HISTORICAL EFFECTS OF LOGGING ON THE FORESTS OF THE CASCADE AND SIERRA NEVADA RANGES OF CALIFORNIA

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1990 TRANSACTIONS OF THE WESTERN SECTION OF THE WILDLIFE SOCIETY 26:12-23

Abstract: Ponderosa pine, Jeffrey pine, mixed conifer, and white fir forests of the Cascade and Sierra Nevada Ranges of California have been important resources and were extensively altered by timber harvest between 1850 and 1950. Many historical logging operations were small in size and of short duration. Other operations encompassed thousands of acres and existed for relatively long periods of time. Before settlement of California by Europeans, there were extensive forests in the Cascade and Sierra Nevada Ranges of California, much of it suitable for timber production. The forests were dominated by a variety of tree species depending on factors such as elevation, precipitation, aspect, and soils of the particular location. Tree species found as monocultures or in mixed assemblages include ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), sugar pine (*P. lambertiana*), lodgepole pine (*P. contorta)*, California white fir (*Abies concolor lowiana*), incense-cedar (*Calocedrus decurrens*), and California black oak (*Quercus kelloggii*). The forests, especially those dominated by ponderosa and Jeffrey pine, generally were composed of small stands of even-aged trees interspersed with other even-aged patches of different ages. Vegetation found under the forest canopy was generally composed of perennial grasses with few shrubs. The logging industry evolved from the labor-intensive and inefficient days of the 1850's to the relatively efficient railroad logging methods of the 1930's and later. Annual production of timber ranged from as little as 500,000 board feet in the early 1850's to nearly 5 billion board feet by 1950. By 1950, at least 20 percent of the forests in the Cascade and Sierra Nevada Ranges had been harvested as least once. Because of their value as lumber and the susceptibility of sugar pine to white pine blister rust (*Cronartium ribicola*), ponderosa and sugar pine declined, and incense-cedar and California white fir increased over those parts of the forest where they coexisted. At present, trees are, in general, younger and smaller in diameter and height; however, occasional larger, older trees that were left after logging can still be found. Also, grasses have declined and higher amounts of shrubs and small trees are now found under the tree canopy.

The existing landscape of California and its constituent flora and fauna are the result of the climatic regime, characteristics of the landscape before settlement by Europeans, and effects of their activities (e.g., grazing, agricultural development, timber harvest, wildfire suppression and prevention) subsequent to settlement. Timber harvest, in particular, has caused dramatic changes in vegetation composition and structure. Timber harvest, especially in the forests of the Cascade and Sierra Nevada Ranges of California, affected extensive acres of forest especially between 1860 and 1950. Many sources document the growth of and methods used by the timber industry in California; however, they generally do not characterize the composition and structure of the vegetation before and after harvest.

This paper describes the effects of timber harvesting between about 1860 and 1950 on ponderosa pine, Jeffrey pine, mixed conifer, and white fir forests in the Cascade and Sierra Nevada Ranges of California. It also describes the composition and structure of the forest before 1850 and the evolution of the lumber industry in California. To characterize typical long-standing harvest practices, it details the effects of the logging operations of the Weed/Long-Bell, Michigan-California, and Madera Sugar Pine companies.

We thank W. Baker, D. Behrens, R. L. Callas, W. D. Carrier, J. Fiske, J. G. Kie, D. S. Laudenslayer, E. R. Loft, R. Markley, R. Motroni, L. Saslaw, K. Stephens, J. Westfall, S. Young, and anonymous referees for their helpful comments on an earlier draft of this manuscript.

METHODS

The basic information source for this report was historic literature. In addition, we examined early photographs and available timber valuation reports (descriptions of the vegetation communities on lands that were transferred to the U.S.D.A. Forest Service by timber companies for cutting rights on National Forests).

