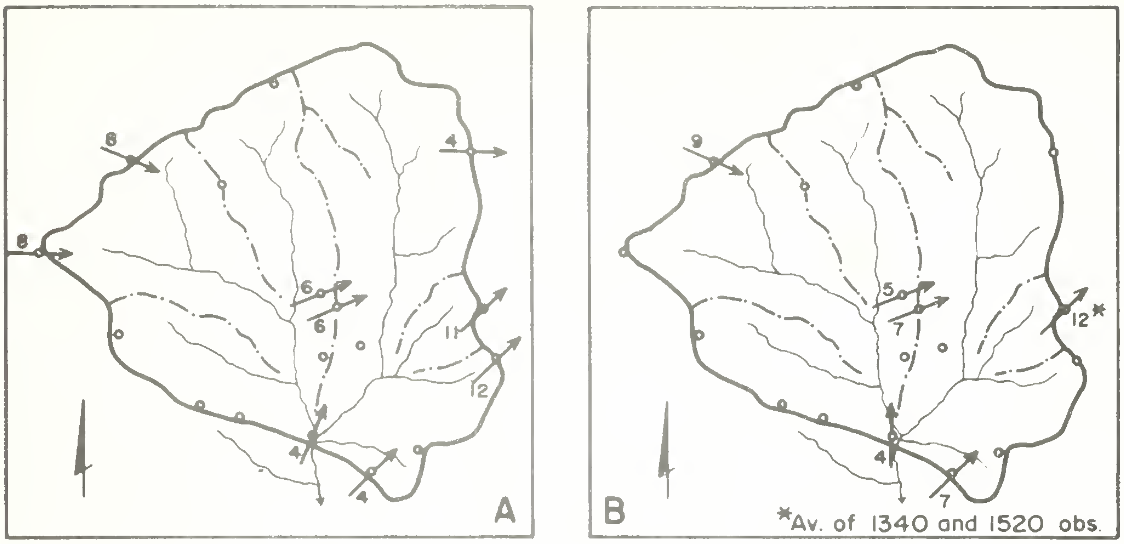


Figure 6.--Observed winds Tuesday, August 28, 1956. A, 1000-1100 PST. B, 1400-1500 PST.

Wind patterns in the burn area reflected the general weather pattern and the air flow aloft as shown on the surface and upper-air weather maps.[1/] From the afternoon of August 26 through most of August 27, when surface winds in the burn area tended to blow from the north, the winds aloft were rather strong northerly over northern California. This pattern was the result of a low pressure center aloft which had moved from the Puget Sound area to western Montana, while high pressure aloft remained along the coast. The northerly winds aloft over northern California had decreased by the evening of August 27 and remained rather light the next day.

We determined from the weather maps that the local wind pattern on Tuesday, August 28, was probably the usual summertime pattern for the area.

## Weather Forecast and Results

The general weather data available indicated that a low pressure center would develop aloft over southern California, making showers likely in the central and southern Sierra Nevada mountains. We did not expect this development to influence the weather or surface wind flow in the burn area.

We noted indications August 28 that a greater inflow of marine air into the central Sacramento Valley would occur the following day. Logically this would mean higher wind speeds, lower afternoon temperatures, and higher afternoon relative humidities in the burn area.

1/ Made available by the U. S. Weather Bureau Fire-weather Forecaster from Redding who helped in the survey and assisted in preparing the forecast.

Consequently, the weather forecast we made that night for mid-afternoon of August 29 called for lower than normal temperatures ($78^{\circ}$ to $83^{\circ}$ maximum), higher than normal humidity (20-25 percent minimum), and a windflow pattern similar to August 28 but with somewhat higher speeds. Predicted winds for the burn area were plotted on a small map (fig. 7) for use by the fire boss.

Weather observations made the morning of the burn, and synoptic reports received by radio tended to substantiate the forecast made the night before. The readings did indicate that the humidities would not be as low as forecast, but the probable difference was not great enough to issue a revised forecast.

The actual winds measured in the burn area shortly before the scheduled burn were plotted on a map (fig. 8). The expected increase in wind speeds did not materialize. The wind speeds turned out to be about the same as on the day before. The forecast directions were correct, however. The marine air did spread into the central valley and even into the burn area. Humidities were even higher than had been forecast. The lowest humidity was 27 percent, but some stations had no readings lower than 33 percent that afternoon.

## Effects of Fire on Wind Pattern

To measure the effect of the fire on local winds, we continued observations during the fire at three of the station sites (A, B, and C, fig.1), at two locations on the western ridge, and at one location on the southwest side of the fire area.

At station A in the canyon bottom, the wind speed increased from 3.5 miles per hour to 5 miles per hour shortly after the fire was touched off. Wind speed also increased slightly at the two observation points on the west side ridge. The fire had no noticeable effect at station B or at the observation point on the southwest side of the fire.

The effect of the fire was pronounced at station C, the low saddle on the east rim. Here the wind was 11 miles per hour from the west-southwest when the fire was ignited at 1610 PST. As the fire developed, the wind became variable in both speed and direction. We observed east winds at 1629 and 1634. The main fire was centered on the middle ridge and in the canyons on either side. At about 1640 it merged into one column almost due west of station C and effectively blocked any flow of westerly wind through the saddle. During the next half hour the wind continued to vary a great deal, blowing mostly from east around through south and southwest. At one time, 1659 PST, a southeast wind of 7 m.p.h. was observed. At 1715 the convection column split, and observers at station C could see the western rim between the two columns. By then the wind at the saddle returned to a southwest to west-southwest direction.

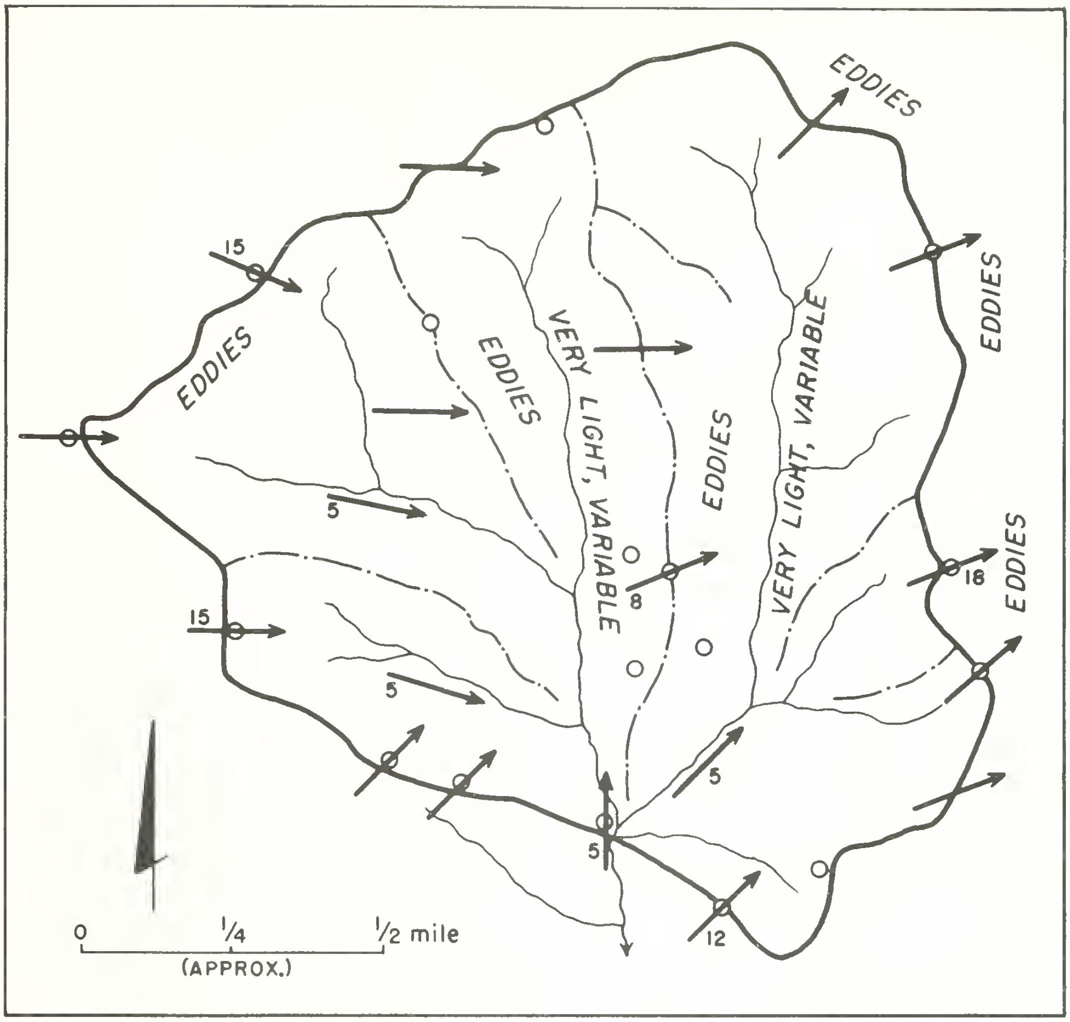


Figure 7.--Forecast winds for afternoon of Wednesday, August 29, 1956.

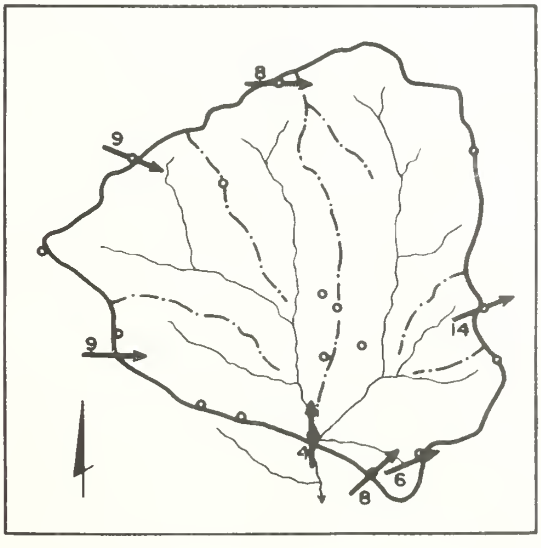


Figure 8.--Observed winds for Wednesday, August 29, 1956, 1400-1500 PST.

The relatively great influence of the fire on the winds at station C leads to an interesting hypothesis which, if true, would explain some peculiarities of fire behavior. This station is some 200 feet higher than the canyon bottom directly to the west and 350 feet higher than station A. The relatively small effect on the wind at station A indicates the lack of a strong indraft into the base of the fire. This was confirmed by men firing some distance down from the rim of the canyon. The observations, therefore, suggest that the entrainment of air into the side of the convection column was considerably greater than the indraft into the base of the fire. It is possible that the topography influenced the effect in this case.

## Conclusions

1. Fire-weather surveys, and particularly wind studies, may be misleading unless the interaction between the fire itself and pertinent weather elements is considered.

2. It appears possible for an experienced team of observers to move into an area with weather instruments and in a relatively few days (at least in the interior of California during the summer season) determine local fire-weather patterns, relate them to synoptic weather patterns, and provide other weather information that will greatly assist the fire-weather forecaster in preparing detailed forecasts for the area.

3. Fire-weather surveys such as this can add considerably to our knowledge of local fire-weather patterns and the effect of fire on them. They also may provide information which will allow more accurate prediction of fire behavior.

4. Lightweight weather instruments and supports designed specifically for this type of survey are needed.

5. Some instruments are needed to record weather data continuously at selected key points. Then observers with portable instruments could explore fire-weather patterns in more detail.

TECHNICAL
PAPER
NUMBER 22

# SILVICAL CHARACTERISTICS OF TANOAK

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BERKELEY - DECEMBER 1957

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

## Preface

The Forest Service is engaged in assembling information on the silvical characteristics of important forest trees of the United States. Much material that is of value in silviculture and research is widely scattered and difficult to locate. This report presents, in preliminary form, the information that has been collected for one species of tree. Similar reports are being prepared for other species at the California Forest and Range Experiment Station and at other forest experiment stations. Readers are encouraged to notify the authors of omissions, errors, or new information affecting the silvical characteristics of the species.

Cover picture: The spire-shaped tanoak growing on a clear-cut block in the Douglas-fir type of northwestern California is typical of tanoak trees found in dense coniferous stands. Its diameter is 32 inches at breast height and the height is 84 feet.

