

# PACIFIC SOUTHWEST Forest and Range Experiment Station

FOREST SERVICE

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## Cutting a Young-Growth, Mixed-Conifer Stand to California Forest Practice Act Standards

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Cutting by the minimum standard of the Rules of California's North Sierra Pine Forest District was evaluated for effects on species composition, seed fall, regeneration, and residual growth at the Challenge Experimental Forest, central California. Cutting removed 74 percent of the stand basal area and 94 percent of the merchantable volume. The heavy cut changed the species composition from primarily ponderosa pine to hardwoods and tolerant conifers. Sound seed was deficient in quantity, although trees in the cut blocks produced more seed than did trees in the control. Regeneration of ponderosa pine was less than that of hardwoods and tolerant conifers. Basal area growth was greater in the cut blocks for all species and diameter classes. About half of this growth in both cut and control was lost in tree mortality. After 5 years, the cut blocks were understocked with mostly slow-growing, currently less valuable species. The minimum standard cutting did not utilize the full potential of the site.

*Oxford*: 187X426; 221.0; 228.12(794); 174.7 *Pinus ponderosa*.

*Retrieval Terms*: Pacific ponderosa pine type; cutting method; regeneration; species composition; basal area; seed production.

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I ncreasing criticism is being directed at logging operations on private land. Many people are concerned about the impact of logging on the environment, particularly on the quality of open space, watershed, streams, fisheries, and recreation. Their concern extends to public as well as private timberland.

California is one of 17 States that regulate the cutting of forests. In several States, many of the laws and regulations are sketchy, requiring only that an adequate seed source be present after logging or that some other provision be made for regeneration. Other States, including California, have stricter regulations. District forest practice rules developed under its State Forest Practice Act (California Division of Forestry

1953) are relatively exacting in regard to cutting practices, restocking standards, logging practices, and soil and hazard reduction standards.

But are the standards strict enough? Are adequate seed sources left after logging to restock the stand? What is the amount, distribution, and species composition of the regeneration? In terms of growth, release, and mortality, what happens to the remaining trees?

This study attempts to answer such questions for a given site within the North Sierra Pine Forest District in northern California. The information gained may lead to recommendations for maintaining the productivity of the State's privately owned timberlands and furthering the continuation of the forest industry.

## METHODS

### *Site and Stand Characteristics*

The setting for this study, the Challenge Experimental Forest, Yuba County, California,<sup>1</sup> lies within the area designated in the California Forest Practice Act as the North Sierra Pine Forest District. The most important attribute of the Experimental Forest is its high site quality. Growth rates are rapid, and the dominant species—ponderosa pine (*Pinus ponderosa* Laws.)—averages 140 feet in height in 100 years (Arvanitis *et al.* 1964). Deep soil, warm temperature, and adequate precipitation combine to favor nearly complete site occupancy by vegetation 5 years after clearing. Historically, this vegetation has been coniferous and hardwood timber.

High site is typical of over 1-1/2 million acres of highly productive timberland along the lower west slopes of the Sierra Nevada (*fig. 1*). Consequently, results from this study are applicable to portions of the North Sierra Pine Forest District having similar forest and stand conditions.

Timber stands at the Experimental Forest are young-growth and mixed-conifer. They are even aged, largely because of earlier harvesting. Logging first began in 1855, when in response to heavy demand by the goldmining industry, a fairly large sawmill was constructed. This mill, located within the present boundaries of the Experimental Forest, became the center of logging for the area until the early 1900's. Except for a few old firs, most of the virgin timber on the Forest was either harvested or burned by 1870. Consequently, the present conifer overstory is about 100 years old.

Wildfires continued to be frequent, and in 1910 fire killed most of the hardwoods and small conifers on the Forest. The hardwoods promptly sprouted to form the present hardwood stands, and many of the more shade tolerant conifers became established at this time.

In stand volume, ponderosa pine is the dominant species, followed by Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), sugar pine (*Pinus lambertiana* Dougl.), white fir (*Abies concolor* (Gord. & Glend.) Linda.), and incense-cedar (*Libocedrus decurrens* Torr.). Hardwoods are scattered throughout, usually as individual trees or clumps, or in small groves. The

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<sup>1</sup> U.S. Forest Service research at the Challenge Experimental Forest is conducted in cooperation with the Soper-Wheeler Company, Strawberry Valley, California.



**Figure 1**—This 90-year-old mixed-conifer stand is typical of the Challenge Experimental Forest, Yuba County, California, as it appeared in 1958.

most common hardwood is California black oak (*Quercus kelloggii* Newb.), with tanoak (*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.), and Pacific madrone (*Arbutus menziesii* Pursh) about equal in abundance.

Early research objectives at the Experimental Forest were keyed to evaluating various cutting methods in terms of species composition, regeneration, and growth of residual trees. This research also encouraged investigation of a basic concern of silviculture—vegetative succession, not just into the over-story, but into each stand strata.

### ***Logging and Layout of Blocks***

In the summer of 1958, three 6-acre rectangular compartments were cut to the minimum standard set by the North Sierra Pine Forest District. This minimum permitted the removal of all merchantable

timber at least 20 inches in diameter at breast height (d.b.h.) with no other restrictions.

Each compartment was on relatively level ground (slopes 10 percent or less), supported a stand of conifers and hardwoods which contained nearly 260 square feet of basal area per acre, and was on a generally east-facing exposure (*fig. 2*). Stand volume of trees larger than 12 inches in diameter averaged slightly over 47,000 board feet per acre (Scribner rule). The logging "chance" consisted of gentle slopes, no rock, and little down timber, but a great many stems.

Flexibility was the rule in logging, and landings were quickly and cheaply constructed on the edge of the compartments at convenient locations. Timber fallers were instructed to cut all conifers above the 20-inch limit in the fastest, most economical way. Skidding was at the discretion of the operators, who used 113-drawbar horsepower, bulldozer-equipped tractors. Loading was also done with a large tractor