STUDY AREA

Our study area is the region occupied by ponderosa pine, Jeffrey pine, mixed conifer, and white fir forests in California from the Oregon border, east and west of the Cascades and Sierra Nevada, south to the Tehachapi Mountains (Fig. 1). Our study area is also defined in time from the date of the first commercial logging operations in these forests, in the 1860's, until the demise of railroad logging in those areas, about 1950.

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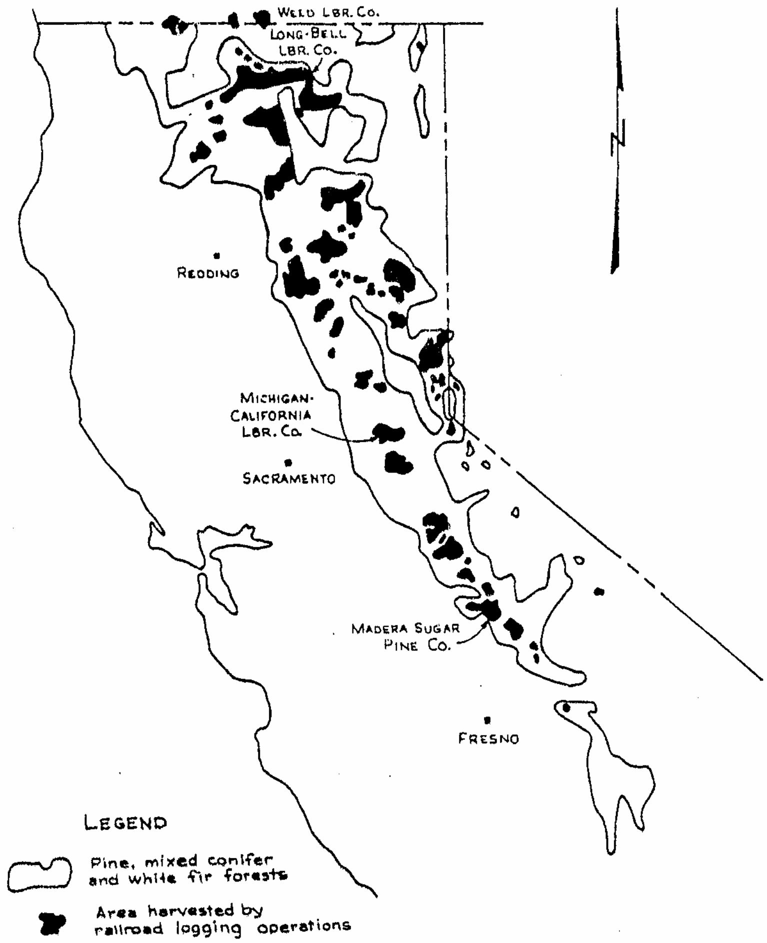

Fig. 1. Distribution of ponderosa pine, Jeffrey pine, mixed conifer, and white fir forests in the Cascade and Sierra Nevada Ranges of California, general locations where logging, principally railroad logging, took place, and locations of the Weed/ Long-Bell Lumber Co., Michigan-California Lumber Co., and Madera Sugar Pine Co.

RESULTS AND DISCUSSION

Presettlement Forest Composition and Structure

Before settlement by Europeans, the ponderosa pine, Jeffrey pine, mixed conifer, and white fir forests of California were quite variable in composition. On large expanses of land, especially east of the Sierra Nevada crest, these forests consisted of monotypic stands or mixtures of ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*P. jeffreyi*), or mixtures with Washoe pine (*P. washoensis*) (Berry 1917, Applegate 1938, Laudenslayer et al. 1989). On other sites, especially west of the Sierra Nevada crest, ponderosa and Jeffrey pines were found in association with sugar pine (*P. lambertiana*), lodgepole pine (*P. contorta*), western white pine (*P. monticola*), California white fir (*Abies concolor lowiana*), incense-cedar (*Calocedrus decurrens*), and California black oak (*Quercus kelloggii*) (Fitch 1900*a,b*; Marshall 1900, Sudworth 1900).