# SILVICAL CHARACTERISTICS OF TANOAK

By D. F. Roy, Forester,
Division of Forest Management Research

Technical Paper No. 22 December 1957

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

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The Experiment Station is maintained at Berkeley, California in cooperation with the University of California

\griculture--Forest Service, Berkeley, California

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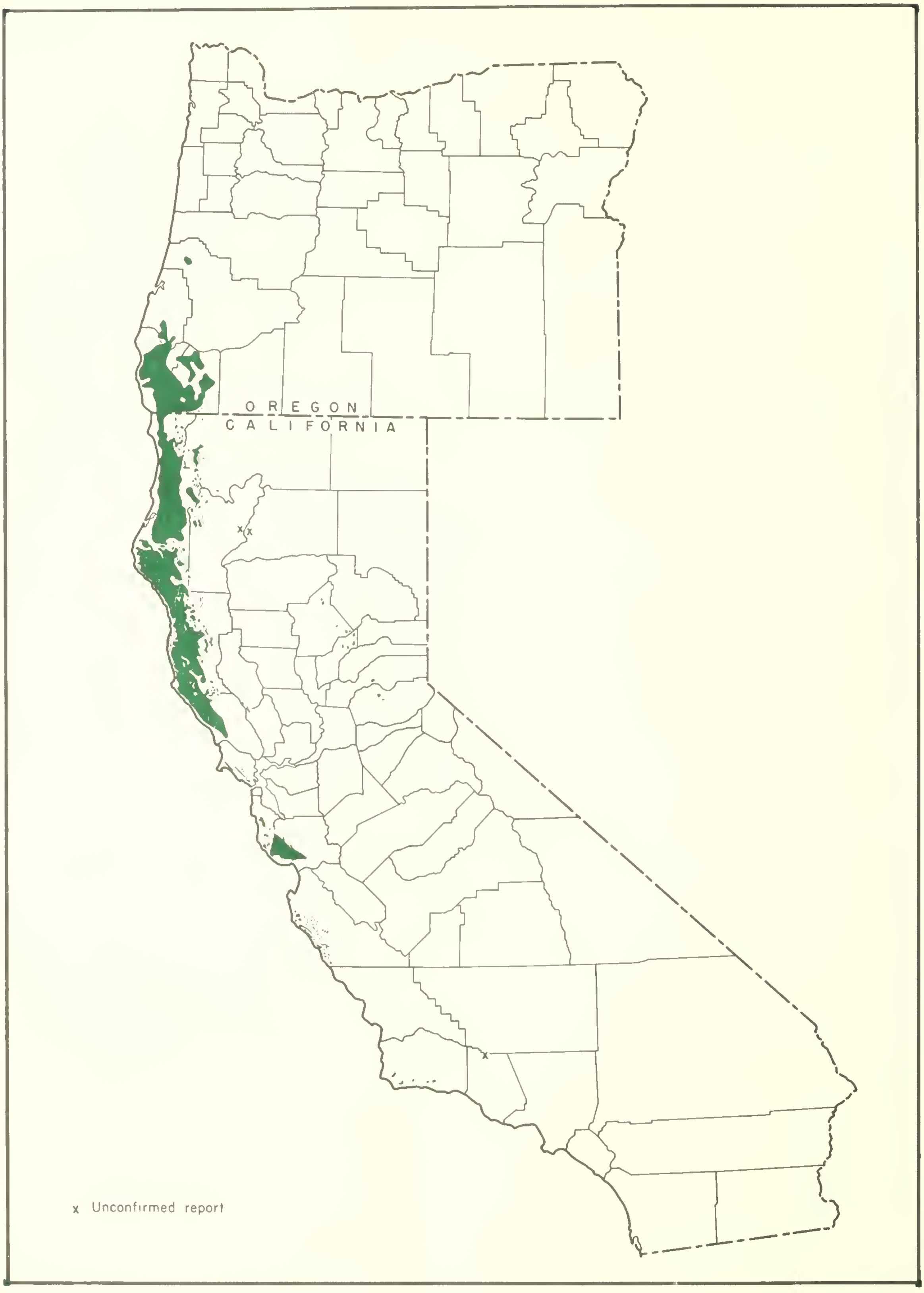


Figure 1.--The natural range of tanoak. This map was prepared by Ronald R. Tidball working under the direction of Paul J. Zinke, School of Forestry, University of California.

# SILVICAL CHARACTERISTICS OF TANOAK

By D. F. Roy, Forester,
Division of Forest Management Research

Tanoak (Lithocarpus densiflorus (Hooker and Arnott) Rehder) is an evergreen hardwood which ranges from slightly north of the Umpqua River in southwestern Oregon southward through the Coast Ranges to the Santa Ynez Mountains north of Santa Barbara, California. The natural range also extends eastward from the Humboldt Bay region to the lower slopes of Mount Shasta, thence intermittently southward along the west slope of the Sierra Nevada as far as Mariposa County (fig. 1) (33). 1/ In the Sierra tanoak is most common between the Feather and American Rivers.

## HABITAT CONDITIONS

### CLIMATIC

Tanoak grows in a climate broadly classified as humid (45). The annual precipitation, however, is seasonal and varies throughout the natural range from 40 to 100 inches. Some precipitation falls as snow. Summer and early fall are dry and the winter rainy. The months of June through September have less than 1 inch of rain per month. In fact, precipitation during these months amounts to only 5 percent of the year's total. Most of the precipitation--about 70 percent--falls between November and February.

Average mean daily temperatures range from 36°F. to 42°F. during January and 60°F. to 74°F. in July. The last killing frosts in the spring occur between March 8 and April 30; the first killing frosts come between October 20 and November 20. The number of days free of killing frosts range between 160 and 249 (42). Over a 30-year period the maximum temperature recorded at a 600-foot elevation in the center of tanoak's maximum development was 113°F. The minimum was 9°F.

### EDAPHIC

Tanoak grows well on a variety of soils developed from igneous, metamorphic, or sedimentary rocks, or sedimentary rock alluvium. It grows best on those which are deep, well-drained, and loamy, sandy, or gravelly. Tanoak also is found on serpentine sites which are

1/ Numbers in parentheses refer to literature cited.

intermediate between the moist and dry extremes, but is limited to a shrubby form (48). It is seldom found on heavy clayey soils.

High-site soils for redwood (*Sequoia sempervirens* (D. Don) Endl.) or Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), such as the Hugo, Josephine, Melbourne, Empire, Sites, and Larabee series, are also well suited for the growth of tanoak. These soils have been derived from either consolidated or soft sedimentary rocks. They are light grayish brown or light reddish brown to brown in color and are moderately to strongly acid. Soil textures grade through loam, sandy loam, fine sandy loam, silt loam, to clay loam.

Besides growing well on deep soils, tanoak also thrives on stony and shallow soil phases where conifers thin out. Yet tanoak requires more moisture than many other hardwoods. It will grow well on the shallow and stony soils of north slopes, for example, but it will be supplanted by Pacific madrone (*Arbutus menziesii* Pursh), Oregon white oak (*Quercus garryana* Dougl.), or California black oak (*Quercus kelloggii* Newb.) on the warmer, drier south slopes.

## PHYSIOGRAPHIC

Throughout the Coast Ranges from the northern limit of the natural range (latitude 43°42' N.) to the Santa Lucia Mountains (latitude 35°40' N.) tanoak grows from sea level to elevations of 4,000 or 5,000 feet. This mountainous area is geologically mature. The terrain is rough, steep, and extremely dissected both by major streams and smaller drainages. In the Santa Ynez Mountains, at the southern limit of its range (latitude 34°34' N.), tanoak grows at 2,400 to 4,700 feet. In the northern Sierra Nevada it occurs at 1,900 to 4,000 feet elevation and in the central Sierra at 3,000 to 5,000 feet (44). At its southern limit in the Sierra tanoak was discovered between 5,000 and 6,500 feet near Signal Peak (latitude 37°08' N.) in the Sierra National Forest. 2/

Tanoak is most abundant and attains its largest size in Humboldt and Mendocino Counties between elevations of 500 to 3,000 feet on northerly and easterly slopes and toward the summits of the seaward part of the Coast Range. In the southern Coast Ranges tanoak is common in the Santa Cruz and Santa Lucia Mountains, particularly on the westerly slopes. And in the central Sierra where the climate is less humid it grows in valleys, coves, ravines, along low mountain and foothill streams, and on north slopes.

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2/ Wagner, Roy G. File memorandum, S-SUPERVISION, Timberland Acquisition, Redwood Region. U. S. Forest Serv., Region 5, 3 pp. Typewritten. February 17, 1937.

## BIOTIC

Tanoak occurs within the life zones classified as the Canadian and the Transition (31). It is the most abundant hardwood species found in timber stands of the Coast Ranges of California and southwestern Oregon, where it is a component of four timber types. Tanoak is commonly found in the redwood and Port-Orford-cedar--Douglas-fir types, but is particularly important in the Pacific Douglas-fir and oak-madrone types (41).

The principal body of tanoak is a broad band along the inland side of the redwood belt. Here tanoak sometimes forms almost pure stands. More often it occurs as an understory tree with Douglas-fir or as a component of hardwood stands or of mixed hardwood and conifer forests. The most common hardwood associated with tanoak is Pacific madrone.

Other hardwoods occurring more or less commonly with tanoak are (10):

| | |
|---|---|
| _Acer macrophyllum_ Pursh | bigleaf maple |
| _A. negundo_ L. | boxelder |
| _Aesculus californica_ (Spach) Nutt. | California buckeye |
| _Alnus rhombifolia_ Nutt. | white alder |
| _A. rubra_ Bong. | red alder |
| _Castanopsis chrysophylla_ (Dougl.) A.DC. | golden chinkapin |
| _Cornus nuttallii_ Audubon | Pacific dogwood |
| _Fraxinus latifolia_ Benth. | Oregon ash |
| _Quercus agrifolia_ Nee | California live oak |
| _Q. chrysolepis_ Liebm. | Canyon live oak |
| _Q. kelloggii_ Newb. | California black oak |
| _Q. garryana_ Dougl. | Oregon white oak |
| _Q. sadleriana_ R. Br. Campst. | deer oak |
| _Salix_ L., spp. | willows |
| _Umbellularia californica_ (Hook. & Arn.) Nutt. | California laurel |

Although we find tanoak more often with Douglas-fir and redwood than with any other conifers, it also grows with:

| | |
|---|---|
| _Abies concolor_ (Gord. & Glend.) Lindl. | white fir |
| _A. grandis_ (Dougl.) Lindl. | grand fir |
| _Chamaecyparis lawsoniana_ (A. Murr.) Parl. | Port-Orford-cedar |
| _Picea sitchensis_ (Bong.) Carr. | Sitka spruce |
| _Pinus attenuata_ Lemm. | knobcone pine |
| _P. jeffreyi_ Grev. & Balf. | Jeffrey pine |

| | |
|---|---|
| *P. lambertiana* Dougl. | sugar pine |
| *P. monticola* Dougl. | western white pine |
| *P. ponderosa* Laws. | ponderosa pine |
| *Taxus brevifolia* Nutt. | Pacific yew |
| *Thuja plicata* Donn | western redcedar |
| *Torreya californica* Torr. | California torreya or nutmeg |
| *Tsuga heterophylla* (Raf.) Sarg. | western hemlock |

A large variety of shrubs, forbs, grasses, sedges, and ferns also associate with tanoak. Generally these plants are not abundant on forested land, but, with tanoak sprouts, often become aggressive on burned or cutover areas. Among the shrubs are:

| | |
|---|---|
| *Amelanchier alnifolia* Nutt. | western service berry |
| *Arctostaphylos canescens* Eastw. | hoary manzanita |
| *A. columbiana* Piper | hairy manzanita |
| *A. glandulosa* Eastw. | Eastwood manzanita |
| *Baccharis pilularis* DC. | coyote brush |
| *Ceanothus cordulatus* Kell. | mountain whitethorn |
| *C. foliosus* Parry | wavyleaf ceanothus |
| *C. incanus* T. & G. | white thorn |
| *C. integerrimus* H. & A. | deer brush |
| *C. parryi* Trel. | lady bloom |
| *C. sorediatus* H. & A. | jim brush |
| *C. thyrsiflorus* Eschsch. | blueblossom |
| *C. velutinus* Dougl. | snowbrush |
| *Corylus rostrata* var. *californica* A. DC. | California hazel |
| *Cytisus scoparius* Link | Scotch broom |
| *Diplacus aurantiacus* Jepson | brush monkey-flower |
| *Gaultheria shallon* Pursh | salal |
| *Holodiscus discolor* (Pursh) Maxim. | cream bush |
| *Lonicera ciliosa* (Pursh) Poir. | orange honeysuckle |
| *Myrica californica* Cham. | Pacific bayberry or wax myrtle |
| *Photinia arbutifolia* Lindl. | Christmas berry or toyon |
| *Rhamnus californica* Eschsch. | coffee berry |
| *R. purshiana* DC. | cascara sagrada |
| *Rhododendron macrophyllum* D. Don | Pacific rhododendron |
| *R. occidentale* Gray | western azalea |
| *Rhus diversiloba* T. & G. | poison oak |
| *R. trilobata* Nutt. | squaw bush |
| *Ribes cruentum* Greene | blood Sierra gooseberry |
| *R. divaricatum* Dougl. | straggly gooseberry |
| *R. glutinosum* Benth. | nutmeg currant |
| *R. lobbii* Gray | Lobbs or gummy gooseberry |
| *R. menziesii* Pursh | Menzies or canyon gooseberry |
| *R. sanguineum* Pursh | flowering currant |

| | |
|---|---|
| *Rosa californica* C. & S. | California wild rose |
| *Rubus leucodermis* Dougl. | western raspberry |
| *R. parviflorus* Nutt. | thimble-berry |
| *R. spectabilis* Pursh | salmon-berry |
| *R. vitifolius* C. & S. | California blackberry |
| *Sambucus glauca* Nutt. | blue elderberry |
| *Vaccinium ovatum* Pursh | California huckleberry |
| *V. parvifolium* Sm. | red bilberry |
| *Vitis californica* Benth. | California wild grape |

Two smaller plants producing woody growth above ground are:

| | |
|---|---|
| *Chimaphila umbellata* Nutt. | Prince's pine |
| *Berberis nervosa* Pursh | longleaf mahonia |

Some of the forbs plentiful in the tanoak range are:

| | |
|---|---|
| *Achlys triphylla* (Sm.) DC. | deerfoot vanillaleaf |
| *Apocynum androsaemifolium* L. var. *pumilum* Gray | mountain hemp |
| *Adenocaulon bicolor* Hook. | American adenocaulon |
| *Cirsium arvense* Scop. | Canada thistle |
| *C. lanceolatum* (L.) Scop. | bull thistle |
| *Erechtites arguta* DC. | New Zealand fireweed |
| *E. prenanthoides* DC. | Australian fireweed |
| *Hypericum perforatum* L. | Klamath weed |
| *Lathyrus torreyi* Gray | Torrey peavine |
| *Vancouveria parviflora* Greene | inside-out flower |
| *Whipplea modesta* Torr. | western whipplea |

Sword fern (*Polystichum munitum* Presl.) and bracken (*Pteris aquilina* L. var. *lanuginosa* (Bory) Hook.) sometimes grow abundantly with tanoak. Sedges (*Carex* L., spp.) and grasses also are represented in some places. The most common grass species are:

| | |
|---|---|
| *Avena fatua* L. | wild oat |
| *Bromus carinatus* Hook. & Arn. | California brome |
| *B. laevipes* Shear. | woodland brome |
| *B. mollis* L. | soft chess |
| *B. vulgaris* (Hook.) Shear. | narrow-flowered brome |
| *Festuca californica* Vasey | California fescue |
| *Hierochloe occidentalis* Buckl. | California sweetgrass |
| *F. idahoensis* Elmer | Idaho fescue |
| *F. megalura* Nutt. | foxtail fescue |
| *F. occidentalis* Hook. | western fescue |

Animals, birds, and insects are also parts of the biotic habitat conditions under which tanoak reproduces, grows, and dies. Each plays some role in the life history of tanoak.