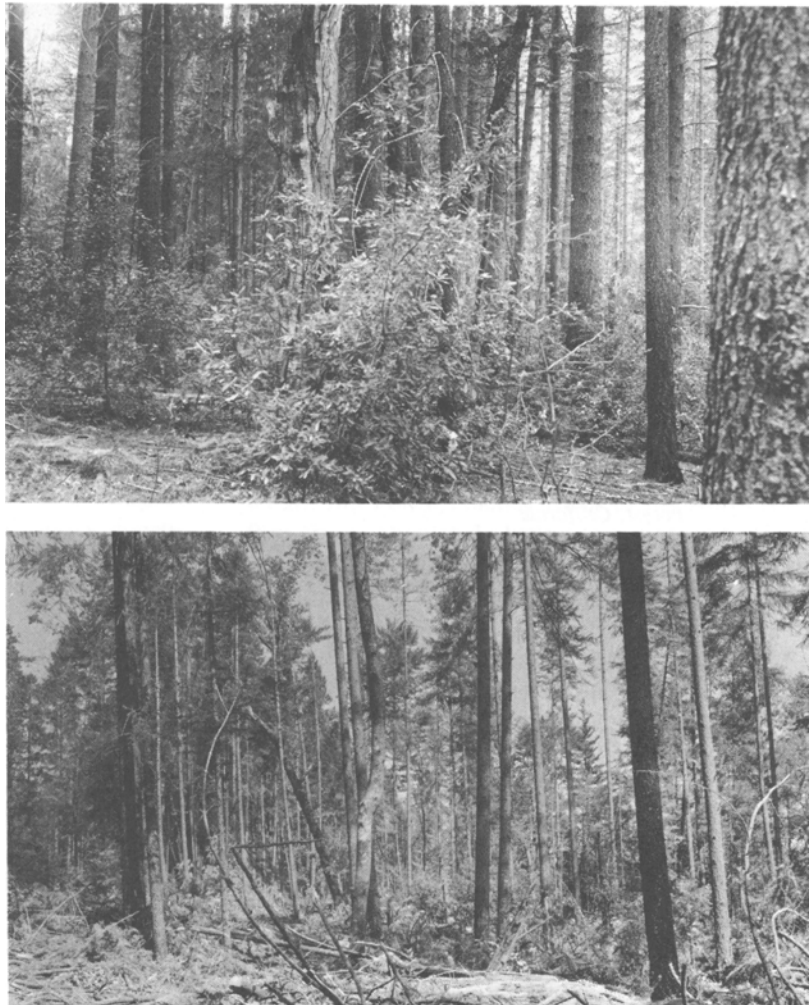
equipped with hydraulic forks. Large-sized tractors were necessary because the logger was primarily harvesting old-growth timber on land other than the Experimental Forest and had to fit his equipment to the larger trees.

Additional treatments, not specified in the District Rules, were performed to reduce the understory and enhance regeneration of conifers. Combined slash disposal and site preparation was accomplished on about 25 percent of each compartment. Here most of the slash and some of the understory was machine-piled for burning, although advance reproduction and pole-size trees were left wherever possible. Also, cull trees were removed throughout each compartment. These treatments removed many stems—mostly small ones—which represented a relatively small basal area.

Within each compartment, a 4-acre rectangular

block was defined, and within each block every tree larger than 3.5 inches d.b.h. was numbered to facilitate remeasurement. Trees were measured before logging in 1958, after logging in 1959, and after five full growing seasons (1963). Tree mortality was recorded annually.

An adjacent compartment of similar size with similar terrain and stand structure was given a light improvement cut in 1958, when about 20 percent of the volume in trees over 12 inches d.b.h. was removed. Site preparation (as described above) was accomplished on about 15 percent of the compartment. This compartment thus seemed well suited as a yardstick against which results on the test blocks could be measured. It also was subdivided into a 4-acre block where all trees larger than 3.5 inches d.b.h. were numbered and recorded.



**Figure 2**—Before logging, the test cut block contained about 30 merchantable-size trees per acre, 60 percent of which were ponderosa pine. After logging, ponderosa pine was a minor species component in the much more open stand.

## RESULTS

In the evaluation of results after 5 years, the comparison between cut and control blocks was emphasized. Changes in stand structure and species composition were evident, and the effects of the cut on productivity were indicated by seed fall estimates, the observed amount of regeneration, and the measured growth of the residual stand.

### ***Stand Structure and Species Composition***

Stand tables, by species and 4-inch diameter classes, were prepared for each block in 1958 and 1963. Statistical analyses showed no significant differences in blocks with reference to species or diameter classes for either year (5 percent probability level). This lack of difference among blocks is remarkable because the total sample was large—3,310 trees before logging and 1,235 trees 5 years later. Because differences among blocks continued to be small in 1963, mortality from logging and natural causes was similar in all blocks. Therefore, a composite stand table for both 1958 and 1963 is presented ( *table 1* ).

After the light cut and slash disposal, the control Hock contained almost the same number of trees (252 per acre) as the average test cut block before logging (276 trees per acre). A statistical comparison of the control block after the improvement cut and

the test cut blocks before logging (based on all species and the same diameter classes noted in *table 1*) showed no significant differences between cut blocks and control (5 percent probability level).

After logging, however, major differences existed between the cut blocks and the control. For example, in the 3.5- to 20-inch diameter range, the control contained twice as many ponderosa pines and incense-cedars as the average cut block, and five times as many hardwoods.

The reduction of trees in the cut blocks was accounted for as follows:

|                                                 | <i>Trees lost,<br/>per acre</i> |
|-------------------------------------------------|---------------------------------|
| Cutting                                         | 30                              |
| Site preparation-slash<br>disposal—cull removal | 134                             |
| Natural mortality (1958-<br>1963)               | <u>9</u>                        |
| Total                                           | 173                             |

The change in stand volume and basal area represented by this reduction in numbers indicates the severity of this cutting method. Stand basal area was reduced 74 percent to 67 square feet per acre. Better than half the reduction occurred in the merchantable tree category (above 20 inches d.b.h.). Volume decreased by 94 percent or 44,000 board feet per acre. All of that which remained (3,000 bd. ft. per acre)

Table 1—Stand table by test cut blocks before logging and 5 years later,<sup>1</sup> Challenge Experimental Forest, California

| Species                 | Trees per acre, by diameter classes (inches) . . . |           |            |            |        |                |
|-------------------------|----------------------------------------------------|-----------|------------|------------|--------|----------------|
|                         | 3.5 to 8                                           | 8.1 to 12 | 12.1 to 16 | 16.1 to 20 | 20.1+  | All<br>Classes |
| Conifers:               |                                                    |           |            |            |        |                |
| Ponderosa pine          | 4 (1)                                              | 5 (2)     | 6 (3)      | 6 (3)      | 18 (1) | 39 (10)        |
| Sugar pine              | 2 (1)                                              | 1 (1)     | 1 (1)      | 1 (1)      | 4 (0)  | 9 (4)          |
| Douglas-fir             | 30 (10)                                            | 14 (10)   | 9 (8)      | 4 (4)      | 5 (1)  | 62 (33)        |
| White fir               | 6 (1)                                              | 3 (1)     | 2 (1)      | 1 (1)      | 2 (0)  | 14 (4)         |
| Incense cedar           | 62 (16)                                            | 17 (7)    | 3 (2)      | 1 (1)      | 11 (0) | 84 (26)        |
| Total                   | 104 (29)                                           | 40 (21)   | 21 (15)    | 13 (10)    | 30 (2) | 208 (77)       |
| Hardwoods:              |                                                    |           |            |            |        |                |
| Tanoak                  | 7 (2)                                              | 2 (2)     | 1 (0)      | 0 (0)      | 0 (0)  | 10 (4)         |
| California<br>black oak | 20 (5)                                             | 4 (2)     | 4 (2)      | 2 (2)      | 3 (2)  | 33 (13)        |
| Pacific madrone         | 17 (4)                                             | 7 (4)     | 1 (1)      | 0 (0)      | 0 (0)  | 25 (9)         |
| Total                   | 44 (11)                                            | 13 (8)    | 6 (3)      | 2 (2)      | 3 (2)  | 68 (26)        |
| Total                   | 148 (401)                                          | 53 (29)   | 27 (18)    | 15 (12)    | 33 (4) | 276 (103)      |

<sup>1</sup>Data for 5 years later shown in parentheses. These data include ingrowth into each diameter class.

was submerchantable (12 to 20 inches d.b.h.).