Forest structure was also quite variable. Younger forests (40 to 60 years old) were often dense. These dense stands were later opened by frequent fire and natural thinning (Sudworth 1900). In older forests, trees were larger, both in diameter and height, and there were fewer trees in contrast with forested stands of today. Fitch (1900*b*) reported that many standing ponderosa, sugar, and western white pines in the Yosemite region exceeded 200 feet in height and 7 feet in diameter. On a single half-acre, Fitch (1900*b*) found 19 sugar pines averaging 70 feet in height from the ground to the first limb and 50 inches in diameter. Ground cover, especially in forested areas that were relatively open, was composed largely of perennial grasses. Shrub cover was generally less than it is today.

Wildfire in the ponderosa pine, Jeffrey pine, mixed conifer, and white fir forests of California contributed substantially to the historical structure of the forest (Biswell 1989). For the 10-year period preceding 1920, forests dominated by ponderosa or Jeffrey pine, averaged 350 lightning-caused fires each year, and 415,000 acres were burned (Show and Kotok 1924). Fire frequencies, on the areas studied by Show and Kotok, ranged from three to eleven years; most of these fires were of light intensity. Biswell (1989) concluded that widespread fires in Sierra Nevada mixed-conifer forests occurred at approximately eight-year intervals; in Oregon, intervals between widespread fires were approximately eight years and in Arizona intervals were between six and seven years.

The volume of standing timber in ponderosa pine, Jeffrey pine, mixed conifer, and white fir forests, before substantial timber was harvested, also varied. Estimates of board feet may be made using several methods. The following reports did not specify the rule used to estimate volume; therefore, one must be cautious when making comparisons. Sudworth (1900) reported that standing volume of pine forests on the Stanislaus and Lake Tahoe Forest Reserves averaged about 20,000 board feet per acre but, on some sites, reached 50,000 board feet per acre. In the ponderosa and sugar pine forest northeast of Sonora, Fitch (1900*a*) reported that approximately 30,000 board feet per acre was standing. At selected sites in the Yosemite area, Fitch (1900*b*) reported from 80,000 to 140,000 board feet per acre. Marshall (1900) reported, for the forests in the vicinity of Mount Lyell, that an average stand of timber had 20,000 board feet per acre, but better sites exceeded 40,000 board feet per acre. Berry (1917) indicated that standing volume east of the Sierra Nevada crest averaged 11,000 board feet per acre, but standing volumes west of the Sierra Nevada crest, in areas where sugar pines were prevalent, averaged 50,000 board feet per acre; the maximum stand volume recorded by Berry was 200,000 board feet per acre, of which about 75 percent was sugar pine.

Evolution of Lumber Industry

Wood and wood products have long been important in the development of California. Wood was harvested for logs, timbers, boards, and shingles to construct dwellings, barns, commercial buildings, and other structures. Wood fuel was used for heating, cooking, and fueling steam-powered equipment. Other uses of wood were for timbers and planks for mines, water ditches, and railroads, and for box shook (wooden slats for fabricating fruit boxes), coffins, and sash and door stock.

Small quantities of wood products were produced in California from the time of the earliest Spanish settlements (Zivnuska et al. 1965). During the Spanish and Mexican periods (before 1848), wood was used sparingly as a building material because much of the development was in areas relatively far removed from timber growing lands (Ayres 1958). Much of the lumber that was used before about 1840 was imported from South America or the eastern United States (Supernowicz 1981). However, hardwoods used in the floors of houses owned by the wealthy Spanish and Mexican elite may have been imported from Spain or Australia (Ayres 1958).