## LIFE HISTORY

### SEEDING HABITS

#### Flowering and fruiting

Blossoms may appear in the spring, summer, or autumn (5, 17, 44). However, most tanoaks bloom in June, July, or August (29, 46). Trees at lower elevations and near the coast bloom earlier than trees at higher elevations and further inland.

Almost all the flowers, both male and female, are borne on new shoots of the year (5, 34, 44), where they grow from the axils of the new leaves (17). Flowers also occasionally develop from buds found at the base of leaves of the previous year's growth (5, 44).

Female flowers are borne at the base of erect male catkins (7). The profusion of the yellowish blossoms which sometimes conceal the foliage suggested the tree's specific scientific name (7, 23). The calyx is pale green; the stamen filament is white; and the anther yellow.

The fruit, which is similar to oak acorns, ripens in the second autumn (22, 30, 44, 46). Acorns are usually borne singly, in twos, or in threes (17, 25, 46), but sometimes several are clustered together.

#### Seed production

Tanoak is a heavy seeder (9, 17, 18 20, 44). In fact, no oak on the Pacific coast produces such heavy crops of acorns (23).

In general, viable seeds are borne in abundance after the thirtieth to fortieth year (19), although 5-year old sprouts also have produced fairly heavy crops. Trees are heavily laden almost every alternate year and complete seed crop failures are rare (38). When scanty crops occur they are generally caused by frosts or a dry year. However, a long dry period at pollination time is important for setting of acorns. "Jayhawking"--peeling the bark from standing trees--has shown that girdling produces excessively large acorn crops before the trees die (20).

Mature trees produce the most acorns. One estimate places annual acorn production of a veteran tanoak 30-inches in diameter at about 1,000 pounds (35). Since there are about 110 acorns to the pound (46), this production amounts to about 110,000 acorns. Other estimates showed that trees between 18 and 24 inches in diameter produced 3,900 to 4,600 acorns (38).

Insects destroy a significant number of acorns. One study found insect larvae infesting 51 percent of the acorns. The insects identified were: the filbert weevil (*Curculio uniformis* (Lec.)), the filbertworm (*Melissopus latiferreanus* (Wlsm.)), and a grey moth similar to *Valentinia glanulella* (Riley) which was tentatively identified as *Holcocera* sp. (38). Other insect larvae which have been found in tanoak acorns are: a cynipid (*Andricus eldoradensis* Beutenmüller), and two moths, one a gelechiid (family *Gelechiidae*) and the other a pyralid (family *Pyralididae*, subfamily *Phycitinae*) (35).

### Seed dissemination

Mature tanoak acorns are dropped between September 20 and November 15. Many immature acorns have been seen on the ground as early as August 25, but these probably were knocked down by a heavy early rain.

The first acorns to fall usually are insect infested. Those falling later are sound. (Indians placed a taboo on collecting acorns for food until their medicine women held a ceremonial festival which celebrated the falling of sound acorns.) 3/

Because the acorns are large (1.0 to 2.0 inches long, (22, 46) and 0.6 to 0.7 inches in diameter) and heavy, most of them fall straight to the ground and are found under the crowns of the trees. Only a few bounce from lower branches or roll for short distances on steep slopes. In one small study, acorns were counted under trees 18 to 24 inches in diameter at rates of 78,400 to 91,500 per acre (38).

## VEGETATIVE REPRODUCTION

Tanoak reproduces prolifically by vigorous sprouts which appear at practically any time under a wide variety of conditions

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3/ Radtke, Leonard B. Notes on the mast of the Hoopa (U. S. Dept. Int. Indian Serv.) 14 pp., illus. Typewritten, 1939.

(9, 47). 4/ Sprouts may start to grow after a relatively minor basal injury, after bark has been stripped from the tree for tannin extraction, or when the aerial parts of the tree are destroyed by fire or logging (17, 18, 34, 36, 44). Even healthy trees sometimes sprout.

Sprouts develop from conical woody buds which lie under the bark at the base of the tree. Most of these buds are found below the ground line. Since the number of buds varies from few to thousands the number of sprouts also varies. As many as 1,400 have been counted on one large stump. The only mechanical damage which prevents sprouting occurs when bark is stripped below the ground level and the buds are exposed (20, 23).

Sprouts grow rapidly in good light. Measurements show they may grow as tall as 5.6 feet the first year and 13.6 feet in the fifth year. The size of the parent tree determines the height and diameter growth of sprout clumps, and the number of sprouts in a clump. Larger parent trees produce greater sprout development. The living sprouts are reduced drastically in numbers early in their life and growth is concentrated on the dominant stems (table 1) (36, 37). In the first 15 or 20 years sprouts will average about 2 feet in height a year. Often, a circle of 4 to 8 slender 30-year old poles grows around the stump of a parent tree (20, 21). These poles will average 12 to 15 inches in diameter (14).

Although not as aggressive as sprouts of some other associated hardwoods, such as bigleaf maple, madrone, and Oregon white oak (36), tanoak sprouts are much more important as competitors because tanoak is more abundant, especially in conifer stands. It often quickly dominates the vegetational cover after logging or fire. Although this ability helps reduce soil erosion, tanoak sprouts often provide severe competition to conifer reproduction and may suppress it. And the thick, stiff, flat, leathery leaves which decay slowly often smother young conifer seedlings and transplants or cover the ground so thoroughly that conifer seeds cannot germinate (10, 30, 36, 37).

Propagation of tanoak by grafting or cuttings has not been reported.

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4/ Wagner, Roy G., op. cit.

Table 1.--Tanoak sprout development

| Time after burning or logging | Sprout clumps measured | Height of tallest sprout in clump: Ave. | Range | Crown diameter of sprout clumps: Ave. | Range | Sprouts per clump: Ave. | Range |
|---|---|---|---|---|---|---|---|
| | Number | Feet | | | | Number | |
| Logged: | | | | | | | |
| First year | 120 | 2.4 | 0.7 -5.6 | 2.6 | 0.6 -7.4 | 16 | 1-162 |
| Burned: | | | | | | | |
| Second year | 50 | 5.2 | 2.2 -8.3 | 6.2 | 2.9-11.5 | 27 | 7 -79 |
| Third year | 50 | 6.8 | 2.2-10.3 | 7.0 | 3.4-12.1 | 12 | 4 -25 |
| Fourth year | 50 | 7.9 | 2.3-11.3 | 8.4 | 3.4-14.3 | 10 | 4 -25 |
| Fifth year | 50 | 9.3 | 2.7-13.6 | 9.9 | 4.8-15.2 | 10 | 4 -25 |
| Sixth year | 49 | 10.3 | 3.5-14.7 | 10.3 | 5.0-15.6 | 9 | 1 -25 |

## SEEDLING DEVELOPMENT

### Establishment

Under proper conditions tanoak reproduces well by seed. Acorns germinate readily in sunny, open spots (21) where the seedbed is a loose, mineral soil. However, the dense shade of virgin forests, and the thick litter found under tanoaks, madrones, or other hardwoods, seem to hinder germination. Seedlings are rare in these places (21). Tanoak germination is hypogeous.

A limited number of tests show germination rates vary from 19 to 80 percent (20, 46).

Seedlings may appear in the fall if the weather is mild. Seed collectors have found that acorns must be planted immediately in light soil. Seedlings appear 3 weeks after planting. To retard germination until spring, acorns must be stratified at a temperature just above freezing (46).

Natural tanoak seedlings have been counted under parent trees left after the Douglas-fir overstory had been cut. Although one year's acorn crop produced 160 to 380 seedlings per acre under trees 20 to 26 inches in diameter, the efficiency of the sound acorns in producing seedlings was only 0.64 percent. This means only 1 seedling grew from 156 sound acorns (38).

Biotic factors contribute to the low seed crop efficiency. Although the acorns have hard seedcoats 5/, many animals devour them with gusto. Some of these animals are (38) 6/:

| | |
|---|---|
| Balanosphyra formicivora bairdi (Ridgway) | California woodpecker |
| Columba fasciata fasciata Say | band-tailed pigeon |
| Cyanocitta stelleri frontalis (Ridgway) | blue-fronted jay |
| Ixoreus naevius naevius (Gmelin) | Pacific varied thrush |
| Eutamias townsendii Bachman | Townsend chipmunk |
| Neotoma fuscipes fuscipes Baird | dusky-footed wood rat |
| Otospermophilus grammurus douglasii (Richardson) | Douglas ground squirrel |
| Sciurus douglasii mollipilosus (Audubon & Bachman) | redwood chickaree |
| Sciurus griseus griseus Ord. | California gray squirrel |
| Euarctos americanus americanus (Pallas) | American black bear |
| Odocoileus hemionus columbianus (Richardson) | Columbian black-tailed deer |

Hogs and cattle also prevent seedling reproduction by devouring the acorns and browsing the tender foliage of seedlings (19).

Early growth

First-year growth of tanoak seedlings is vigorous. Heights measured from cotyledons to growing tip in one study varied from 1.9 to 8.3 inches and averaged 5.2 inches. These seedlings were measured on July 22. Therefore, total first-year growth might have been more. The heights in July, however, were greater than first-year height growth of conifers on the same site (38). After the first year the seedling growth rate is moderate (19).

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5/ The generic name, Lithocarpus, from the Greek "Lithos" meaning rock, and "karpos" meaning fruit, alludes to the hard acorn (29).

6/ Knauss, A. C. File memorandum. RP-NW-TIMBER CONVERSION, Utilization, Tan Oak (U. S. Forest Serv., Pacific Northwest Region) 4 pp., illus. Typewritten. April 15, 1947.

New tanoak seedlings quickly develop a husky tap-root. By the end of July many seedlings have roots penetrating more than 24 inches deep. Tanoaks eventually grow a deep tap-root system (34). Seedlings, however, have difficulty to survive on dry, unprotected slopes.

Although best early growth is found where seedlings get partial shade, tanoak is intolerant to heavy shade during its early growth. It becomes more shade-enduring with age (35).

## SEASONAL GROWTH

Records on the seasonal growth of tanoak are scanty. Some observations have been made in the vicinity of Salyer, California. Here, in the Trinity River valley and on the low mountain slopes up to 2,000 feet elevation, tanoak vegetative buds open in mid April. From 2,000 to 3,500 feet buds burst in mid May; from 3,500 to 4,400 feet in late May. At its elevational limit, which is about 4,500 feet buds open in early June. The new leaves of a season persist for 3 to 4 years (5, 44).

The growing season lasts 4 to 5 months in the mountains and somewhat longer at lower elevations and nearer the coast.

## SAPLING STAGE TO MATURITY

### Growth and yield

The form of tanoak varies greatly. The four general forms of growth are: the spire shaped, similar to conifers; the round headed; the shrubby or deep shade form; and the stunted chaparral form. In close stands, particularly the dense coniferous forests, tanoaks develop one central axis, the crowns are narrow, the branches upright and the trunks long and clear for 30 to 80 feet. In this form tanoak is one of the most stately broadleaved trees in the west. In open stands, however, especially in association with Pacific madrone and California black oak, tanoaks are free branching, the crowns are broad, the limbs horizontal and large, and the trunks short and thick. The main trunk divides into several large branches and forms a rounded crown (17, 20, 23, 44).

Tanoak usually is classed as medium sized (46). Mature trees generally are 50 to 90 feet tall but frequently grow 150 feet high (17, 22, 35, 39, 44). The tallest tree reported was 208 feet high and 4.5 feet in diameter. It was found on the North Fork of the Little Sur River, Monterey County, California. 7/

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7/ Larsen, L. T. File memorandum. U. S. Forest Serv. Region 5. 1 pp. June 26, 1914.

The diameters of mature trees usually vary from 1 to 4 feet (17, 20, 35, 39, 44). 8/ The largest diameter breast high of record is 7 feet 7.9 inches, measured on a tanoak near Cazadero, Sonoma County, California. The height of this tree was 80 feet and its crown had a spread of 84 feet (2). Tanoaks growing largest in diameter are generally found in open stands where height growth is less. The following tabulation illustrates the diameter-height relationship (20). 9/

| Diameter, inches: | Height, feet: | Age, years: |
|---|---|---|
| 4 - 9 | 30 - 50 | 20 - 40 |
| 10 -12 | 40 - 80 | 40 -100 |
| 13 -18 | 80 -100 | 70 -125 |
| 19 -24 | 90 -120 | 100 -159 |
| 25 -36 | 115 -140 | 125 -180 |
| 37 -46 | 100 -120 | 150 -210 |
| 47 -60 | 100 -120 | 170 -250 |

The growth of tanoak has been called slow (39, 47), moderate (34), and fairly rapid (18). Exact knowledge about growth rate is limited, for only a few trees have been measured. Seven trees near Sherwood, Mendocino County, California, which varied from 14 to 27 inches in diameter 2 feet above the ground, had from 10 to 20 rings per inch (23). At another place, trees 48 years old averaged 10 inches in diameter and 35 feet tall. Trees 14 to 18 inches in diameter were from 80 to 128 years old; 20 to 60 inch trees, from 150 to 250 years old (44).