Changes in the species composition of submerchantable and understory (3.5-12 inches d.b.h.) trees were minor during the 5-year period (table 2). The largest increase occurred in Douglas-fir, which gained in both these stand strata. Ponderosa pine decreased markedly in the submerchantable stratum, mostly because of windsnap and insects.

Natural mortality was evaluated by losses in the submerchantable and understory size classes. These were few in number, but had an important effect on species distribution. In the submerchantable class, three trees per acre died, two of which were ponderosa pine. The other was white fir. In the understory class, two Douglas-firs and one each of ponderosa pine, white fir, incense-cedar and hardwood perished. In both classes, windsnap was the most injurious agent. Insects, chiefly the western pine beetle (*Dendroctonus brevicomis* Lec.) in ponderosa pine, and the Douglas-fir engraver (*Scolytus unispinosus* Lec.) in Douglas-fir, ranked next, with unknown causes far behind.

Natural mortality in the control was remarkably similar to that in the test cut blocks. The same number of trees per acre were affected and the major cause of death to individual species was identical except in ponderosa pine, where insects caused greater losses than windsnap. Losses by individual species were similar except for California black oak, which incurred greater losses in the control. Suppression was the cause.

Trees smaller than 3.5 inches d.b.h. were not tallied specifically, but new trees which grew into this diameter class, or ingrowth, were recorded. Douglas-fir was the most abundant ingrowth species, constituting 32 percent of the new trees. Next were the hardwoods (29 percent), followed by incense-cedar (27 percent), white fir (9 percent), sugar pine (2 percent), and ponderosa pine (1 percent). Altogether ingrowth in the cut blocks averaged eight trees per acre over the 5-year period.

In the control block, ingrowth averaged 16 trees per acre and was of the same species as in the cut blocks. The ranking of species also was similar.

The primary effect of this cut on stand structure and species composition was to eliminate completely the ponderosa pine overstory. A secondary effect was to reduce greatly the number of smaller trees in the lower stand strata while not appreciably changing the species composition. A combined effect was release of these trees and freeing them for better growth.

In the control area, ponderosa pine remained the dominant species. Overstory and understory stood

Table 2—Species composition in lower stand strata of test cut blocks before logging and 5 years later, Challenge Experimental Forest, California

| Species                                | Percent before logging | Percent after 5 years | Percent change |
|----------------------------------------|------------------------|-----------------------|----------------|
| Understory: 3.5-12 inches d.b.h.       |                        |                       |                |
| Ponderosa pine                         | 4                      | 4                     | 0              |
| Sugar pine and white fir               | 6                      | 5                     | -1             |
| Douglas-fir                            | 22                     | 30                    | +8             |
| Incense-cedar                          | 39                     | 33                    | -6             |
| California black oak                   | 12                     | 11                    | -1             |
| Tanoak and Pacific madrone             | 17                     | 17                    | 0              |
| Submerchantable: 12.1-20 inches d.b.h. |                        |                       |                |
| Ponderosa pine                         | 29                     | 21                    | -8             |
| Sugar pine and white fir               | 12                     | 12                    | 0              |
| Douglas-fir                            | 29                     | 38                    | +9             |
| Incense-cedar                          | 12                     | 11                    | -1             |
| California black oak                   | 12                     | 10                    | -2             |
| Tanoak and Pacific madrone             | 6                      | 8                     | +2             |

essentially intact. There was little release or lessening of shade, and most trees remained cramped for growing space.

## Seed Fall

By allowing the removal of all trees over 20 inches d.b.h., the Forest Practice Rules of the North Sierra Pine Forest District do little to promote natural seed fall. Small ponderosa pines do not produce many cones (Fowells and Schubert 1956, Sundahl 1971). Undoubtedly production is related to the size of the crown, its vigor, and state of development. For example, Fowells and Schubert (1956) found that ponderosa pines and white firs in the intermediate and suppressed crown classes produced almost no cones.

If a tree is injured during logging, as many were in this test cut, its growth rate is affected adversely. Development of the crown and, ultimately, seed production are delayed. Thus, when the overstory is removed, the remaining trees are likely to be erratic seed producers. Some trees produce a surprising quantity of cones, others produce nothing. Timing of cone production is a major concern. Predicting when cones will be produced and in what quantity is nearly impossible.

**Figure 3**—Cutting in a stand may stimulate remaining trees. This 90-year-old, 18-inch diameter ponderosa pine with a deformed top (old break) had no old cones or cone remnants beneath it before logging in 1958. In 1960, it produced 43 cones and in 1962, 11 cones.

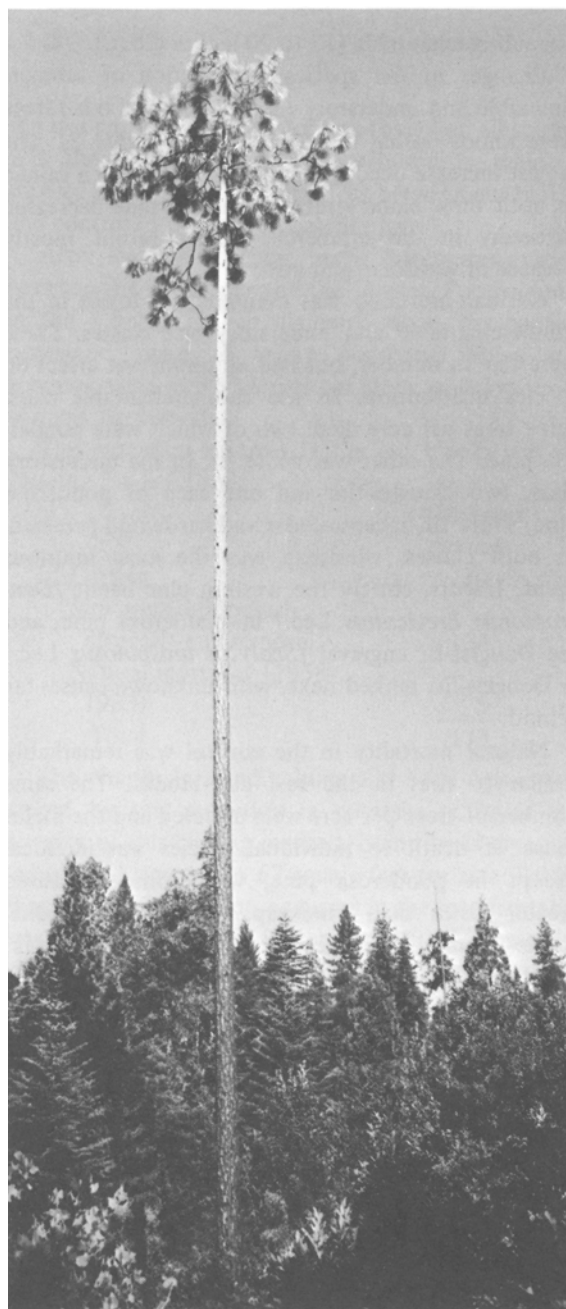
The high moisture and fertility levels of high sites should speed up the cone-producing process, however. Fowells and Schubert (1956) reported data for site indexes 72 and 130 for ponderosa pine and showed that maximum seed production was nearly 30 percent greater on the higher site. After the heavy test cut, even more moisture and nutrients, and increased light, became available to stimulate the remaining trees. Consequently, seed had a good chance of being produced quickly, given the high site and young trees, and this could be important in evaluation of the cut.