Sawmills began to appear in California about 1818 with a mill at Fort Ross. Mills were established before 1850 near San Gabriel (1822) (Cox 1974), Sonoma, and Yerba Buena (San Francisco) (1838), at a location in Santa Cruz County (1842), near Oakland, at several locations in Marin County, and at Coloma (Ayres 1958). The demands of mines of the Gold Rush period, beginning in 1848, caused expansion of the timber industry, especially the redwood industry. By 1852 there were 70 mills along the Mendocino coast sending lumber to market (Ayres 1958).

Technology used to harvest and mill lumber also developed as the industry grew. Early procedures that were very labor intensive were quickly replaced by efficient, labor-saving machines. Initially, trees were felled, limbed, and cut into logs with axes and hand-powered saws. Logs were then taken to the mill using animal power by skidding them on the ground, along a lubricated, log-lined chute, or with high wheels, or hauling on wagons (Niles and Supernowicz 1990). If the terrain was relatively steep, logs were moved by gravity on lubricated chutes.

The earliest mills were located close to the timber to be harvested because adequate methods for transporting logs were lacking. Whipsaws were used to saw logs in these inefficient mills. Two sawyers, positioned above and beneath the log, slowly made lengthwise cuts through logs, producing boards.

Beginning in the 1870's, if adequate water supplies were available, logs or lumber could be shipped from the woods using flumes. Several of these flume systems were quite extensive, exceeding 50 miles in length (Johnston 1968). Inclines and gravity-powered rail lines were also used to move logs where terrain permitted.

The application of steam power to timber harvest, beginning in the mid-1800's, increased the efficiency of timber operations. Steam-powered donkey engines, tractors, and, especially, railroads substantially increased the amount of timber that could be moved to the mill and decreased the time in doing so. By the early 1920's, gasoline-powered (and later diesel-powered) vehicles, such as tractors and trucks, permitted exploitation of timber resources without the labor-intensive and expensive construction of railroads.

Water power, when available, was harnessed to power sawmills. By the mid-1840's, steam-powered mills were established in California (Ayres 1958). Shortly after the turn of the century, production from individual mills ranged from less than 200 thousand board feet per year for small circular saw mills to around 100 million board feet per year for a mill with two double band saws (Berry 1917). The application of electric saws to the milling process in later years resulted in even greater efficiency.

Approximately 80 railroad logging operations are known to have existed in the Cascade and Sierra Nevada Ranges of California (Fig. 1). An operation, for the purposes of this study, was a logging company and its successors that harvested a relatively contiguous piece of forest over time. Although many of these were small operations, several harvested large acreages over relatively long periods of time.

Historic Lumber Production

Ponderosa and sugar pine were, and still are, among the most valuable trees in the pine region of California (Show and Greeley 1926, Calif. Dep. For. and Fire Prot. 1988). Historically, pine lumber comprised approximately 48 percent of that produced in California (May 1953). In 1899, approximately 45 percent of the harvest in California was ponderosa and sugar pine. This proportion increased to about 49 percent by 1923 and declined to about 36 percent in 1950. Much of the remaining timber produced during this period was redwood (*Sequoia sempervirens*), about 25 percent, and Douglas-fir (*Pseudotsuga menziesii*), about 15 percent (May 1953).

Early figures for lumber production in California show that about 500,000 board feet were produced in 1849 (May 1953). Production increased through time so that by the turn of the century annual production approached 1 billion board feet (May 1953). By the 1920's, annual production approached 2 billion board feet and production exceeded 4 billion board feet by the early 1950's (May 1953). Timber production reported from California, between 1850 and 1950, exceeded 100 billion board feet; production from our study area, including ponderosa and sugar pine, California white fir, and incense-cedar, for this period, was approximately 53 billion board feet (May 1953). These figures do not include the volume of wood used for fuel or not reported by small sawmills or shake-makers and therefore underestimate the total volume of timber harvested from the Cascade and Sierra Nevada Ranges in this period.