The age at which trees mature differs for various sites. One report gives the age of mature trees as 80 to 190 years (20); another states maturity is reached in 200-300 years (34). The average age of tanoaks in virgin stands seems about 180 years (14).

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8/ Knauss, A. C., op. cit.

9/ Bauer, Patricia McCollum. History of lumbering and tanning in Sonoma County, California since 1812. Thesis (M.A.), Univ. Calif., 189 pp., illus. Typewritten, 1951.

The present sawtimber volume of tanoak has been estimated as 2,036 million board-feet in California and 1,700 million board-feet in Oregon (16, 40). The volume of tanoak on commercial forest land in California is divided into diameter-class groups as follows (15):

| Diameter class group, inches: | Volume, million board-feet: |
|---|---|
| 11.0-20.9 | 855 |
| 21.0-30.9 | 765 |
| 31.0-40.9 | 329 |
| 41.0 + | 87 |
| | 2,036 |

Reaction to competition

Tanoak is generally rated as tolerant (3, 4, 34). It is aggressive and extremely well-fitted by its reproductive habits, vigor, and remarkable shade endurance to compete for possession of the ground (20). Although tanoak can endure considerable shade throughout life, it grows best with top light (17, 44). In conifer stands where it has an equal opportunity to grow, it is able to compete with redwood and Douglas-fir (20). In dense stands natural pruning produces long clear boles (17).

Under stands of dense redwood or Douglas-fir where tanoak obtained a late start, low tanoak shrubs or small trees may be abundant. When the coniferous overstory is removed, the tanoak quickly dominates the logged areas (20, 23). Suppressed trees often develop with remarkable speed after being released from dense shade (19).

Tanoak is a climax species where it grows in the broad-sclerophyll forest formation which is dominated mainly by sclerophyllous evergreen trees but includes a number of deciduous species. It is successional, however, where its range overlaps those of conifers, and postclimax in its overlap with the climax chaparral (10).

Principal enemies

Fire is the principal enemy of individual tanoak trees (9, 17, 23). Ground fires, as well as crown fires, are sometimes fatal. More often, however, fires will leave long vertical wounds reaching from 4 to 10 feet up the trunks (23). Although the bark of mature trees is at least 1 to 3 inches thick, and occasionally 4 or 5 inches (23), some trees are burned badly.

Fire injuries to small trees often heal over, but fungi usually enter the wounds on older trees. The exposed wood on these larger trees rots and the wounds do not heal (23). Sometimes one-third to one-half the diameter of the tree is eaten away as a result of repeated fires and decay. If decayed wood catches fire it burns readily and the original wound is enlarged.

Until injured by fire, tanoak is relatively free from insects and fungus diseases, and is windfirm (9, 17, 47). Even slight injury to the trunk, however, allows fungi to enter. Wind and heavy snows eventually fell many trees originally injured by fire and subsequently weakened by decay.

Fire and fungi cause tanoak to be fairly defective. 10/ A large part of this defect occurs in cull trees--sawlog-size trees where more than 60 percent of the board-foot volume is cull. One study (27) based upon 90 trees showed the percentage of sawlog cull (from stump to top diameter of 10 inches) to be:

| | All trees | Cull trees | Trees not cull |
|---|---|---|---|
| | - - - - - - - | -Percent- | - - - - - - - - - |
| Cubic feet basis | 13 | 39 | 8 |
| Board-feet (Scribner) basis | 33 | 80 | 26 |

Fungi found on living trees are the beefsteak fungus (*Fistulina hepatica* (Huds.) Fr.)--which causes a brown cubical rot, the weeping conk (*Polyporus dryadeus* Fr.)--a white root rot, and a necrophyte (*Shizophyllum commune* Fr.)--which causes a sap rot on injured areas of standing trees. 11/

Several insects have been found feeding on tanoak but generally are minor in importance. Two of these are armored scales identified as the greedy scale (*Hemiberlesia rapax* (Comstock)) and the oak scale (*Quernaspis quercus* (Comstock)) (28). The greedy scale chiefly infests the bark but also occurs on the leaves. The oak scale feeds on the undersides of leaves. Two other insects which resemble the soft unarmored scales also feed on the undersides of leaves. They are the glacial white fly (*Trialeurodes glacialis* Bemis) and the Stanford white fly (*Tetraleurodes stanfordi* Bemis). Ehrhorn's oak scale(*Mycetococcus ehrhorni* (Ckll.)) is found on stems and the white sage mealybug (*Pseudococcus crawi* Coquillett) on stems and leaves (13).

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10/ Knauss, A. C., op. cit.

11/ From the Host Index File, Division of Forest Disease Research, California Forest and Range Experiment Station.

In 1957 the California oakworm (Phryganidia californica Pack.) completely destroyed the current year's foliage of tanoaks growing on Hennessey Ridge, near Salyer, Trinity County. This damage was localized and was not observed at other places nearby.

Other insects work under the bark. Adults of a twig girdler, Agrilus angelicus Horn, feed on foliage, but its larvae mine spiral galleries which girdle twigs, small limbs and trunks, or sprouts. The California oak twig girdler (Styloxus californicus (Fall)), a long-horned beetle or roundheaded borer, also girdles tanoak sprouts (17, 24).

Tanoak is avoided by livestock unless better feed is unavailable (11). Columbia black-tailed deer (Odocoileus hemionus columbianus (Richardson)) rarely browse it (47). The current year's growth of tanoak leaves and twigs is protected by a covering of fasicled hairs, which are unpleasant to inhale.

## SPECIAL FEATURES

Tanoak and the other trees in the genus Lithocarpus Blume are considered links between the chestnut, Castanea Mill., and the oak, Quercus L. (12, 29). The chestnut characteristics of tanoak are the erect elongated catkins, parallel lateral veins of the leaves, pistillate flowers at the base of the staminate catkins, and a bur-covered acorn cup. Some of the oak characteristics are the acorn cup instead of a closed bur, the single pisillate flower in an involucre, and the bitter tasting true acorn (29). One successful attempt to graft European chestnut (Castanea sativa Mill.) scions to tanoak stumps has been reported from southern Mendocino County. 12/

Tannin from tanoak bark also has properties intermediate between chestnut tannin and the usual oak tannin of commerce (26). However, the extract from tanoak bark furnishes the best tannage known for the production of heavy leathers (20, 21). For example, it gives excellent plumping when used to tan sole or saddle leather (26). The superiority of tanoak bark extract is attributed to the presence of certain other acids, such as gallic and acetic, with the tannic acid (20). Tanoak tannin has also been used medicinally (43).

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12/ Source of information was Mr. "Buck" Zeni, Zeni Ranch, Yorkville-Anchor Bay Road, Mendocino County, California, through Paul J. Zinke, School of Forestry, University of California.

In relation to tannin production, tanoak is the most important Pacific Coast hardwood (18)--first, because the bark is rich in tannin (19, 46) and, second, because the trees are abundant. The area occupied by tanoaks suitable for tannin production has been estimated at 3 million acres with an average count of 20 trees per acre (6).

The tannin content of tanoak bark varies between 8 and 29 percent (14, 18, 26). Trees must be at least 75 years old before the bark is valuable for its tannin. 13/ In individual trees the tannin content is highest in the bark near the base of the trunk (1) and decreases with height above the ground. 14/

Trees growing on better sites produce less extract from a given volume of bark than those on poorer sites where growth is slower. 15/ The best bark comes from trees growing on ridges, open grown trees, or trees growing in scattered clumps. When grown in dense stands or mixed with other species tanoak will yield less valuable bark. 16/

Tanoak sapwood is extremely thick, the sapwood percentage being as high as 66 percent even on large trees (16). This thick sapwood helps the tree live after the bark has been stripped. Consequently, standing trees sometimes live several years after being peeled, but they never produce a second crop of bark which has commercial value. 17/ The root systems of peeled trees which survive probably are fed by sprouts or by other trees through natural root grafts.

The Indians in California's North Coast Range obtained one of their principal foods from the tanoak. In fact, the main fare of many Indian communities was salmon and tanoak acorns. The large acorns were ground, leached, and then prepared as a soup, cooked mush, or kind of bread. After being leached, the acorns are said to have an agreeable acid taste. They also contain a comparatively

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13/ Wagner, Roy G., op. cit.

14/ Smith, H. H., Utilization of tanbark oak. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. 1 p. Typewritten. 1950.

15/ Wagner, Roy G., op. cit.

16/ Smith, H. H., op. cit.

17/ Jepson, Willis Linn. The tanbark oak and its relation to the California tanning industry. (File, U. S. Forest Serv. Calif. Forest and Range Expt. Sta.) 40 pp., Typewritten. 1910.

large amount of oil. On this account tanoak acorns were preferred by the Indians over all other kinds. Ground tanoak acorns have also been fed to chickens (8, 20, 35).

## RACES AND HYBRIDS

A shrubby variety of tanoak (*L. densiflora* var. *echinoides* (R. Br.) Abrams) grows near Mount Shasta, on the west slope of the northern Sierra Nevada, in the Salmon and Klamath Mountains, and northward through the Siskiyou Mountains into southern Oregon (29). 18/ 19/ This dwarf or mountain variety is part of the chaparral cover found on mountain tops and ridges. It assumes many of the characteristics of the other chaparral shrubs, such as low stature, ranging from 1 to 10 feet high, rigid branches, and small, thin leaves (23).

There are no known hybrids of tanoak. Although *Lithocarpus* comprises about 100 species, all but tanoak are native to southeastern Asia (18).

## LITERATURE CITED

(1) Anon.
1918. Tanbark oak of California yields riches. The Timberman 19 (8):36, illus.

(2) Anon.
1956. These are the champs, Part II. Amer. Forests 62(4):33-40, illus.

(3) Baker, F. S.
1949. A revised tolerance table. Jour. Forestry 47(3):179-181.

(4) __________
1950. Principles of silviculture. 414 pp., illus., New York, Toronto, London.

(5) Britton, Nathaniel Lord, and Shafer, John Adolf.
1908. North American trees (being descriptions and illustrations of the trees growing independently of cultivation in North America, north of Mexico and the West Indies). 894 pp., illus., New York.

---

18/ Bauer, Patricia McCollum, op. cit.

19/ Wagner, Roy G., op. cit.

(6) Carr, Myra
1956. Shoe trees--leather men search the West for nature's stores of tannin. Pacific Discovery 9(6):6-12, illus.

(7) Cater, Ruth Cooley.
1950. Tree trails and hobbies. 324 pp., illus. Garden City, N. Y.

(8) Chestnut, V. K.
1902. Plants used by the Indians of Mendocino County, California. Contrib. U. S. Natl. Herbarium 7(3): 295-408, illus.

(9) Collingwood, G. H., and Brush, Warren D.
1955. Knowing your trees. 1955 Ed., 328 pp., illus. Washington, D. C.

(10) Cooper, William S.
1922. The broad-sclerophyll vegetation of California--an ecological study of the chaparral and its related communities. Carnegie Inst. Washington Pub. 319, 124 pp., illus.

(11) Dayton, William A.
1931. Important western browse plants. U. S. Dept. Agr. Misc. Pub. 101, 214 pp., illus.

(12) Eliot, Willard Ayres, and McLean, G. B.
1938. Forest trees of the Pacific Coast. 565 pp., illus. New York.

(13) Essig, E. O.
1926. Insects of western North America. 1035 pp., illus. New York.

(14) Flinn, E. S.
1947. The necessity and feasibility of the commercial development of the California tanbark oak for tannin and wood pulp. Conf. Cult. Drug and Assoc. Econ. Plants in Calif. Proc. 1947:168-171.

(15) Forest Survey Staff.
1954. Forest statistics for California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Survey Release 25, 66 pp., illus.

(16) Graham, Robert D.
1954. Seasoning and preservative treatment of tanoak. Jour. Forest Prod. Res. Soc. 4 (2):92-95, illus.

(17) Green, George Rex
1934. Trees of North America (Exclusive of Mexico). Vol. II--The broadleaves. 344 pp., illus.

(18) Harlow, William M.
1930. The dendrology of the more important trees of the United States. Part I--Hardwoods. New York State College of Forestry, 140 pp. (Processed)

(19) __________, and Harrar, Ellwood S.
1950. Textbook of dendrology covering the important forest trees of the United States and Canada. Ed. 3, 555 pp., illus. New York, Toronto, London.

(20) Jepson, Willis Linn
1910. The silva of California. Mem. Univ. Calif. 2, 480 pp., illus.

(21) __________
1923. The trees of California. Ed. 2, 240 pp., illus. Berkeley.

(22) __________
1925. A manual of the flowering plants of California. 1238 pp., illus. Berkeley.

(23) __________, Betts, H. S., and Mell, C. D.
1911. California tanbark oak. U. S. Dept. Agr. Forest Serv. Bul. 75, 34 pp., illus.

(24) Keen, F. P.
1938. Insect enemies of western forests. U. S. Dept. Agr. Misc. Publ. 273, 280 pp., illus. (Revised 1952).

(25) Kellogg, A.
1882. Forest trees of California. Calif. State Mining Bur. 148 pp.