Seed fall data were gathered annually for the first 5 years after cutting (1958-1962). Both cone counts and seed traps were used to quantify seed fall. Seed production for all conifers at the Experimental Forest failed completely in 1958 and 1959. In 1960, ponderosa pine generated a bumper seed crop, its only productive year during the study period. Douglas-fir produced cones in 1960, 1961, and 1962. In 1962, white fir yielded some cones and incense-cedar bore a bumper seed crop. Sugar pine produced few cones during the study.

### Cone Counts

All cones produced in the study blocks were counted by using tripod-mounted 6 X 30 binoculars. The number of cones observed was increased by a factor of 1.5 for ponderosa pine and white fir (Fowells and Schubert 1956) and by 1.6 for Douglas-fir. Cones of Douglas-fir are difficult to count because they are small, clustered, and often blend with the surrounding foliage. Counting is easiest during the short ripening period when they are yellowish, a fact that led to use of the factor 1.6 instead of 2 as used by Garman (1951).

The 1960 seed year was one of the most productive on record for ponderosa pine throughout northern and central California. More than 100,000 sound ponderosa pine seed per acre were produced by uncut stands at the Experimental Forest that year. In the cut blocks, the ponderosa pine population in 1960 was 112 trees. Of these, 59 produced 1 to 353 cones



per tree. Of the cone-producing trees, 14 percent were less than 12 inches in diameter. These small trees produced only 2 percent of the cones.

For comparability, cones of each species in the control were counted only on trees 20 inches d.b.h. and smaller. Although the number of ponderosa pine cone-bearing trees greater than 12 inches in diameter in the control was proportional to those in the average cut block, cone production in the cut was 2-1/2 times that of similar-sized trees in the control. The number of cone-bearing trees less than 12 inches in

the control was proportionally fewer than in the cut block, although the yield per tree was about equal. For both size groups combined, the number of cones per producing tree was 39 for the cut and 11 for the control (*fig. 3*).

In the northern hemisphere, a 3-year interval is required from the time the male and female strobili are initiated until the time that seeds mature (Stanley 1957, p. 583). In this study, new strobili were formed in 1958—before logging. Cutting, then, could not have caused the large numbers of strobili, which eventually led to the bumper seed crop in 1960. The stimulation that did occur probably resulted from the enhanced development and survival of the strobili already present. The release-induced factors of additional light, soil moisture, and nutrients during the cone development period contributed to the stimulation.

No cones were found in the cut blocks in 1961 or 1962. Not only could cutting have stimulated primordial initiation in 1959 and 1960, but also the trees had had sufficient time to develop and respond to their new, more favorable environment. But since no cones developed, the effects of stimulation obviously were short lived.

Douglas-fir cone crops at the Experimental Forest seem to be characterized by frequency rather than size—trees produce light to medium crops biennially. This species also produces cones on trees younger and smaller than cone-producing trees of other species.

Table 3—Douglas-fir cone production in the test cut blocks for three successive years, Challenge Experimental Forest, California

| Diameter class (inches) | Total trees possible | Total cone-bearing trees | Total cones | Cones per tree |
|-------------------------|----------------------|--------------------------|-------------|----------------|
| <b>1960</b>             |                      |                          |             |                |
| Under 12                | 272                  | 32                       | 2,318       | 72             |
| 12 - 20                 | 122                  | 68                       | 22,896      | 337            |
| Total                   | 394                  | 100                      | 25,214      | 252            |
| <b>1961</b>             |                      |                          |             |                |
| Under 12                | 272                  | 5                        | 12          | 4              |
| 12 - 20                 | 122                  | 29                       | 470         | 26             |
| Total                   | 394                  | 34                       | 482         | 23             |
| <b>1962</b>             |                      |                          |             |                |
| Under 12                | 272                  | 34                       | 728         | 21             |
| 12 - 20                 | 1122                 | 61                       | 10,227      | 168            |
| Total                   | 394                  | 95                       | 10,955      | 115            |

<sup>1</sup> Several cone-bearing trees died from storm damage in 1962, but after the cone counts were completed.

The 1960 and 1962 Douglas-fir cone crops were similar: (a) about 25 percent of the trees produced cones (*table 3*); (b) the number of cones per tree varied widely—ranging from 1 to 1,145; (c) diameters of cone-producing trees ranged from 5 to 19 inches d.b.h., with a mean diameter of 13 inches; and (d) most of the cone-producing trees were larger than 12 inches d.b.h. and these yielded most of the cones. The two crops differed mainly in the number of cones per producing tree; the average in 1960 was over twice that of 1962. The 1961 cone crop occurred on larger trees which averaged over 14 inches in diameter at breast height.

Frequency of cone production varied considerably. Some Douglas-firs produced cones for 3 consecutive years (1960, 1961, 1962). Others produced during 2 consecutive years (1960 and 1961 or 1961 and 1962). Most trees yielded cones only once during the study, however. The number of trees bearing cones consecutively for either 2 or 3 years was similar, but four times as many trees produced cones in alternate years (in 1960 and again in 1962).

A difference in Douglas-fir cone production was evident between the average cut block and control, although the number of Douglas-fir trees and their distribution above and below 12 inches were nearly equal. While many trees less than 12 inches in diameter yielded cones in the cut blocks, not one tree in this diameter class produced a single cone in the control for any of the 5 years studied. The number of cone-producing trees 12 inches d.b.h. or greater in the average cut block increased over the control, from the same number in 1960 to three times as many in 1961, and seven times as many in 1962. Total cone production in these trees exceeded that of the control (by a 2:1 ratio) only in 1960, however. In 1961 control trees out produced trees in the cut blocks by 9:1 and in 1962 by 2:1.

The heavy cut apparently stimulated more small trees to produce cones than usual. The quantity of cones produced, however, could not be linked to any stimulation from cutting. Apparently such factors as weather conditions during flowering and the early formative period (Roeser 1942), and the number of primordia which develop (Owens 1969), quickly surmount any effect of cutting.

About 11 percent of the white fir population in the cut blocks produced cones in 1960. All producing trees were greater than 12 inches d.b.h. Cones averaged about 90 per tree and ranged from 8 to 188. No cones were produced in the control.

Dissection of Douglas-fir cones showed about 50 developed seeds in each. Ponderosa pine cones hold

about 70 developed seeds per cone and white fir about 185 (Fowells and Schubert 1956). For the principal seed crops, production was much higher in the cut blocks than in the control (table 4).

### Seed Traps

Eighteen seed traps, 1 foot square, were systematically arranged (random start) in each block. They produced a statistically reliable sample 19 times out of 20 (Freeze 1967) for the principal seed crops of the study period. The traps were emptied annually in winter and cleaned and checked in late summer. No comparison with the control was possible because of inability to differentiate between seed from the control's overstory and trees 3.5 to 20 inches d.b.h.—the size range necessary for comparison to the cut.