Although we only studied timber harvest practices up until 1950, examination of the volumes of timber harvested between 1950 and 1985 will help put the historical (pre-1950) levels of harvest into perspective. Timber production continued to increase in the years immediately after 1950 and peaked in 1959 with more than 6 billion board feet produced (Zivnuska et al. 1965). Since the 1950's, production has declined, and (as of 1985) the average annual harvest level is approximately 3.9 billion board feet (Calif. Dep. For. and Fire Prot. 1988). Between 1950 and 1985, approximately 170 billion board feet of timber were taken from California forests (Calif. Dep. For. and Fire Prot. 1988), and nearly one-third of that amount, 53 billion board feet, was produced between 1950 and 1960 (Zivnuska et al. 1965).

Timber Harvest Practices

In general, early logging companies harvested all the trees that were considered to be merchantable (e.g., Shoup and Baker 1981, Polkinghorn 1984). Tree species and sizes considered merchantable varied with time and location depending on market conditions. The most merchantable trees in our study area were sugar and ponderosa pine; Jeffrey pine was considered equal to ponderosa pine (Berry 1917). At certain locations and times, incense-cedar and Douglas-fir were also considered to be marketable for certain purposes. Only trees that would produce lumber of desired dimensions were taken under most circumstances. Diameters of trees left after harvest, residual trees, varied considerably. On private timberlands, generally trees under 12 in. dbh (diameter at breast height) were left standing (Ayres 1958). However, National Forest sales, in the 1920's and '30's, generally called for leaving trees under 24 to 28 in. dbh depending on species. Trees that were defective were frequently left standing. Seed trees were left on private lands by operators concerned with sustained yields, however this was not a common practice especially in the early years of the industry (Ayres 1958). On National Forests, regeneration cutting on a large scale was not common. Rather, sanitation, salvage, and selective cutting were normal (J. Fiske, pers. comm). On sites where intensive harvests were allowed, operators were required to leave the smaller trees, that were not merchantable, and some residual overstory trees to reforest the site.

California tax policy also influenced timber harvest practices on private lands. In the 1920's, taxes assessed on the industry were based on timber inventories rather than yield. If more than 70 percent of the standing timber was harvested, the remaining timber growing on the site would be exempt from property taxes for 40 years. This practice discouraged professional selection management and commercial thinnings. This tax policy encouraged clearcutting and shelterwood harvest methods, as well as harvesting within 39 years of the last cut, before the young forests reached physical or economic maturity (J. Fiske, pers. comm.).

Historically, logging generally left large amounts of material on the ground after harvest. Only desirable logs were taken to the mill, while undesirable logs and the logging slash were usually left on the site. The shake industry was particularly known to leave large amounts of material after harvest.

Leaving residual trees did not necessarily ensure their survival after harvest. Yarding logs, especially when high-lead cable logging was used, frequently damaged residual trees. Wildfires also could reduce the residual stand of trees. The risk of fire after harvest was high because of the large amounts of logging debris left and the common use of open fires for cooking and heating. Steam-powered engines, especially those that were wood fired, also increased the risk of wildfire. Often cutover lands were severely burned, sometimes intentionally but often inadvertently.

Stump height and the number of snags remaining after harvest were also variable. In many pine stands, the tree butts were swollen or scarred as a result of the frequent, naturally occurring low-intensity fires that burned before fire prevention and suppression programs existed (Munger 1917, Show and Kotok 1924). Trees with these characteristics were cut high, up to 36 inches above the ground (Berry 1917), to avoid having to deal with these flaws at the mill. National Forests however, required much shorter stumps, usually 18 inches or less in height (Supernowicz 1981). Snags were generally removed from the forest on private and public lands because of concerns about wildfire and potential injury to forest users. Forest Service policy regarding timber sales dating from the 1920's vigorously stipulated removing snags (Ayres 1958). Snag removal was of such importance that machines were developed to more easily drop snags. Burning snags in the wet season was also an effective method of removal.