(26) Kidder, Monroe C., and Finney, William H.
1947. California tanbark oak--its immediate availability and possibilities as a source of tannin and wood pulp. Conf. Cult. Drug and Assoc. Econ. Plants in Calif. Proc. 1947:149-152.

(27) Kimmey, James W.
1950. Cull factors for forest-tree species in northwestern California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Survey Release 7, 30 pp., illus.

(28) McKenzie, Howard L.
1956. The armored scale insects of California. Calif. Insect Surv. Bul. 5:1-209, illus.

(29) McMinn, Howard E.
1951. An illustrated manual of California shrubs. 663 pp., illus. Berkeley, Los Angeles.

(30) __________, and Maino, Evelyn
1935. An illustrated manual of Pacific Coast trees. 409 pp., illus, Berkeley.

(31) Merriam, C. Hart
1898. Life zones and crop zones of the United States. U. S. Dept. Agr. Biol. Surv. Bul. 10, 79 pp., illus.

(32) Mirov, N. T., and Kraebel, C. J.
1937. Collecting and propagating the seeds of California wild plants. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 18, 27 pp.

(33) Munns, E. N.
1938. The distribution of important forest trees of the United States. U. S. Dept. Agr. Misc. Pub. 287, 176 pp., illus.

(34) Preston, Richard J., Jr.
1948. North American trees (Exclusive of Mexico and tropical United States). 371 pp., illus. Ames, Iowa.

(35) Radtke, Leonard B.
1937. Shall we destroy the tanoaks of the Hoopa Indian Reservation in northern California. U. S. Indian Serv. 25 pp., (Processed)

(36) Roy, D. F.
1955. Hardwood sprout measurements in northwestern California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 95, 6 pp., illus.

(37) __________
1956. Killing tanoak in northwestern California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 106, 9 pp., illus.

(38) __________
1957. A record of tanoak acorn and seedling production in northwestern California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Res. Note 124, 6 pp., illus.

(39) Sargent, Charles Sprague
1922. Manual of the trees of North America (Exclusive of Mexico). Ed. 2, 910 pp., illus. Boston, New York.

(40) Smith, H. H.
1956. Improved utilization of western hardwoods by modern drying. Forest Prod. Jour. 6(3):121-124.

(41) Society of American Foresters, Committee on Forest Types
1954. Forest cover types of North America (Exclusive of Mexico). 67 pp., illus. Washington, D. C.

(42) Sprague, Malcolm
1941. Climate and man. Climate of California. U. S.Dept. Agr. Yearbook 1941:783-797, illus.

(43) Stuhr, Ernst T.
1933. Manual of Pacific Coast drug plants. 189 pp. Lancaster.

(44) Sudworth, George B.
1908. Forest trees of the Pacific slope. U. S. Dept. Agr. Forest Serv. 441 pp., illus.

(45) Thornthwaite, C. W.
1941. Atlas of climatic types in the United States, 1900-1939. U. S. Dept. Agr. Misc. Pub. 421, 7 pp., 96 plates.

(46) U. S. Forest Service
1948. Woody plant seed manual. U. S. Dept. Agr. Misc. Pub. 654, 416 pp., illus.

(47) Van Dersal, William R.
1938. Native woody plants of the United States, their erosion-control and wildlife values. U. S. Dept. Agr. Misc. Pub. 303, 362 pp., illus.

(48) Whittaker, R. H.
1954. The ecology of serpentine soils. IV. The vegetational response to serpentine soils. Ecol. 35(2):275-288, illus.

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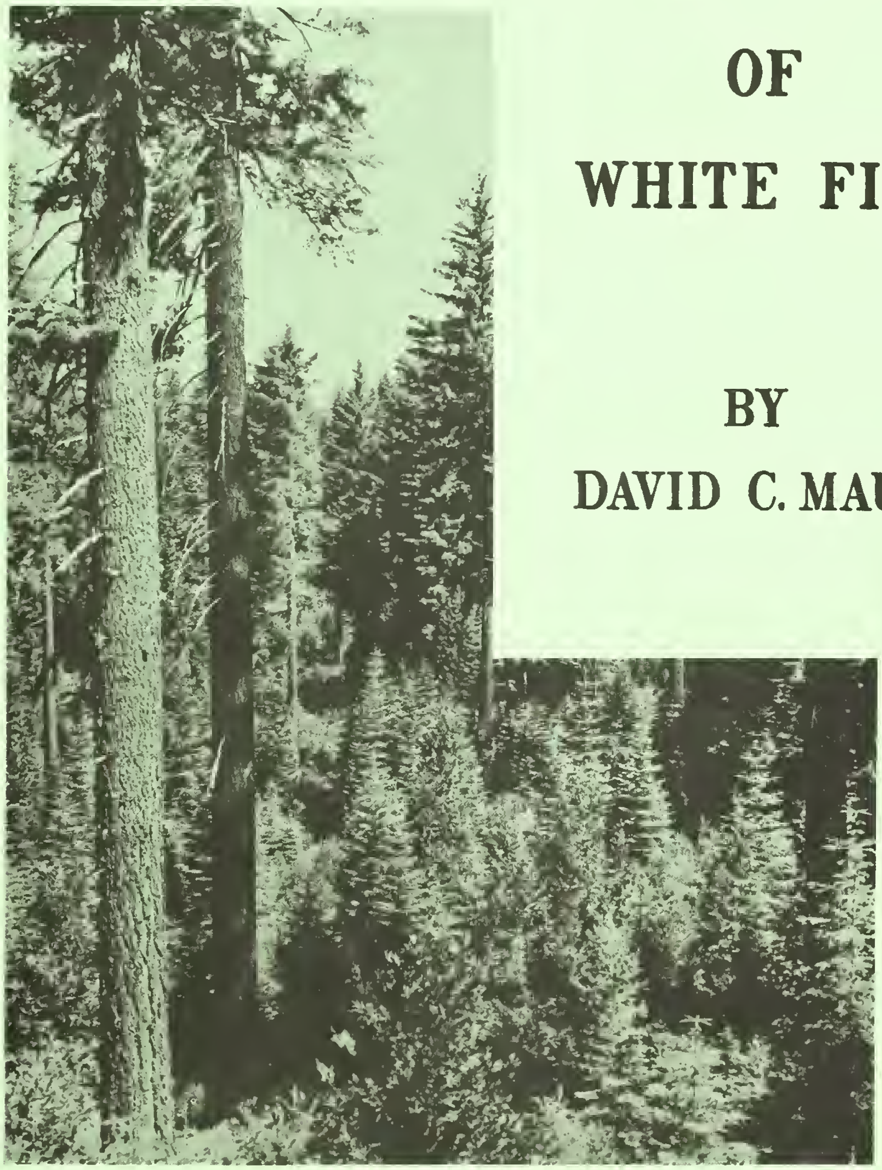
# SILVICAL CHARACTERISTICS OF WHITE FIR



BY
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CALIFORNIA
FOREST AND RANGE
EXPERIMENT STATION
KEITH ARNOLD, DIRECTOR
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FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

# SILVICAL CHARACTERISTICS OF WHITE FIR

By David C. Maul, Forester,
Division of Forest Management Research

Technical Paper No. 25 October 1958

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

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The Experiment Station is maintained at Berkeley, California in cooperation with the University of California.

Agriculture--Forest Service, Berkeley, California

CONTENTS

# SILVICAL CHARACTERISTICS OF WHITE FIR

By David C. Maul [1]

## RANGE

White fir (Abies concolor Gord. and Glend.) Lindl.) is an economically important native tree in western United States and parts of Mexico. In the United States it is widely distributed in the Rocky Mountain and Pacific Coast regions, extending from New Mexico and Wyoming, westward to Oregon and California (19, 21) (Fig. 1). It attains best development in California and southwestern Oregon.

## HABITAT CONDITIONS

### CLIMATIC

White fir is found primarily in the Transition Life Zone but also in the Canadian Life Zone. In general, white fir occurs in the higher mountain areas characterized by moderately humid to humid climate, with long winters and moderate to heavy snow deposits. Where white fir occurs in California, Oregon, Idaho, and the Great Basin country, the summers tend to be dry. In Colorado, Utah, and the Central Rockies, the portion of the annual precipitation falling as rain is fairly evenly distributed over the summer period. In Arizona and New Mexico the spring season is drier than the summer period (34).

White fir grows best in cool, moist situations (32). The lower limit of precipitation for the species is about 20 inches per year and 20 to 35 inches is common over much of the drier parts of its range. In some of the higher mountain areas and parts of the north coastal range of California precipitation on white fir sites ranges between 35 and 75 inches. The best stands of white fir develop in areas receiving 40 to 60 inches of precipitation. Annual precipitation is from 40 to 50 inches in the vicinity of Shaver Lake, Fresno County, California (lat. 37° 8' N., long. 119° 17' W.) where site conditions appear to be about optimum. Temperature extremes range from -38° F. in Colorado to 98° F. in southern California (32).

### EDAPHIC

White fir grows on a great variety of soils. It develops best on moderately deep, rich, moist loam but it is often found on dry, coarse, disintegrated rock and among boulders. Heavy clay soils do not favor its development (32).

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1/ The author acknowledges appreciation for valuable help from several reviewers, particularly E. L. Mowat of the Pacific Northwest Forest and Range Experiment Station and C. R. Quick and W. W. Wagener of the California Forest and Range Experiment Station.

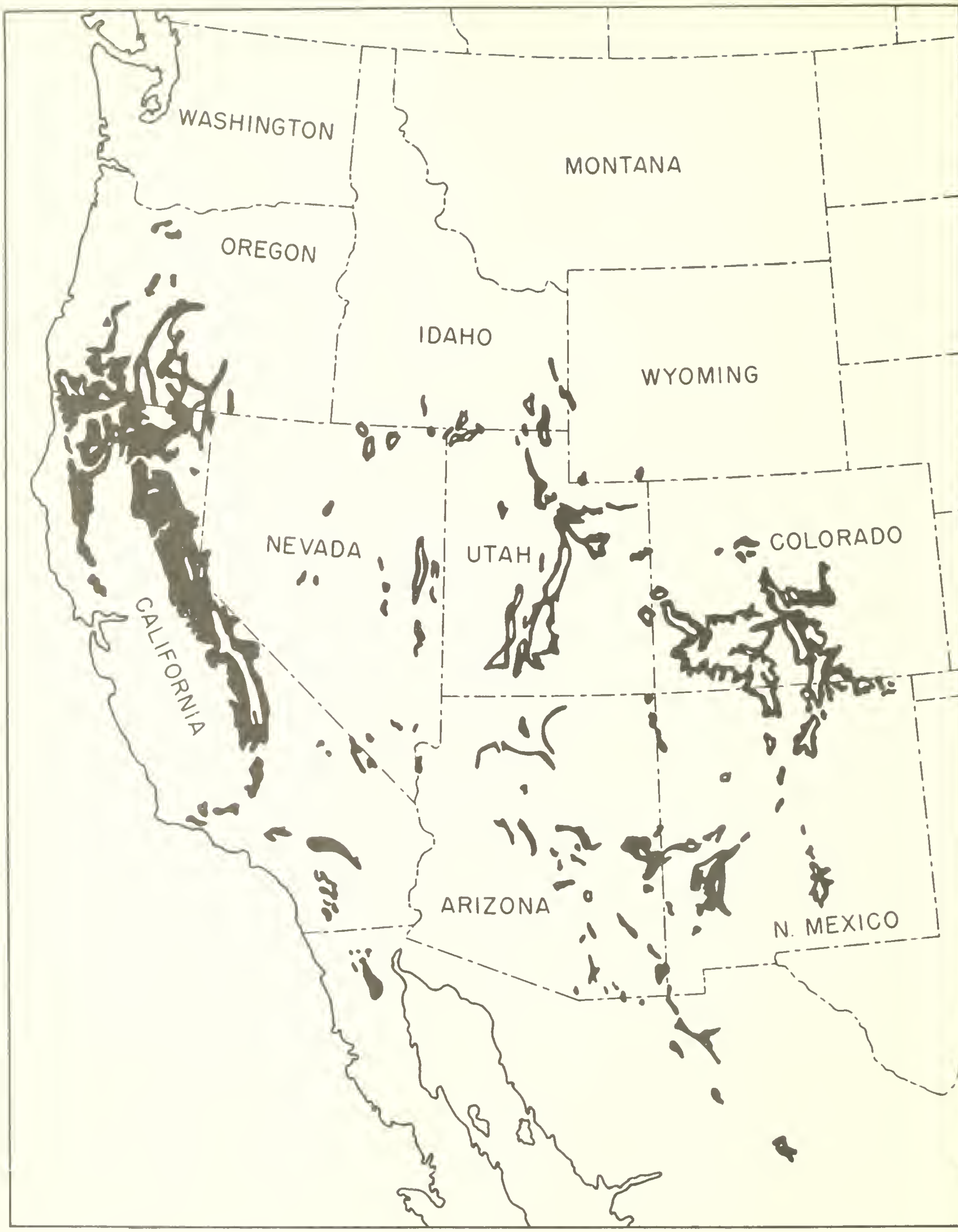


Figure 1.--The natural range of white fir. (Adapted from Munns, E. N. 1938. The distribution of important forest trees of the United States. U. S. Dept. Agr. Misc. Pub. 287, 176 pp., illus.)

Throughout its range, white fir may be found growing on soils derived from a variety of parent materials such as andesite, dacite, diorite, latite, rhyolite, basalt, granite, pumice, sandstone and shale. The deeper and more permeable soils, when supplied with adequate moisture, are most conducive to good growth.