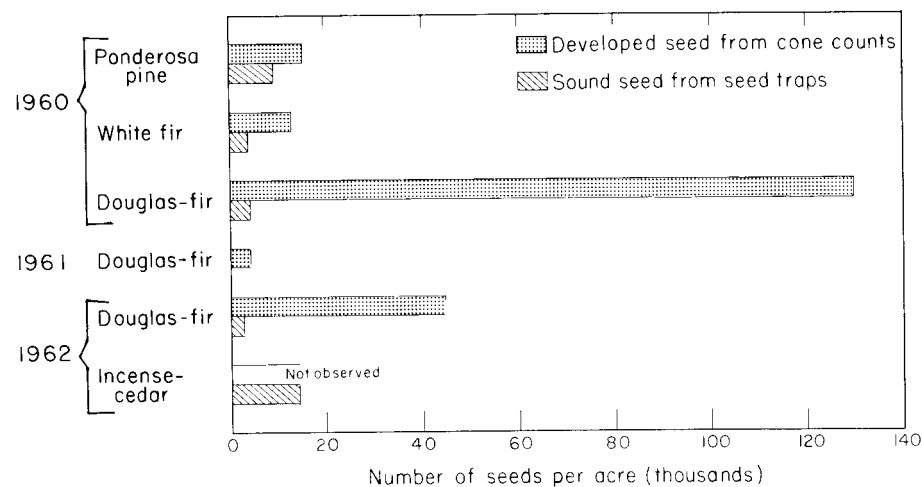
Estimates of seed production from traps were lower than those from cone counts (fig. 4). Fowells and Schubert (1956) use the term "developed" for seed from their ponderosa pine and white fir cone counts. I also used it for seed from the Douglas-fir cone count. Sound seed, as determined by cutting test, usually is the gauge of production from seed traps. Because a seed can be fully developed externally, and not filled internally, sound seed is a better measure than developed seed for estimating reproductive potential.

Table 4—Seed production estimates based on cone counts for principal seed crops in test cut blocks and control, 1958-1962, Challenge Experimental Forest, California

| Species        | Year of seed crop | Developed seed per acre . . . |         |
|----------------|-------------------|-------------------------------|---------|
|                |                   | Test                          | Control |
| Ponderosa pine | 1960              | 15,488                        | 6,720   |
| White fir      | 1960              | 12,395                        | 0       |
| Douglas-fir    | 1960              | 130,667                       | 16,650  |
| Douglas-fir    | 1961              | 3,403                         | 2,912   |
| Douglas-fir    | 1962              | 45,063                        | 4,888   |

Seed production estimates between cones and traps differed most for Douglas-fir. Lack of pollination and insect depredations were probable explanations. Allan (1942) found that Douglas-fir was capable of producing viable seed as early as 20 years. He also noted that in young trees, a high percentage of seed reached full size but was undeveloped internally due to lack of pollen. Roy (1960) found that larger trees also produce large amounts of fully developed, but empty, seed due to lack of fertilization. Insects, chiefly the cone moth larvae (*Barbara colfaxiana* (Kearf.)) and the gall midge (*Contarinia* spp.), either completely eat the developed seed or cause any remainder to adhere to the cone scales. These two influences illustrate likely sources of discrepancy between seed traps and cone counts for Douglas-fir,

Figure 4—Estimates of seed production derived from cone counts are markedly different from estimates of sound seed obtained from seed traps. These composite data are from test cut blocks.



and to a lesser extent for white fir (Keen 1958). Cone counts cannot measure the amount of "light" seed that blows out of the study area nor that destroyed by insects.

Here seed traps yield the best estimate of seed production. It totaled about 34,000 sound seed over the entire cut area during the study period. Such production is 5 to 10 times lower than seed fall for comparative time spans and areas from uncut stands nearby.

## Regeneration

Fifty years ago, Dunning (1923) noted the inadequacy of pine regeneration and the prevalence of fir and incense-cedar following heavy cutting in old-growth timber. In 1951, Fowells and Schubert studied regeneration in central California from old-growth stands from which 40 to 90 percent of the merchantable timber had been removed. Even with five sugar and ponderosa pine seed trees per acre, including one over 30 inches in diameter, seedlings became established at the rate of only 70 per acre. Incense-cedar and white fir seedlings became so dense, however, that pines comprised only 5 percent of the reproduction after 20 years.

Because of this evidence and because it was quite probable that seed fall would be poor or erratic after the cut, techniques that might enhance seedling establishment seemed worthwhile. Thus as described earlier, a site preparation and slash disposal treatment above and beyond the Forest Practice Act requirements was applied. This meant that if regeneration were successful, conclusions on the adequacy of the cutting practice used would be overly favorable. But if regeneration were inadequate or unsuccessful, on this high site, then it would probably be unsuccessful elsewhere.

For sampling, 30 circular milacre subplots per cut block were established along three transects whose points of origin were randomly located. Every subplot was visited each spring and all seedlings, coniferous and hardwood, were recorded. At the first measurement in 1959 only those plants less than 4.5 feet tall rated as "seedlings". Each hardwood clone was recorded as one plant even though the individual sprouts per clone often were numerous. All new seedlings were "tagged" to denote species and year of origin. Thus the survival of individual seedlings could be followed year by year. Mortality trends also were readily definable. New seedlings were 1 to 2 months old at the time of survey, hence most viable seeds had germinated, but seedling mortality had not yet begun.

Table 5 – *Milacre stocking and number of seedlings per acre in 1963 from principal seed crops (composite cut blocks), Challenge Experimental Forest, California*

| Species            | Age of seedlings (months) |     |       |
|--------------------|---------------------------|-----|-------|
|                    | 2                         | 14  | 26    |
| Percent stocked    |                           |     |       |
| Tolerant conifers  | 44                        | –   | 37    |
| Ponderosa pine     | –                         | –   | 42    |
| Hardwoods          | 14                        | 28  | 39    |
| Seedlings per acre |                           |     |       |
| Tolerant conifers  | 1,287                     | –   | 710   |
| Ponderosa pine     | –                         | –   | 1,022 |
| Hardwoods          | 800                       | 400 | 2,160 |

Thus seedling abundance was at or near maximum at each measurement.

Regeneration was evaluated by number of seedlings per acre and stocking percent (percentage of milacre plots having one or more seedlings). Results were evaluated for tolerant conifers (Douglas-fir, white fir, and incense-cedar), hardwoods, and ponderosa pine (*table 5*).

The seed-to-seedling 'ratio often reflects many of the agents and conditions that affect germination and early seedling survival. In this cut, the ratio for ponderosa pine was 5:1—meaning that for every five sound seed that fell in the fall of 1960, one ponderosa pine seedling was tallied in the spring of 1961. The ratio was 8:1 if based on seed estimates from the cone count. In another study at the Challenge Experimental Forest where the seedbed was mostly bare mineral soil, and rodents were not controlled, 14 sound seeds produced one ponderosa pine seedling (McDonald 1966). Fowells and Schubert (1956) rated the seed-to-seedling ratio at 40:1 for ponderosa pine on seedbeds having a medium-to-heavy cover of vegetation, litter, or logging debris, and several hundred to one with no seedbed or rodent control measures. Therefore, in this cut a remarkable number of ponderosa pine seedlings were produced from the meager seed crop.