The pattern of timber harvest, regardless of operation, was generally similar. In contrast to today's practice of distributing small cut units throughout the landscape, historic logging practice was to gradually work across relatively large blocks of land. Railroads and roads were costly to construct, and revenues derived from timber harvest had to be great enough to cover construction and other costs and return a profit to the investors. Harvesting relatively large blocks of land at one time reduced the cost of railroad and road construction relative to income. The size and patterning of the blocks varied depending on costs of development of the access system and harvest, the quality of timber available, and the market conditions.

Weed/Long-Bell Lumber Company

The Weed Lumber Co. (Fig. 1) began operations in 1900 and by 1918 became part of the Long-Bell Lumber Co. Timber harvested was predominately ponderosa pine with lesser amounts of California white fir, sugar pine, Douglas-fir, incense-cedar, and California black oak. Initial timber harvests occurred near Weed in eastern Siskiyou County, and over time operations moved east to near Crank Mountain overlooking the Pit River in Modoc County (Signor 1982, Shoup and Baker 1987) (Fig. 2). The operation was based on a logging railroad that hauled raw logs to the mill at Weed for processing. The main line of the railroad extended 80 (Signor 1982) to 100 miles (Shoup and Baker 1987) into the forest. In addition to the main

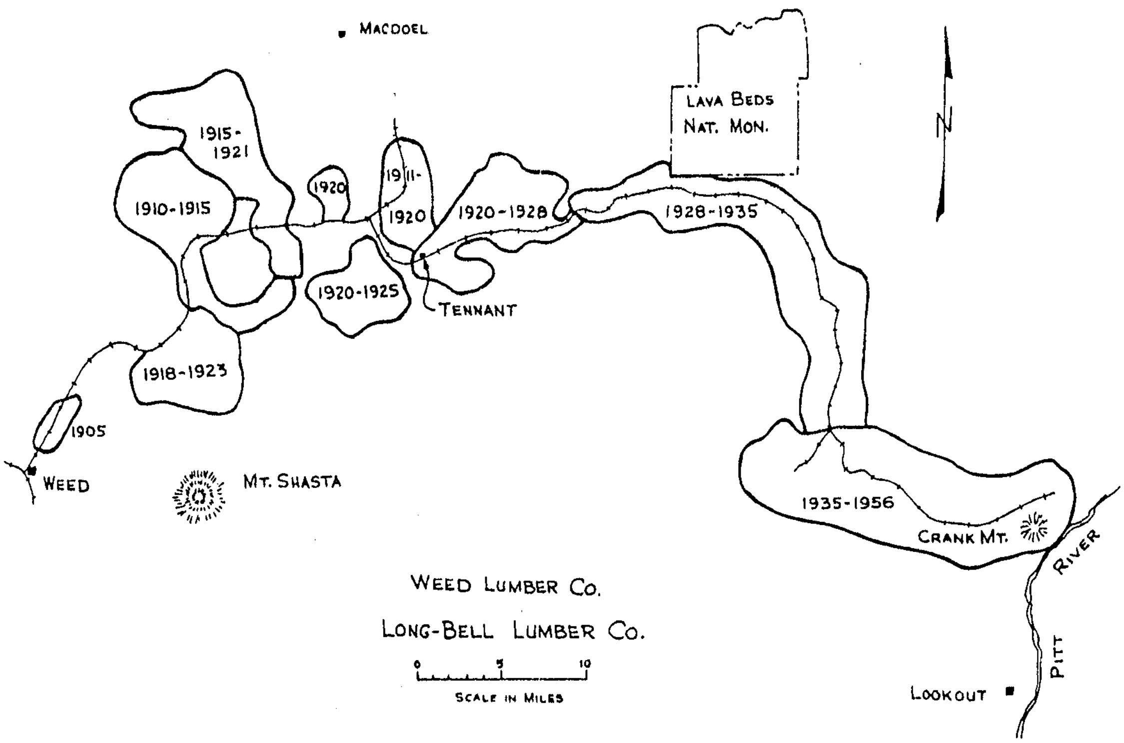

Fig. 2. The Weed/Long-Bell Lumber Co. operations (1900 to 1955) showing the general location of the main logging railroad line and the general locations of harvest units through time.

line, approximately 500 miles of logging spurs were constructed. Log trucks gradually increased in importance so that by 1956 the railroad was scrapped (Shoup and Baker 1987).