In California 2/ white fir has been found on the Aiken, Holland, Hugo, Olympic, Sheetiron and Sites Soil Series. In northeastern California many stands grow on soils of volcanic origin. In the central and northern Coast Range the species often occurs on the Hugo soils which are derived from sandstone and shale rocks. This series, grayish brown to pale brown in color, is generally of a friable, granular loam structure and is slightly to strongly acid in reaction. In the mixed conifer type of the central Sierra some of the finest specimens of white fir occur on the Holland series. These soils, of a sandy loam or loam type, are developed from weathered granitic and similar quartz-bearing crystalline rock; they are free of lime and predominantly slightly acid.

Good development is also common on soils of the Olympic series. These soils are distributed through the mountains and foothills of the Sierra Nevada, Cascade, and the Coast Range in Oregon and central and northern California. They are developed from basaltic and andesitic rocks and are moderately to strongly acid in reaction. They usually have a friable, granular, clay loam structure.

PHYSIOGRAPHIC

White fir is found over rather widely varying altitudes in its extensive geographical range. Presumably occurrence is governed mainly by temperature extremes, quantity and seasonal distribution of precipitation, and aspect.

In Oregon, it occasionally grows at elevations as low as 2,000 feet on slopes in the headwaters of the Willamette River. Farther south, along the western slopes of the Cascade range, it grows from about 3,000 to 6,000 feet. On the east side of the Cascades, near Mt. Jefferson, it occurs at altitudes of 4,000 to 7,500 feet, and in the Klamath River basin from 5,000 to 7,700 feet (32).

On the west side of the North Coast Range of California white fir is sometimes found as low as 3,000 feet; on the eastside of these mountains, between 4,500 and 7,400 feet. It ranges up to 8,100 feet or more on the higher peaks in the Warner Mountains of northeastern California. In the San Bernardino Mountains of southern California it grows at elevations of from 4,800 to 10,000 feet and is found mostly on north slopes. In Lower California it occurs in the San Pedro Martir Plateau at 8,000 to 11,000 feet (32). The bulk of the white fir in California is found at elevations of 4,000 to 7,000 feet along the western Sierra Nevada.

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2/ Information on soils in California was supplied by Robert E. Nelson, California Forest and Range Experiment Station.

In the interior parts of its range, including the Rocky Mountain area and the Southwest, white fir occurs from 6,000 to 11,000 feet, but it is most frequently found at elevations between 7,000 and 9,000 feet. Usually it grows on north slopes and in some localities is fairly abundant on benches and sides of moist canyons (33).

Along the outer ranges of the Rocky Mountains, east of the Continental Divide and south of the divide separating the Platte and Arkansas Rivers, white fir occasionally occurs up to 11,000 feet (24). In the Southwest it is common in ponderosa pine, Douglas-fir, and spruce-fir forests between 5,500 and 10,000 feet (18).

BIOTIC

White fir is represented in 11 forest cover types of Western North America and occurs as scattered individuals, in small groups, or in practically pure stands (30). The white fir type, as such, is found in the Cascade Mountains and in the ranges immediately to the east in Oregon and California. This type often covers fairly large areas. It may be a climax type whether in pure stands or with a light mixture of associates.

Mixtures of California red fir (*Abies magnifica* A. Murr.) and white fir are common in northern California. Whether in practically pure type, or in heavy mixture with red fir, the stands are often very dense and contain little or no underbrush. White fir is also a prominent species in the ponderosa pine-sugar pine-fir type, often called the mixed-conifer type. White fir often constitutes a transition species at the lower limits of the red fir belt; within the red fir type it is frequently the major associate.

White fir is also found as a minor component in the following cover types: Pacific Douglas-fir, Pacific ponderosa pine--Douglas-fir, Pacific ponderosa pine, California black oak, Jeffrey pine, interior ponderosa pine, interior Douglas-fir, and blue spruce (30).

In the northern part of its range on the Pacific Coast, including Oregon and northern California, white fir is often associated with (33):

| | |
|---|---|
| *P. ponderosa* Laws. | ponderosa pine |
| *P. jeffreyi* Grev. and Balf. | jeffrey pine |
| *P. contorta* Dougl. | lodgepole pine |
| *P. lambertiana* Dougl. | sugar pine |
| *Abies magnifica* A. Murr. | California red fir |
| *Abies grandis* (Dougl.) Lindl. | grand fir |
| *Pseudotsuga menziesii* (Mirb.) Franco | Douglas-fir |
| *Libocedrus decurrens* Torr. | incense-cedar |

Throughout south-central Oregon and northeastern California, forests of ponderosa pine and white fir are common. In the southern part of its Pacific Coast range, which includes central and southern California, and Lower California, Mexico, white fir is associated with ponderosa pine, jeffrey pine, sugar pine, lodgepole pine, western white pine (*P. monticola* Dougl.), incense-cedar, red fir, and giant sequoia (*Sequoia gigantea* (Lindl.) Decne.).

Associated plants and shrubs which commonly occur with white fir in the Pacific Coast region vary according to the altitudinal and latitudinal distribution of the various species. Some of the woody plants that may be present in the different locations include:

| | |
|---|---|
| *Ribes roezlii* Regel. | Sierra gooseberry |
| *Ribes viscosissimum* Pursh. | sticky currant |
| *Symphoricarpos rotundifolius* Gray | roundleaf snowberry |
| *Arctostaphylos nevadensis* Gray | pinemat manzanita |
| *Arctostaphylos patula* Greene | greenleaf manzanita |
| *Ceanothus integerrimus* H. and A. | deerbrush ceanothus |
| *C. parvifolius* Trel. | littleleaf ceanothus |
| *C. cordulatus* Kell. | mountain whitethorn ceanothus |
| *Castanopsis sempervirens* Dudley | Sierra evergreen chinkapin |
| *Chamaebatia foliolosa* Benth. | bearmat |
| *Gaultheria shallon* Pursh. | salal |

Reports that mention white fir east of the Pacific Coast region usually refer to it as a minor component of the forest cover. Its economic importance and abundance diminish greatly as its range extends eastward from the Pacific Coast region.

Throughout the interior parts of the range, white fir never forms pure stands of mature trees over large areas, but frequently forms small nearly pure stands (33). It is most commonly associated with Douglas-fir, less commonly with ponderosa pine, and infrequently with Engelmann spruce (*Picea engelmannii* Parry) and blue spruce (*Picea pungens* Engelm.). White fir penetration into the Engelmann spruce-alpine fir or blue spruce types is not nearly as prevalent at the higher elevations in the northern part of its range as it is farther south. In the Southwest it is also found associated with subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), and aspen (*Populus tremuloides* Michx.), and limber pine (*Pinus flexilis* James) and Mexican white pine (*Pinus strobiformis* Engelm.) (23).

Some of the more common herbaceous and woody plants which are represented in the ground cover of the interior Douglas-fir are:

| | |
|---|---|
| *Carex* spp. L. | sedges |
| *Pteridium aquilinum pubescens* Underw. | western bracken |
| *Vicia americana* Muhl. | American vetch |
| *Aquilegia* spp. L. | columbine |
| *Helenium Hoopesi* Gray | orange sneezewood |
| *Sambucus* spp. L. | elder |
| *Ribes* spp. L. | currant or gooseberry |

Snowberry (Symphoricarpos spp. L.) and Fendler ceanothus (*Ceanothus fenderli* Gray) occur only in small areas receiving sufficient sunlight. Underbrush and aspen are common in the areas thinned by fire. Forests of the Engelmann spruce-alpine fir and blue spruce types are often dense and shrubs and grasses are practically absent (22).

## LIFE HISTORY

### SEEDING HABITS

#### Flowering and Fruiting

White fir cones mature in a single growing season. The species generally flowers in May or June and the cones ripen in September or October (35). Seed-bearing or ovulate conelets occur as erect, individual bodies on the uppermost branches of the crown. Elongated staminate conelets bearing the pollen are suspended on the underside of the branches below the level of ovulate flowers. Both male and female conelets are found on branchlets formed in the previous year (3). Staminate conelets drop shortly aften pollen release. Seed-bearing cones grow to a length of 3 to 5 inches and mature as closely packed cylinders of cone scales. Each cone scale covers two seeds (5).

Mature seeds consist of a thin, rather soft seed coat with several resin vesicles on its surface, and an embryo with 4 to 10 cotyledons surrounded by a fleshy endosperm (35).

The overlapping cone scales fall away from the central spike-like axis during the period of seed dispersal; consequently, no cones are found on the ground under the trees except for immature or ripening cones which have been cut by squirrels.

The time of flowering and cone ripening of white fir varies somewhat, depending upon annual variations in the seasons and different climatic conditions throughout the range of the species. On the Stanislaus National Forest in the central Sierra Nevada, California, at about 6,000 feet, Fowells and Schubert (11) found that the pistillate strobili of white fir were first discernible in early May. By middle or late May the conelets were about 1 inch long. Pollen was disseminated during the last half of May. Some conelets were killed by severe frosts during May and early June. The cones were about 2 inches long by the first of July and full size was attained in early August. Seeds averaged about 185 per cone. Cones began to disintegrate and shed seeds in late September or early October.

#### Seed Production

A 28-year study of seed production, chiefly in the central Sierra Nevada, showed that individual white fir trees did not produce cones every year and relatively few had cones every other year (11). Cone crops occurred at irregular intervals, and heavy cone crops were produced at from 3 to 9 year intervals, the average being about 5 years. Relatively small proportions of white fir seeds were sound, even in good seed years; viability ranged from 4 to 57 percent.

Amount of seed production was also found to vary with dominance and tree size. In one study, 88 percent of the white fir cones occurred on dominant trees, 12 percent on codominants, and almost none on the intermediate and suppressed trees. Trees from 12 to 36 inches d.b.h. were the best cone producers. Cone production reached a peak at about 30 inches and then gradually diminished as diameter increased. Trees with a diameter range of 22 to 34 inches averaged about 65 cones annually, while those with a 10 inch diameter averaged 30 to 35 cones (11). The minimum seed-bearing age for white fir has been reported to be 40 years, and optimum cone production to be from 50 to 100 years (35).

The maximum number of cones reported on an individual tree was 987 on a 25-inch tree; this is equivalent to about 190,000 seeds weighing 12-1/2 pounds (11). The Woody-Plant Seed Manual (35) states that a bushel of cones yields from 3 to 5 pounds of cleaned seed which average 15,000 seed per pound.

In the Rocky Mountain area white fir has good seed years at irregular intervals of 2 to 4 years (33). Seed bearing continues for many years but is more abundant during the period of rapid height growth.(between ages of 50 and 100 years). Pole-size trees in dense stands usually bear seeds only when their leaders reach full sunlight.

Because cones are borne almost exclusively in the uppermost part of the crown, any tree-top damage caused by insects, diseases, and mechanical agents such as ice, snow, or wind, directly reduces cone production. Fowells and Schubert (11) found that white fir in the larger diameter classes frequently bore relatively few cones because of crown decadence caused by fir mistletoe (Phoradendron pauciflorum Torr.) and western dwarfmistletoe (Arceuthobium campylopodum forma abietum (Engelm.) Gill.). Some tops were also killed by the fir engraver beetle (Scolytus ventralis Lee.). However, trees which had lost their tops sometimes developed new terminals and resumed cone bearing.

Seed chalcids (Megastigmus spp.) often damage white fir seed, and the poor quality of much of the seed is attributed to infestations of these insects (11); no practical way of preventing damage by seed chalcids has been found (13). Fir-cone moths (Barbara spp.) often seriously injure cones (13); considerable damage to cones is also attributable to the cone maggots (Earomyia spp.) which bore through cone scales and seeds.

Rodents and birds sometimes eat white fir seed. The Douglas pine squirrel (Tamiasciurus douglasii Bachman) in California has been observed cutting white fir cones and storing them in fairly large caches. When both ponderosa pine and white fir cones were available, squirrels exhibited a greater preference for ponderosa pine (11).

### Seed Dissemination

Seeds are disseminated mostly by wind and to a very minor extent by rodents. In general, seed dissemination begins in September and continues through October, but the timing varies with elevation and climate; some cones, apparently sealed with resin, remain intact until December or later. One study (11) in California found that seeds fell irregularly during the autumn and not all seeds were shed during the autumn months; seeds were observed on the snow in midwinter, suggesting that either cones disintegrate slowly or seeds temporarily lodge in the foliage before sifting down.

White fir seed has a relatively short, broad wing for its weight and consequently falls more rapidly than seeds of pines and spruces, which have wings much longer than their width. Sound white fir seeds average about 0.070 gram in weight and, in still air, fall at a rate of 5.7 feet per second (29).

Computations based on work by Siggins (28) and assuming smooth air flow, show the following theoretical horizontal flight distances for white fir seed:

| Average wind speed, m.p.h.: | Height of seeds in tree | | |
|---|---|---|---|
| | 50 ft. | 100 ft. | 150 ft. |
| 5 | 64 | 128 | 193 |
| 10 | 128 | 256 | 385 |
| 15 | 193 | 385 | 513 |
| 20 | 257 | 513 | 770 |
| 25 | 322 | 644 | 967 |

The greatest number of seeds usually fall close to the base of the tree. Seed dissemination is influenced by many factors--weight of individual seeds, height of tree (especially important in white fir which bears cones in the upper crown), surrounding or adjacent forest canopy, terrain, updrafts, air turbulence, and direction of prevailing winds.

In one study of seed production and dissemination in a mixed-conifer stand in the central Sierra Nevada, white fir seeds fell at the rate of 223,000 per acre, including sound and unsound seed (11). This amount would be considered a very high rate of seed dissemination even if only half the seed were sound.

## VEGETATIVE REPRODUCTION

White fir shows no natural tendency to reproduce by sprouting or layering.