Seed-to-seedling ratios for the other seed crops were:

|             |      |      |
|-------------|------|------|
| Douglas-fir | 1960 | 8:1  |
| Douglas-fir | 1962 | 12:1 |
| White fir   | 1960 | 6:1  |

A prime reason for the higher efficiency in 1960 was favorable weather. Precipitation during the critical months of February through May was 10.5 inches

more than Challenge's 30-year average. February, March, and May all had above-normal precipitation. Temperatures were below normal for this period. Such weather favors seedling survival. Cold, wet weather also could have cut down activity of deer mice (*Peromyscus maniculatus*) and resultant seed losses—a factor vital to regeneration at Challenge.

Deer mice levels were probably near minimum in 1960 because no conifer seed had fallen for the 3 preceding years. McKeever (1961) suggested that deer mice populations often ebb and flow with conifer seed crops. Schmidt and Shearer (1971) found that deer mice populations are affected by the previous year's ponderosa pine and Douglas-fir seed crops. In addition, drought and lack of food reduces the number of sexually active mice (Christian 1956, Louch 1956, McKeever 1959), presumably lowering population levels, and 1959 and 1960 were drought years. For these reasons, similar high seed efficiency probably will be rare in other applications of this cut.

Seedbed conditions differentially affected germination and early seedling survival of the various species. Before logging, the seedbed consisted of a 3-

to 4-inch layer of partially decomposed branches, needles, and leaves. The heavy cut disturbed this layer and created small patches of exposed mineral soil. Most of the seedbed, however, became a mixture of soil and organic material, in many cases covered with slash. Residual trees provided partial shade. Together, seedbed and shade formed a favorable regeneration medium for the tolerant conifers and hardwoods.

Tolerant conifer survival decreased sharply the first 14 months and remained constant thereafter (fig. 5). Survival of the second wave of seedlings was lower than the first because vegetative competition increased.

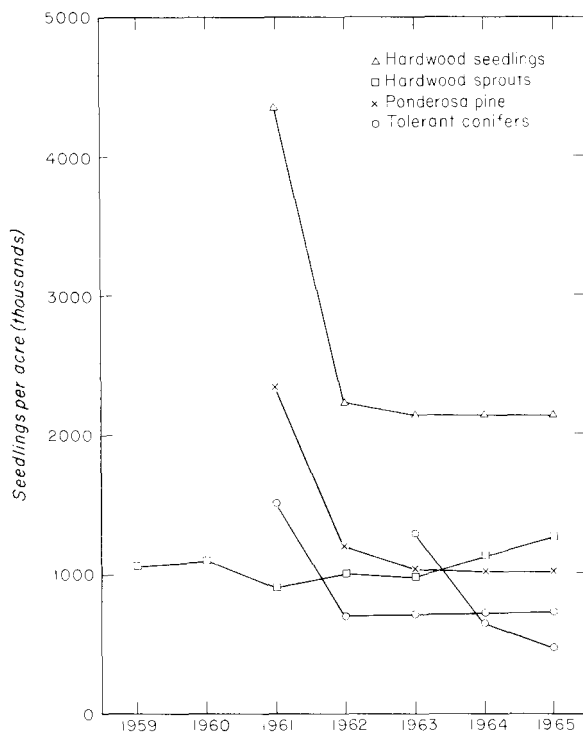
Regeneration of California black oak, tanoak, and Pacific madrone is unique because it is usually a combination of sprouts, seedling-sprouts, and seedlings. Logging and slash disposal knocked down or severely damaged many small hardwood trees, saplings, and seedlings. These promptly sprouted. Other small seedlings died back to the root crown following logging because of shock from increased sunlight. Most of these became seedling-sprouts. The sprouts and seedling-sprouts numbered about 1,000 per acre (fig. 5). Many gained vigor by sprouting which boosted height growth rates to 12 to 20 inches per year, with similar rates of crown expansion.

New waves of hardwood seedlings became established nearly every year. Tanoak and Pacific madrone are frequent and prolific seed producers.<sup>2</sup> If one species does not have a good crop, the other usually does. In addition, California black oak had a good seed crop in 1958. Thus, as for sprouts, new hardwood seedlings were consistently numerous.

The survival for new hardwoods often decreases rapidly because of poorly distributed seedlings (fig. 5). Frequently 20 to 30 seedlings per milacre plot would spring forth only to be reduced by intense competition. In plots containing from 1 to 5 seedlings, almost no mortality occurred. Altogether, hardwood reproduction was much more numerous than conifer reproduction.

The postlogging seedbed was less favorable to ponderosa pine than to other species because of insufficient mineral soil. Several investigators (Curtis and Lynch 1957, Fowells and Stark 1965) have found that survival of ponderosa pine is poorest on seedbeds lacking exposed mineral soil, other conditions being equal. The high seedling mortality for ponderosa pine

**Figure 5**—Seedling survival data (composite cut block) show a pattern of sharp decrease in the first year for the various species. Hardwood sprout survival was more consistent.



<sup>2</sup>See Roy (1957) and unpublished data on file at Pacific Southwest Forest and Range Experiment Station, U.S. Forest Service, Redding, Calif.

(fig. 5) is probably related to this lack. Seedbeds high in organic material often have high surface temperatures deleterious to tender seedling stems. In addition, the mixed-in organic material from the cut impeded the downward-thrusting roots of seedlings, causing them to fall behind the retreating soil moisture front. Consequently, numerous dead seedlings bearing the telltale evidence of drought were often observed during the annual regeneration surveys in the cut blocks. Drought could have been intensified by severe moisture depletion from the well-established hardwood clonal root systems.

Survival is only half the regeneration story; the other half is seedling height growth. On high sites, ponderosa pine can survive in dense shade for a few years (fig. 6). But since the hardwood growth rate is accelerating relative to that of the pine, many overtopped pines will soon die.

### ***Growth of Residual Stand***

Because regeneration is left to chance whenever a stand is cut to the minimum standard of the Forest Practice Rules in the North Sierra Pine District, the trees which remain often furnish the chief hope for a future crop. In dense young-growth stands, some of these trees are battered, barked, or broken. Some lack tops, others limbs. Most recover, however, and together with undamaged trees, form the new stand. Stand recovery often is enhanced by a heavy cut and the increased availability of water, nutrients, sunlight, and growing space. In turn, tree growth rates also benefit.

As previously noted, the growth sample consisted of every tree that remained after logging. This amounted to an understocked stand of 103 trees per acre. Of these, 34 per acre were larger than 12 inches d.b.h.; if they were evenly distributed, the spacing interval would be about 35 feet. The 69 smaller trees per acre remaining give a calculated spacing of about 25 by 25 feet. Tree distribution however, was somewhat clumpy—a condition typical of stands having large species diversity. Thus "growing room" was less than ideal for some trees, but on this high site should have been adequate for most. Growth then, was a function of high site and reasonably good spacing, plus the trees' ability to respond to sudden release and various degrees of logging damage (fig. 7).