The practice of the Weed/Long-Bell operation was to take all merchantable trees, leaving only those too small, defective, or not marketable. The company generally left few seed trees for reproduction of the stand and dense shrub vegetation quickly occupied the areas after harvest (Shoup and Baker 1987). Records indicate that the Weed/Long-Bell operations often left California white fir, incense-cedar and in some locations a residual understory of pine (B.C. Goldsmith 1933, unpubl. land valuation reports on file at the Klamath National Forest Supervisor's Office, Yreka, Calif.).

Timber production increased during the early years of the Weed/Long-Bell operation and then held relatively stable. In 1901, approximately 10.5 million board feet, primarily sugar pine, was produced (Shoup and Baker 1987). Land holdings of the company exceeded 70,000 acres by 1905 and contained over 1.2 billion board feet of ponderosa pine and other conifers. By 1908, approximately 12,000 acres of nearly pure ponderosa pine stands had been harvested (Shoup and Baker 1981). Production in 1905 reached 25 million board feet and by 1915 reached 75 million board feet. From 1921 through 1955 approximately 3.5 billion board feet were produced, an average of 100 million board feet per year (Shoup and Baker 1987). The total production of the Weed/Long-Bell operation, from inception to scrapping of its railroad logging operation, approached 4.3 billion board feet (Shoup and Baker 1981).

Michigan-California Lumber Company

The Michigan-California Lumber Company (Fig. 1) and its predecessors, American River Land and Lumber Co. (1891-1900), El Dorado Lumber Co. (1900-1911), and C.D. Danaher Pine Co. (1911-1918), operated on the Georgetown Divide, El Dorado County (Fig. 3). Ponderosa and sugar pine were the principal tree species harvested, however a large volume of fir was said to have been cut during the Danaher period. In the early years of operation, logs were shipped by a 2900-foot log chute into the South Fork of the American River and then floated to the mill at Folsom. This system was effective only during years with substantial water flows.

By 1901, an alternative transport system was in place. Initial milling was done at a mill near Pino Grande. Rough-cut lumber was shipped over 20