## SEEDLING DEVELOPMENT

### Germination and Establishment

White fir seeds germinate in the spring. Germination is epigeous (cotyledons appear above the ground). Usually not more than 50 percent germinate, owing to dormancy of the embryos, high percentage of seed injury during dewinging, insect infestation, and the transient viability of the seed (35).

The species will grow rather readily on a variety of natural seed beds. Moist humus or mineral soil under partial shade form equally good natural seed beds. Heavy litter is less of a hindrance to white fir than to ponderosa pine.

One recent study in the sugar pine-fir type in the Sierra Nevada of California revealed that, in clear-cut openings, more white fir than sugar pine seedlings died within 2 years (26). For the 2-year period the total mortality was 45 percent for sugar pine and 73 percent for white fir.

Selective cutting in mixed-conifer forests in California tends to favor regeneration of white fir, especially if advance reproduction of the species is present. Even in dense brush, white fir seedlings eventually overtop and suppress the shrubby growth. White fir seedlings are sometimes more abundant than ponderosa pine under a predominantly pine canopy whose shade and litter excludes its own seedlings (7). Generally, under the closed canopy of a predominantly pure white fir stand, seedling development is absent or sparse.

One of the requisites for white fir establishment is available surface soil moisture at germination time. Moisture and suitable temperature for germination go hand in hand. In the Southwest, the early drought period often hampers seedling development. In Colorado and northern New Mexico the summer drought is less pronounced, but winter killing becomes an important cause of mortality (23).

### Early Growth

Growth of white fir is usually exceptionally slow up to about 30 years of age; then growth accelerates markedly. The protection of advanced reproduction in the early period of growth is essential if set-backs in establishment are to be avoided.

In the Klamath basin of Oregon, white fir in about a 25 percent mixture with ponderosa pine was often found to be about 5-1/2 feet in height at 30 years of age (15).

In the Sierra Nevada, white fir seedlings in openings made slow height growth in the early years of development and ranged from 0.2 to 2.3 feet in total height for an 8-year period (26).

The average height was only 0.6 feet. Jeffrey pine averaged 4.3 feet, during this period, sugar pine 2.9 feet. The difference in height growth was not all due to inherent growth characteristics. Late spring freezes had damaged the new growth on white fir. Temperatures below 20° F. completely destroyed the new growth. The only seedlings which encountered little or no damage were those sheltered by other vegetation such as shrubs and pines. Damage to white fir seedlings by deer browsing also was fairly severe. This study suggests that white fir regeneration in clearings may be slow and uncertain.

## SEASONAL GROWTH

Seasonal growth of white fir and associated species was studied for 8 years on the Stanislaus Experimental Forest at 5,200 feet elevation, in the Sierra Nevada of California. Other species were: Jeffrey pine, lodgepole pine, ponderosa pine, sugar pine, and incense-cedar. The average starting date for seasonal height growth in white fir was June 24, a month to 6 weeks later than the average starting dates for the associated species. Height growth was completed in 46 days, on the average this period was 5 days shorter than for sugar pine, which had the next shortest height growth period among the other conifers (10).

Seasonal radial growth of white fir began before seasonal height growth. Of the six species studied, white fir had the shortest period of seasonal radial growth and was the last to start. Radial growth continued for a longer period than height growth (11).

## SAPLING STAGE TO MATURITY

### Growth and Yield

White fir reaches its best growth development in the Pacific Coast region, especially on some of the better sites in California. There good sites are found with either minor or major occurrence of white fir in mixture, as well as in the predominantly pure white fir type. Much of the remaining white fir in California is found in old-growth stands and growth information on young-growth stands is meager.

On the better sites in the Pacific Coast region, mature trees range from 140 to 180 feet in height and from 40 to 60 inches in diameter; occasional trees exceed 200 feet in height and 72 inches in diameter. Out of 951 white firs on which ages were counted on 7 study areas in California and southern Oregon, none was older than 360 years and only 3 were in the 341- to 360-year age class. 3/ In Yosemite National Park, California, a few white firs of very large diameter are older than 500 years (4). One large specimen in

3/ Information supplied by W. W. Wagener, California Forest and Range Experiment Station.

Yosemite reached a height of 189 feet and a diameter slightly larger than 8 feet (1). Trees 6 feet in diameter often contain from 13,000 to 17,000 board-feet, Scribner log rule.

Dominant white fir trees in California grow at about the same rates as ponderosa pine, sugar pine, and Douglas-fir throughout most of their life span. Dunning (8) found this from his studies that led to development of a site classification for the mixed-conifer forests of the Sierra Nevada. He concluded that growth differed so little that dominants of any of the four species could be used for applying the height-age curves. He stated: "Sugar pine is, if anything, slightly taller than the other species at comparable ages, but the differences between the four species are not large or consistent enough to be accepted as significant or important." At the chosen index age of 300 years, the average height of dominants on the best site is 200 feet and on the poorest site only 75 feet (fig. 2). The range in heights at this age is thus very great. At the age 100 years, the range is from about 140 feet down to 52 feet.

Schumacher (27) also studied the relationship between heights of dominant white firs and associated species in California. His findings indicated that ponderosa pine and red fir grow at practically the same rate as white fir on the same sites and within the age limits of the data (45 to 150 years), but sugar pine grows somewhat more slowly. Data for Douglas-fir were inadequate to give a definite conclusion, but its growth appeared to be intermediate between that of white fir and sugar pine.

In fully stocked stands, white fir attains high basal area stocking rather quickly (27):

| Age, years: | Basal area per acre where site index at 50 years is: 90 feet (sq. ft.) | 60 feet (sq. ft.) | 30 feet (sq. ft.) |
|---|---|---|---|
| 50 | 316 | 265 | 166 |
| 100 | 471 | 397 | 249 |
| 150 | 471 | 397 | 249 |

Yields from fully stocked stands in California at age 100 years have been predicted to be 147,800 board-feet per acre on the best sites and 74,000 board-feet on average sites (27). Though such idealistic conditions are unlikely to be duplicated on large areas, the figures show that white fir is capable of exceedingly high production. A mixed stand of mature (200 to 300 years) white and red fir on Swain Mountain Experimental Forest in northeastern California averaged 92,000 board-feet per acre over an area of about 120 acres, and a small part of this area averaged 147,000 board-feet per acre.

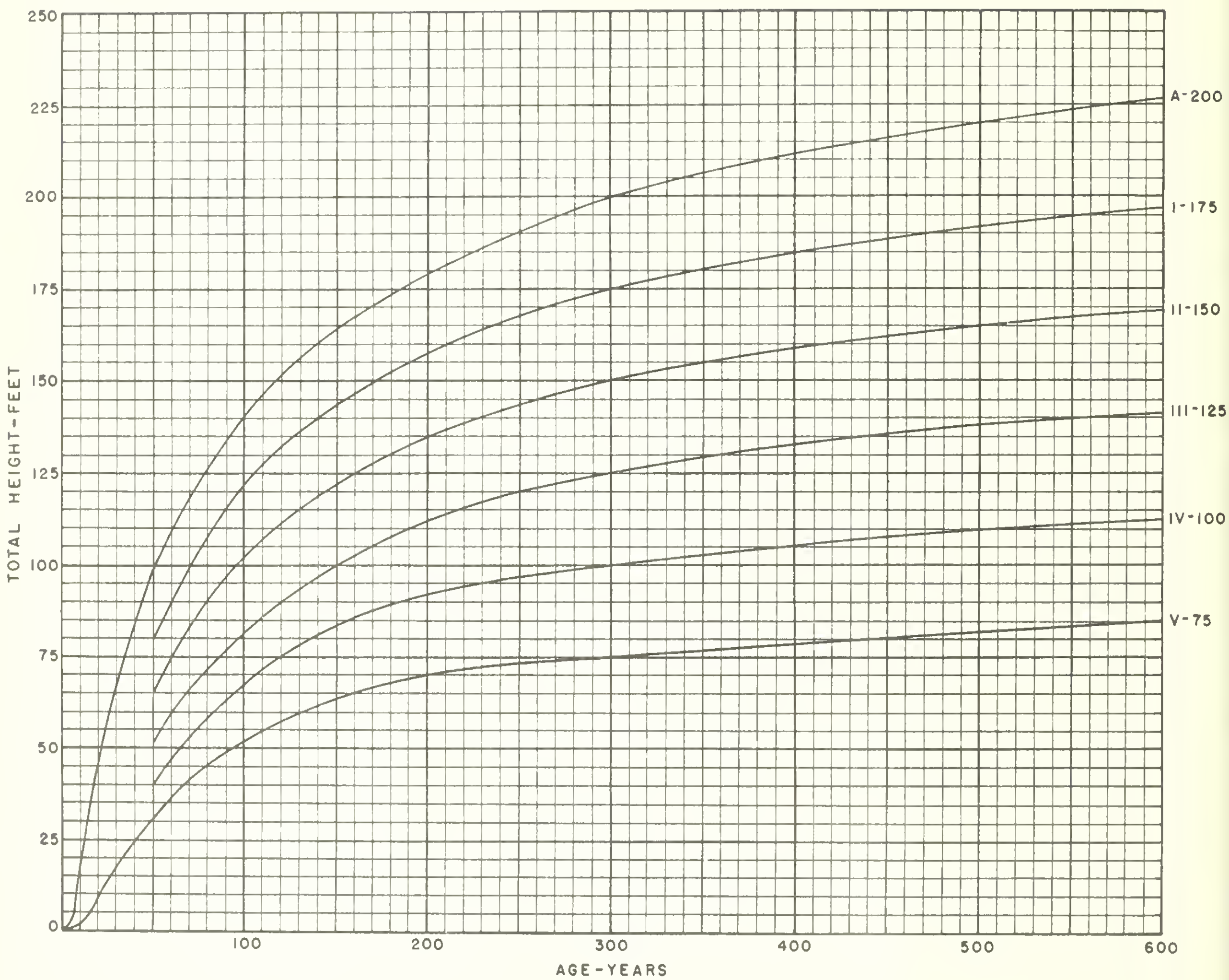


Figure 2.--Height-age site classification curve for the mixed conifer selection forests of the Sierra Nevada (8). (Site classification based on total height of dominants of one or more of the following species: Sugar pine, ponderosa pine, Douglas-fir, and white fir at age 300 years.)

From a study of even-aged white fir plots in California, Schumacher (27) prepared the following stand data:

Site Index 90 feet for White Fir 1/
(Includes trees 8 inches and over)

| Age, years: | Trees per acre (number) | Ave. height (feet) | Ave. d.b.h. (inches) |
|---|---|---|---|
| 60 | 275 | 100 | 15.6 |
| 80 | 238 | 114 | 18.6 |
| 100 | 198 | 122 | 20.8 |
| 120 | 172 | 127 | 22.3 |
| 140 | 155 | 130 | 23.5 |

1/ Based on average dominant white fir of 90 feet at 50 years of age.

Site Index 60 feet for White Fir 1/
(Includes trees 8 inches and over)

| Age, years: | Trees per acre (number) | Ave. height (feet) | Ave. d.b.h. (inches) |
|---|---|---|---|
| 60 | 351 | 70 | 11.8 |
| 80 | 331 | 80 | 14.1 |
| 100 | 287 | 86 | 15.6 |
| 120 | 259 | 89 | 16.5 |
| 140 | 240 | 91 | 17.2 |

1/ Based on average dominant white fir of 60 feet at 50 years of age.

In the Klamath Basin of Oregon, white fir dominants at age 200 average from 110 to 120 feet in height and about 24 inches in diameter (15). Kerr (15) found that white fir attained a maximum diameter growth of 0.17 inch per year at about 100 years of age. Beyond this age, diameter growth diminished to 0.11 inch per year at 250 years of age. Such growth conditions probably would be somewhat similar to white fir development on the better sites of the Rocky Mountain area.

In the interior and Rocky Mountain parts of its range, white fir is seldom more than 125 feet in height, and diameters rarely exceed 3 feet (24). The largest trees probably range from 250 to 275 years of age (33). In these interior regions, white fir does not reach the size or age of trees in the Pacific Coast region.

Ages, diameters and heights of white fir occurring in the Carson National Forest of New Mexico (22, 23) were:

| Age (years) | D.B.H. (inches) | Height (feet) |
|---|---|---|
| 40 | 1.7 | 8 |
| 60 | 4.2 | 18 |
| 80 | 6.9 | 30 |
| 100 | 9.1 | 41 |
| 120 | 10.9 | 49 |
| 140 | 12.2 | 55 |
| 160 | 13.5 | 60 |
| 180 | 14.8 | 65 |
| 200 | 16.2 | 69 |
| 250 | 19.6 | 76 |

Trees 40 to 140 years of age ranged from 7 to 22.2 inches d.b.h. on the former Crook National Forest in Arizona (22).

Natural pruning of branches is slow, especially in young trees. One study (6), found that epicormic sprouts developed 1 to 2 years after trees were artifically pruned; an average of 6 sprouts appeared per tree. Epicormic branches were also found on injured trees. Therefore white fir should not be pruned unless an effective method for control of epicormic sprouting is found.

## Reaction to Competition

On sites favoring its establishment, white fir has usually proved a formidable competitor with associated species. In the mixed-conifer stands of California, heavy cutting of fir to favor other species changes future stand composition very little. Usually enough small and otherwise unmerchantable firs remain on the cutover areas to supply abundant seed. Light cuts plus heavy litter, brush, and ground cover favor fir more than pine. If heavy cutting and fire do not occur in mixed stands, white fir maintains its position unusually well (7).

White fir is rated from tolerant to very tolerant, tolerance remaining strong from seedling stage to maturity (2). However, young growth which endures heavy shade and suppression for long periods grows very slowly. In the Rocky Mountain region the tolerance is reportedly greater on moist sites. There, it is more tolerant than any of its associates except subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) and Engelmann spruce. It is capable of enduring more shade from the seedling stage to the pole stage than during later stages of growth (33).