Five years was selected as the interval necessary to record delayed mortality from logging and also to quantify the growth surge brought about by cutting and release. Growth increment (accretion) during the 5-year period included the basal area growth added to



**Figure 6**—This 14-inch-tall ponderosa pine seedling growing beneath a 7-foot-tall California black oak clone (August 1965) has little chance of survival.

all living trees greater than 3.5 inches d.b.h. and the growth added to trees which died during the measurement period.

Basal area growth per acre was generally proportional to the abundance of each species as shown in table 1. Douglas-fir contributed most to total accretion, showing twice the growth of ponderosa pine, the next largest contributor. Incense-cedar, which ranked second in abundance, was fourth in growth. Of the hardwoods, California black oak was only slightly more abundant than Pacific madrone but contributed twice its growth. Tanoak contributed less than any other conifer or hardwood.

Basal area growth rates per tree for each cut block were tested statistically and combined when no significant differences were found. Ranking of growth rates over all diameter classes showed sugar pine and white fir highest, followed by ponderosa pine and



**Figure 7**—After logging, patches of regeneration of shade-tolerant conifers are evident with scattered poles and some hardwoods. Some firs had broken tops.

Table 6—Comparative growth rates in cut blocks (composite data) and control, by species and diameter class, 1959-1963, <sup>1</sup> Challenge Experimental Forest, California

| Species                     | Diameter class (inches) |             |             |             |          |
|-----------------------------|-------------------------|-------------|-------------|-------------|----------|
|                             | 3.5 to 8                | 8.1 to 12   | 12.1 to 16  | 16.1 to 20  | 20.1+    |
| <i>Square feet per tree</i> |                         |             |             |             |          |
| Conifers:                   |                         |             |             |             |          |
| Ponderosa pine              | 0.03 (0.01)             | 0.08 (0.02) | 0.18 (0.07) | 0.29 (0.17) | — (0.30) |
| Sugar pine                  | .06 —                   | .11 —       | .27 —       | .32 —       | — (.92)  |
| Douglas-fir                 | .05 (.03)               | .10 (.08)   | .17 (.16)   | .25 (.26)   | — (.47)  |
| White fir                   | .07 (.03)               | .11 (.12)   | .21 —       | .33 —       | — (.42)  |
| Incense-cedar               | .02 (.01)               | .10 (.04)   | .14 (.06)   | .22 (.12)   | —        |
| Total                       | .04 (.02)               | .10 (.06)   | .18 (.11)   | .28 (.18)   | — (.32)  |
| Hardwoods:                  |                         |             |             |             |          |
| Tanoak                      | .05 (.03)               | .08 (.07)   | — (.07)     | — (.11)     | — —      |
| California black oak        | .04 (.02)               | .06 (.04)   | .17 (.09)   | .23 (.08)   | — (.10)  |
| Pacific madrone             | .05 (.02)               | .08 (.06)   | .08 (.05)   | — (.05)     | — —      |
| Total                       | .04 (.02)               | .08 (.06)   | .14 (.07)   | .23 (.08)   | — (.10)  |
| Total                       | .04 (.02)               | .09 (.06)   | .17 (.09)   | .26 (.16)   | — (.31)  |

<sup>1</sup> Data for 5 years later shown in parentheses. These data include ingrowth into each diameter class.

Douglas-fir, with the hardwoods and incense-cedar slowest. (table 6). Ranking of growth rates over all diameter classes in the control showed Douglas-fir best, followed by ponderosa pine, incense-cedar, and hardwoods, with sugar pine and white fir too few to be tested.

Differences in growth rates between cut and control blocks were highly significant, with ponderosa pine, incense-cedar, and California black oak outgrowing their counterparts in the control. It is notable that Douglas-fir grew at about the same rate in both cut and control and thus was relatively insensitive to release at least during the study period.

In the cut block, accretion amounted to 10.29 square feet of basal area per acre. In the control, it was 10.43 square feet per acre on trees 3.5 to 20 inches d.b.h. Obviously the growth rate of trees in the cut blocks was much faster than that of trees in the control since the control contained over twice as many trees (103 vs. 220 per acre). Accretion on merchantable trees in the control was an additional 7.32 square feet per acre.

Natural mortality is important in the evaluation of growth with respect to cutting practice. Trees that die after logging are seldom salvaged, and the entire basal area of each tree is thus lost. New increment accruing between the time of initial measurement and the death of the tree also is lost.

In the cut, 5.56 square feet of basal area per acre

were lost, against 5.76 square feet in the control. Accretion lost amounted to about 0.1 square foot per acre during 1958-63 period.

When a tree becomes ingrowth, its initial basal area plus any increment incurred from the time of entry to the end of the measurement period is recorded. Accretion on ingrowth was nearly twice as much in the control as in the cut blocks (1.35 sq. ft. per acre vs. 0.78 sq. ft.), which is since logical since there were twice as many ingrowth trees in the control.

Net growth for all species, consisting of ingrowth plus accretion minus mortality, is shown here in square feet per acre for the 5-year period:

|                    | <u>Cut</u> | <u>Control</u> |
|--------------------|------------|----------------|
| Net growth:        |            |                |
| Accretion          | +10.29     | +17.75         |
| Accretion on trees |            |                |
| that died          | + .10      | + .09          |
| Ingrowth           | + .78      | + 1.35         |
| Mortality          | - 5.56     | - 5.76         |
| Accretion on trees |            |                |
| that died          | - .10      | - .09          |
| Net                | 5.51       | 13.34          |

Thus, although similar basal area losses occurred in both cut and control, the loss constitutes a far larger proportion in the cut. Furthermore, the cut is less productive than the control by a factor of nearly 2.5.

## CONCLUSIONS

As a consequence of following the minimum cutting standard of the North Sierra Pine Forest District, a major change in species composition has taken place. Before logging, ponderosa pine made up 63 percent of the overstory. After logging, ponderosa pine trees exceeding 8 inches in diameter comprised only 14 percent. In contrast, Douglas-fir, increased from 1 to 37 percent of the overstory, hardwoods from 0 to 24 percent, and incense-cedar from 3 to 16 percent. The new stand is decidedly different from the old.

Trees in the 3.5- to 8-inch diameter class are in a better position for growth. Before cutting, most were badly suppressed; now many are in codominant and intermediate positions in the stand. The species composition of this diameter class is overbalanced toward the most tolerant species. Incense-cedar is most abundant, followed by hardwoods and Douglas fir, with only a trace of ponderosa pine, sugar pine,

and white fir. The preponderance of the tolerant species further emphasizes the shift away from ponderosa pine. They and the tolerant ingrowth indicate a trend in vegetative succession which, barring catastrophic events, will persevere for years.

Analysis of seed fall in the cut blocks reinforced this trend. Incense-cedar produced 43 percent of the sound seed that fell during the study period. Douglas fir yielded 21 percent and white fir 10 percent giving the tolerant species 74 percent of the total coniferous seed fall. Ponderosa pine contributed 26 percent of seed production. In general, seed fall was deficient.