Since white fir is less drought resistant than ponderosa pine, it frequently relinquishes its position to pine on the lower, drier sites in the Rockies. However, throughout its range, white fir often occurs on comparatively dry habitats and is considered to be fairly drought resistant. It is about as drought-hardy as Rocky Mountain Douglas-fir (33).

White fir occurs in both even-aged and uneven-aged groups. In the Pacific Coast region, when growing in mixture with red fir, the stands are often even-aged. White fir is considered to be more shade tolerant than red fir.

## Principal Enemies

Because of the notably slow growth of white fir in early youth, protecting established reproduction from damage by logging or fire is of paramount importance if the stand is to fully utilize the growth potential of the site. In early youth the species is easily killed or injured by fire; older trees with thicker bark are more fire resistant. In the high Sierra where snow fall is exceptionally heavy, young trees are often severely damaged by heavy snow.

Old-growth stands of white fir often have a substantial incidence of disease, wind shake, and rift crack. Internal rift cracks (17) arise from internal growth stresses. In white fir these cracks usually spiral, causing cull or serious degrade in the lumber. Sour-smelling water often collects in the lower part of rift cracks and runs out through saw cuts when the trees are being felled. Where temperatures become cold enough to freeze the heartwood, imprisoned water in such cracks is apparently an additional cause of frost crack in the lower bole.

From a preliminary study, Mienecke (20), concluded that pathological defect would limit the rotation to 150 years in the area west of Klamath Lake, Oregon. However, according to Wagener 4/ both growth rate and disease incidence vary widely in the species in different subregions, and it seems doubtful whether any one particular rotation age should be suggested. He suggests that, in most of the Pacific Coast region, disease will not limit the rotation in young-growth white fir. Virgin white fir on the west slope of the Sierra Nevada is more sound than in Oregon, and the new stands coming on will be still more sound because of the increased protection from fire wounds during the last 50 years.

White fir is more subject to windthrow than is ponderosa pine. In some mixed stands which have received heavy selective cuts, severe damage to residual white fir has occurred from uprooting of trees and the breaking of stems at points 10 to 30 feet above the ground.

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4/ Personal communication from W. W. Wagener, California Forest and Range Experiment Station.

Wagener [5] states: "Windthrow in old-growth white fir left as scattered individuals in an otherwise clear-cut stand is often intensified by root rot from Fomes annosus (Fr.) Cke. that has become established through old fire wounds and has developed as a butt rot. Except in pumice soils, the danger of windthrow in second-growth stands should not be unduly high because of the reduction in numbers of fire-wounded trees brought about by fire protection."

White fir is subject to attacks by bark beetles and insect defoliators. The fir engraver beetle (Scolytus ventralis Lec.) sometimes causes severe damage as well as mortality to white fir particularly in California and Oregon (31). The grand fir bark beetle (Pseudohylesinus grandis Sw.) sometimes causes damage when it attacks the trunks or limbs of weakened or dying white fir (13).

The Douglas-fir tussock moth (Hemerocampa pseudotsugata McD.), a defoliator, often causes much damage. Epidemic numbers are sometimes reached by this insect when feeding on the true firs or Douglas-fir. The spruce budworm (Choristoneura fumiferana Clem.) is another one of the more destructive defoliators attacking the true firs and Douglas-fir and often causes great damage in pure stands of these species. The New Mexico fir looper (Galenara consimilis Hein.) has also damaged white fir in the southern Rocky Mountain region, especially in New Mexico. From 1946 to 1948 white fir in Bryce National Park, Utah was considerably damaged by the white fir needle miner (Epinotia meritana Hein.) (13).

In one study in California (9), damage to white fir seedlings from cutworms (Noctuidae) was as high as 34 percent; the damage continued 1 to 2 months after germination. Damage was often more severe in cutover stands than in virgin timber.

White fir is attacked by many other insects of lesser importance.

Heart-rot fungi cause extensive damage in white fir. The principal trunk rot on the Pacific coast is from Echinodontium tinctorium E. and E. which enters almost exclusively through branch stubs and open knots. Butt rots, which may extend up in the trunk for as much as 40 feet are chiefly from Fomes annosus (Fr.) Cke., Pholiota adiposa Fr. and Armillaria mellea (Vahl.) Quel; entrance is principally through fire scars and basal wounds. Limited amounts of decay enter through broken tops, bole wounds, and mistletoe cankers. Frost cracks, common in white fir, often serve as entrance points for damaging fungi. [5] The cull percentage in white fir in northwestern California may run as high as 30 to 50 percent (16).

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5/ Personal communication from W. W. Wagener, California Forest and Range Experiment Station.

Fir mistletoe (Phoradendron pauciflorum Torr.) commonly kills the upper portions of the crowns of white fir in Arizona and in the Sierra Nevada. This mistletoe is limited in range by temperature and does not occur north of the Mokelumne drainage in the Sierras (36). Fir dwarfmistletoe (Arceuthobium campylopodum forma abietinum (Engelm.) Gill) is often found in white fir, and results in deformed tops or crowns as well as swellings in the trunk, which often become decayed. Mistletoe damage may be severe and extensive.

Other diseases deserving of mention include canker from Cytospora abietis Sacc. which may kill branches or entire trees up to pole size east of the Sierra Nevada divide in California and probably elsewhere within the inland range of white fir (37). Damage is particularly severe after late fall drought.

Two needle diseases, from Hypoderma robustum Tub. and Hypodermella abietis-concoloris (Mayr) Dearn., are sometimes severe on young white firs. They have occasionally ruined prospective Christmas tree crops.

In the Rocky Mountains, witches brooms from the rust Melampsorella caryophyllacearum Schrvet. are sometimes prevalent and damaging on white fir.

In northeastern California, "wetwood" resulting from sap fermentation is common in the butt heartwood of white fir. Freezing of this wetwood results in multiple checking of the affected heartwood, often rendering the butt unmerchantable. 6/ Sapling and pole-size white firs are subject to sunscald when suddenly exposed by logging or other agents. Trees with sunscald do not die immediately but succumb 2 to 10 years later--usually as a result of insect infestation following the injury. Trees larger than small pole size, with bark too thick to be killed by sudden exposure, commonly put out secondary crowns after exposure. These crowns arise from epicormic buds. The same thing occurs after pruning but usually is not as extensive.

Many young trees in the 0.5 to 6.0 foot height class die after being severely bent during logging. These trees will succumb a year or two later, even though they may show only superficial injury at the time of logging. In contrast, young pines similarly bent usually recover. Such delayed mortality of young firs was noted particularly on sampling strips set out by forest disease research workers in 1927-1928, in logging slash on Logan Mountain in northeastern California. 6/

In the Klamath Basin of Oregon, the tops and upper branches of white fir are sometimes girdled by porcupines (Erethizon dorsatum Linn.) (15). Seed destroying agents are discussed in the section on Seed Production.

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6/ Personal communication from W. W. Wagener, California Forest and Range Experiment Station.

## SPECIAL FEATURES

White fir was first reported in 1847 near Santa Fe, New Mexico by a Russian plant collector, August Fendler. John Jeffrey discovered it on the Pacific slope in northern California in 1851 (33).

White fir is used as an ornamental tree in the eastern United States from Virginia north into New England and in Europe. It is particularly adapted to landscape planting because of its dense symmetrical crown and ability to stand heavy shade (5). In California and Oregon, the commercial harvesting of white fir for Christmas trees is of considerable importance. Bark of older trees contains a cork-like material.

Most of the bear dens discovered in Yosemite National Park, California are found in white fir, supposedly because they like to build their dens in the soft decayed heartwood of the older white firs (4).

## RACES AND HYBRIDS

In the Cascade mountains of southern Oregon, white fir is found associated with grand fir (*Abies grandis* Lindl.), and some intermediate hybrid forms of these two firs are known but specific identification of these intermediate forms is often difficult (12). A natural hybrid between *Abies concolor* and *A. grandis* has been reported from an arboretum in Germany (25). Nine varieties are listed in Standardized Plant Names (14).

## LITERATURE CITED


(1) American Forests
1951. Report on American Big Trees, Part II, 57 (5): 24-25.

(2) Baker, F. S.
1949. A revised tolerance table. Jour. Forestry 47: 179-181.

(3) Bowers, Nathan A.
1942. Cone-bearing trees of the Pacific coast. 169 pp., illus. New York.

(4) Cole, James
1939. Cone-bearing trees of Yosemite National Park. Yosemite Nature Notes 18 (5), 48 pp., illus.

(5) Collingwood, G. H. and Brush, Warren D.
1955. Knowing your trees. 328 pp., illus. Washington, D. C.

(6) Cosens, Richard D.
1952. Epicormic branching on pruned white fir. Jour. Forestry 50: 939-940, illus.

(7) Dunning, Duncan
1923. Some results of cutting in the Sierra Forests of California. U. S. Dept. Agr. Bul. 1176, 26 pp., illus.

(8) ______
1942. A site classification for the mixed-conifer selection forest of the Sierra Nevada. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Res. Note 28, 21 pp., illus.

(9) Fowells, H. A.
1940. Cutworm damage to seedlings in California pine stands. Jour. Forestry 38: 590-591.

(10) ______
1941. The period of seasonal growth of ponderosa pine and associated species. Jour. Forestry 39: 601-608, illus.

(11) ______ and Schubert, G. H.
1956. Seed crops of forest trees in the pine region of California. U. S. Dept. Agr. Tech. Bul. 1150, 48 pp., illus.

(12) Harlow, W. M. and Harrar, E. S.
1950. Textbook of Dendrology. Edit. 3, 555 pp., illus. New York, Toronto, London.

(13) Keen, F. P.
1952. Insect enemies of western forests. U. S. Dept. of Agr. Misc. Pub. 273, 280 pp., illus.

(14) Kelsey, Harlan P. and Dayton, William A.
1942. Standardized plant names. 675 pp., Harrisburg, Pa.

(15) Kerr, A. F.
1913. White fir in the Klamath Basin. Forestry Quarterly 11: 349-362, illus.

(16) Kimmey, James W.
1950. Cull factors for forest tree species in northwestern California. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Forest Survey Release 7, 30 pp., illus.

(17) Koehler, Arthur
1933. A new hypothesis as to the cause of shakes and rift cracks in green timber. Jour. Forestry 31: 551-556.

(18) Little, Elbert L. Jr.
1950. Southwestern trees; a guide to the native species of New Mexico and Arizona. U. S. Dept. Agr. Handb. 9, 109 pp., illus.

(19) ____________
1953. Check list of native and naturalized trees of the United States (including Alaska). U. S. Dept. Agr. Handb. 41, 472 pp.

(20) Meinecke, E. P.
1916. Forest pathology in forest regulation. U. S. Dept. Agr. Bul. 275: 1-63.

(21) Munns, E. N.
1938. The distribution of important forest trees of the United States. U. S. Dept. Agr. Misc. Pub. 287, 176 pp., illus.

(22) Pearson, G. A.
1931. Forest types in the Southwest as determined by climate and soil. U. S. Dept. Agr. Tech. Bul. 247, 143 pp., illus.

(23) Pearson, G. A.
1935. Timber growing and logging practice in the Southwest and in the Black Hills region. U. S. Dept. Agr. Tech. Bul. 480, 79 pp., illus.

(24) Sargent, Charles S.
1947. The silva of North America. Vol. 12, 139 pp., illus.

(25) Scheplitz, B.
1956. Uber einen naturlichen *Abies*--Bastard, Morphologische and holztechnologische Untersuchung an Artbastarden von Abies concolor x Abies grandis. (A natural *Abies* hybrid.) Investigation into morphology and wood technology of a species hybrid of *A. concolor* x *A. grandis*.) Z. Forstgenet. 5(3): 71-79.

(26) Schubert, G. H.
1956. Early survival and growth of sugar pine and white fir in clear-cut openings. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. Res. Note 117, 6 pp., illus.

(27) Schumacher, Francis X.
1926. Yield, stand, and volume tables for white fir in the California pine region. Calif. Agr. Expt. Sta. Bul. 407, 26 pp.

(28) Siggins, H. W.
1927. Wind carry of forest tree seeds. Timberman 28 (3): 191-192.

(29) ________
1933. Distribution and rate of fall of conifer seeds. Jour. Agr. Res. 47: 119-128, illus.

(30) Society of American Foresters, Committee on Forest Types.
1954. Forest cover types of North America (exclusive of Mexico). 67 pp., illus. Washington, D. C.

(31) Struble, G. R.
1957. The fir engraver, a serious enemy of western true firs. U. S. Dept. Agr. Prod. Res. Rpt. 11, 18 pp., illus.

(32) Sudworth, G. B.
1908. Forest trees of the Pacific slope. U. S. Dept. Agr., Forest Service, 441 pp., illus.

(33) Sudworth, G. B.
1916. The spruce and balsam fir trees of the Rocky Mountain region. U. S. Dept. Agr. Bul. 327, 43 pp., illus.

(34) U. S. Department of Agriculture
1941. Climate and man. U. S. Dept. Agr. Yearbook, 1,222 pp., illus.

(35) U. S. Forest Service
1948. Woody-plant seed manual. U. S. Dept. Agr. Misc Pub. 654, 416 pp., illus.

(36) Wagener, W. W.
1957. The limitation of two leafy mistletoes of the genus *Phoradendron* by low temperatures. *Ecology* 38: 142-145, illus.

(37) Wright, E.
1942. *Cytospora abietis*, the cause of a canker of true firs in true firs in California and Nevada. Jour. Agr. Res. 65: 143-153.