Seed fall could have been stimulated on this high site by the increased availability of soil moisture nutrients, and light following the heavy cut. Indeed, compared to the control, some stimulation did take place. The general result, however, was that more small trees produced a few cones, as in Douglas-fir, or that a brief increase in cone production was followed

by lessened production, as in ponderosa pine. For all species the effect of stimulation was short lived. Its importance was further reduced when cone count results were compared to seed trap data. Large discrepancies between methods indicated major insect damage to Douglas-fir and white fir seed as well as possible lack of pollination or fertilization.

The seed that was produced came at an opportune time when the seedbed was still relatively free of compaction and competitive vegetation. Thus regeneration was better than expected from the small seed crop. Seed-to-seedling ratios for all species ranged from 5:1 for ponderosa pine to 15:1 for incense-cedar. All indicate exceptional seed efficiency—so good, in fact, as to probably be unattainable in other applications of this cutting method, under less favorable weather conditions.

Seedling survival was recorded for 50 months. At the end of this time the hardwoods numbered 3,400 per acre, tolerant conifers 1,180, and ponderosa pines about 1,000 per acre. Subsequent regeneration of ponderosa pine is unlikely because of paucity of seed and because most available mineral soil is now clothed with vegetation. Should existing ponderosa pine seedlings succumb, they have little chance of being replaced. But with time, tolerant conifer and hardwood seed crops will occur. Resultant seedlings will survive and grow because of their ability to become established on duff and litter, among other vegetation, and in shade.

The evaluation of growth and mortality, although covering only the first 5 years after cutting, pointed out the short-term effects of the cut. Except for Douglas-fir, every species in nearly every diameter class responded to the cut, and in terms of basal area growth, outgrew its counterpart in the control. White fir and sugar pine grew best. In general, in spite of some barking and other logging damage, growth rates were near maximum because of understocking and wide spacing. The hardwoods also responded to cutting. For example, California black oak was growing very slowly in the control and some trees were dying of suppression; in the cut scarcely any trees of this species died and many began growing quite well.

Natural mortality, particularly to ponderosa pine, reduced accretion by 54 percent and is considered a serious consequence of the cut. Windsnap was the major cause of mortality, followed by insects.

By 1965, revegetation of these compartments was nearly complete and the forest of the future could be predicted. Ponderosa pine regeneration will probably dominate only in openings 80 to 100 feet in diameter or larger. Elsewhere, the hardwoods and tolerant

conifers either are dominant or eventually will be. Although changes in forb and herb communities on the forest floor will constantly take place, the species composition of the stand is set. Hardwoods or tolerant conifers or both rank first in species abundance, followed by ponderosa pine. This arrangement prevails in the overstory, the submerchantable stand, the understory, the ingrowth and the regeneration.

The very species now most abundant (incense-cedar, Douglas-fir, tanoak, and Pacific madrone) are the slowest growing. There are not enough trees, even of them. The stand is understocked owing to cutting, losses from natural causes, and questionable regeneration. A loss in productivity directly attributable to the cut is indicated. This loss seems contradictory to the intent of the Forest Practice Act of "conserving and maintaining the productivity of the State's privately owned timberlands."

The change in value represented by the change in species distribution is open to question. Currently the now-dominant species are generally less valuable than ponderosa pine. In a particular situation, the shift might be desirable, but in general it would be considered to decrease the value of the stand.

A general impression of the control is that of a dense stand having too many trees and a subdued growth rate. Several facts support this conclusion. First, although trees 20 inches in diameter and below were twice as numerous in the control, accretion was about equal in both. Second, California black oak is the species most susceptible to overcrowding and suppression. Much less mortality occurred for this species in the cut than in the control. Also, insects commonly attack the least thrifty trees. Insects caused nearly all the mortality in the control, particularly to ponderosa pine; windsnap caused the damage in the cut. Finally, the basal area growth rate of Douglas-fir was consistent in cut and control. Yet this species outgrew ponderosa pine in the control but only equaled it in the cut. Obviously ponderosa pine was underproducing in the control. Thus productivity of the control, even though 2-1/2 times that of the cut, was far below its full potential.

The control is in need of cutting. But cutting by a more sophisticated method employing sound silvicultural and ecological principles is needed. The seed-tree or group selection cutting methods are both applicable, the choice between them depending on the species of regeneration desired by the landowner.

Today, the demand for housing and other wood products strongly necessitates higher productivity and better forest management practices on small private lands. A cutting method which increases productivity,

rather than decreases it, is needed in the North Sierra Pine Forest District. The small private landowners are the group most likely to apply the minimum District rules on their land—lands which are most in need of good forest management.

Dissatisfaction of the public and other organizations with existing Forest Practice Rules was reported

by Arvola (1970). Such discontent recently culminated in adoption by three California counties of their own forest practice regulations, prompting Arvola to emphasize "... the urgent necessity of developing further improvements in the basic [Forest Practice] law ...." Results of the present study support that opinion.

## SUMMARY

McDonald, Philip M.

1973. **Cutting a young-growth, mixed-conifer stand to California Forest Practice Act Standards.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif., 16 p., illus. (USDA Forest Serv. Res. Paper PSW-89)

*Oxford*: 187X426: 221.0: 228.12(794): 174.7 *Pinus ponderosa*.

*Retrieval Terms*: Pacific ponderosa pine type; cutting method; regeneration; species composition; basal area; seed production.

In 1958 a high-site mixed-conifer stand on the Challenge Experimental Forest, central California, was logged to the minimum standard of the Forest Practice Rules of the North Sierra Pine Forest District of California. Some site preparation, not called for specifically, was also done to improve chances for regeneration. The cutting was evaluated in terms of its effect on present and future stand structure. In addition each structural component was compared to that in a control block.

Cutting removed 74 percent of the stand basal area and 94 percent of the merchantable volume. The heavy cut changed the species composition from primarily ponderosa pine to hardwoods and tolerant conifers (Douglas-fir, white fir, and incense-cedar). Since the submerchantable stand, understory, and ingrowth became stocked with a higher proportion of shade-tolerant trees, this shift in species composition will be more pronounced in the future.

Natural mortality was highest for ponderosa pine in the submerchantable diameter class. Windsnap was the leading cause.

Seed fall was estimated both by cone counts and seed traps and was found deficient. The heavy cut

briefly stimulated residual trees to produce more cones than comparable species and tree sizes in the control block. Much of the seed was unsound, however.

Most seed fell after logging when the mineral soil was relatively free of competing vegetation. This factor, plus near-optimal weather and lack of rodents, resulted in an exceptional amount of ponderosa pine regeneration from little seed. Nevertheless, regeneration of ponderosa pine was less than that of hardwoods and tolerant conifers. Consequently, the proportional amount of ponderosa pine in the future stand is expected to decrease.

Basal area growth of residual trees for a 5-year period exceeded that of the control block for nearly all conifer and hardwood species and diameter classes present. About half of the growth increment was lost through natural tree mortality, however, in both cut and control blocks. Cutting to the minimum standard of the Forest Practice Rules of the North Sierra Pine Forest District produced an understocked stand of slow-growing, currently less valuable species. The study indicates that this cutting practice did not utilize the full potential of the site.

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