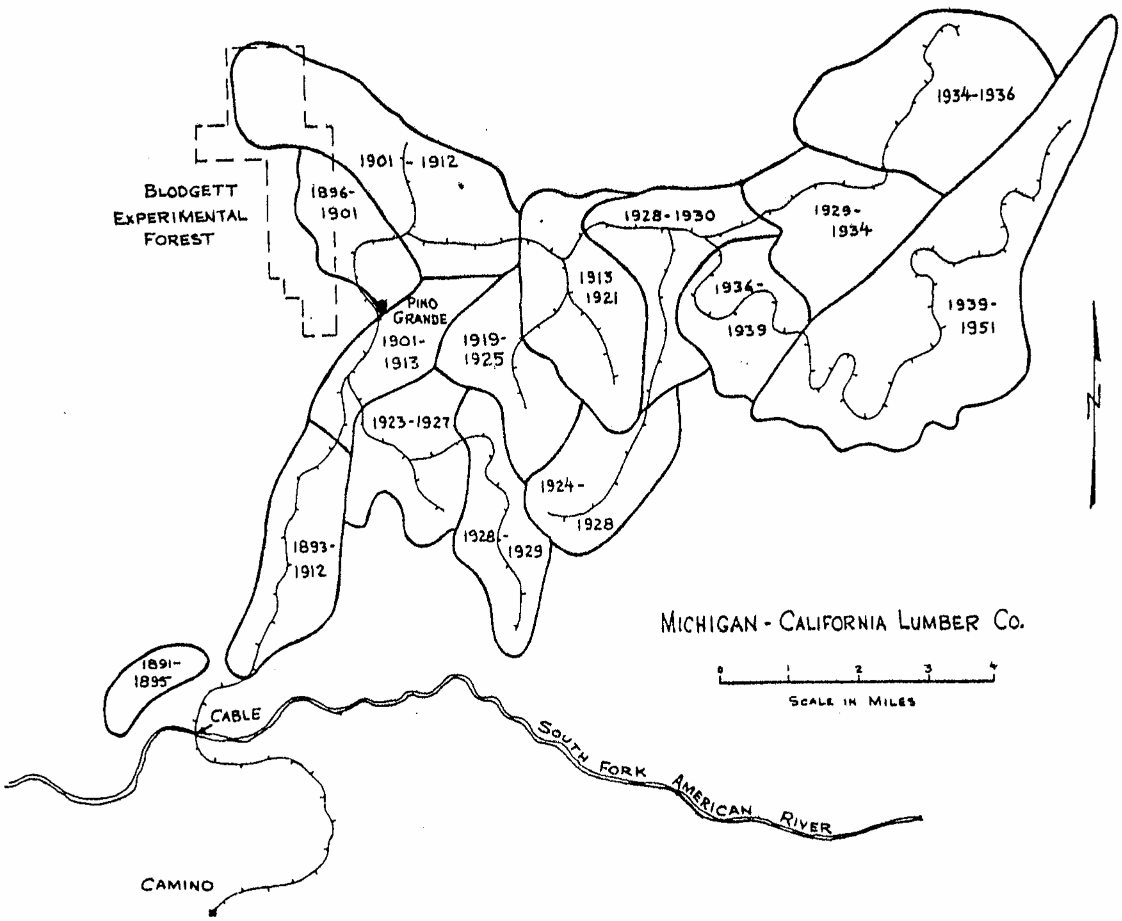

Fig. 3. The Michigan-California Lumber Co. and predecessor company operations (1891 to 1951) showing the general location of the main logging railroad line and the general locations of harvest units through time.

miles of logging railroad to the American River. Loaded lumber cars were transported across a 2600-foot long cableway hung 1200 ft above the South Fork of the American River and then placed back on rails and taken to the mill at Camino. This basic system was used, with increasing reliance on trucks, until 1951 when the cable system and logging railroad were scrapped and the company converted to trucks for hauling logs to the mill at Camino (Polkinghorn 1984).

The general practice of Michigan-California was to harvest all trees containing merchantable logs. Generally, small trees, defective trees, and undesirable species were not harvested. Before 1920, seed trees were not left to reforest the cut-over lands and those trees that were left were often damaged (Polkinghorn 1984). Before 1950, firs and cedars were generally left standing because there was not a market for these species.

Timber production increased through the early years of the Michigan-California logging operation and then stabilized. In 1891, 2.7 million board feet were harvested of which only 700,000 were floated to the mill at Folsom. The remainder grounded in the American River. In 1893-1894, 3 million board feet were put into the river, but very few logs reached Folsom. The log drive in 1894-1895 was nearly successful. The 3 million board feet stranded in the river from the 1893-1894 season, plus the current harvest of 4 million board feet arrived at the mill. Production on the approximately 16,000 acres of company land increased rapidly after 1901 when the new mill at Pino Grande, the cableway across the American River, and the logging railroad connecting the facilities were all completed. By 1903, 16 million board feet were harvested and production in 1905 reached 35 million board feet. In 1917, an additional 60,000 acres of forest land were added to the company's land base and the company continued to harvest approximately 35 million board feet annually. Some of this later harvest was taken from National Forests (Polkinghorn 1984). The total amount of timber harvested from 1891 to 1950 by Michigan-California approached 1.4 billion board feet.

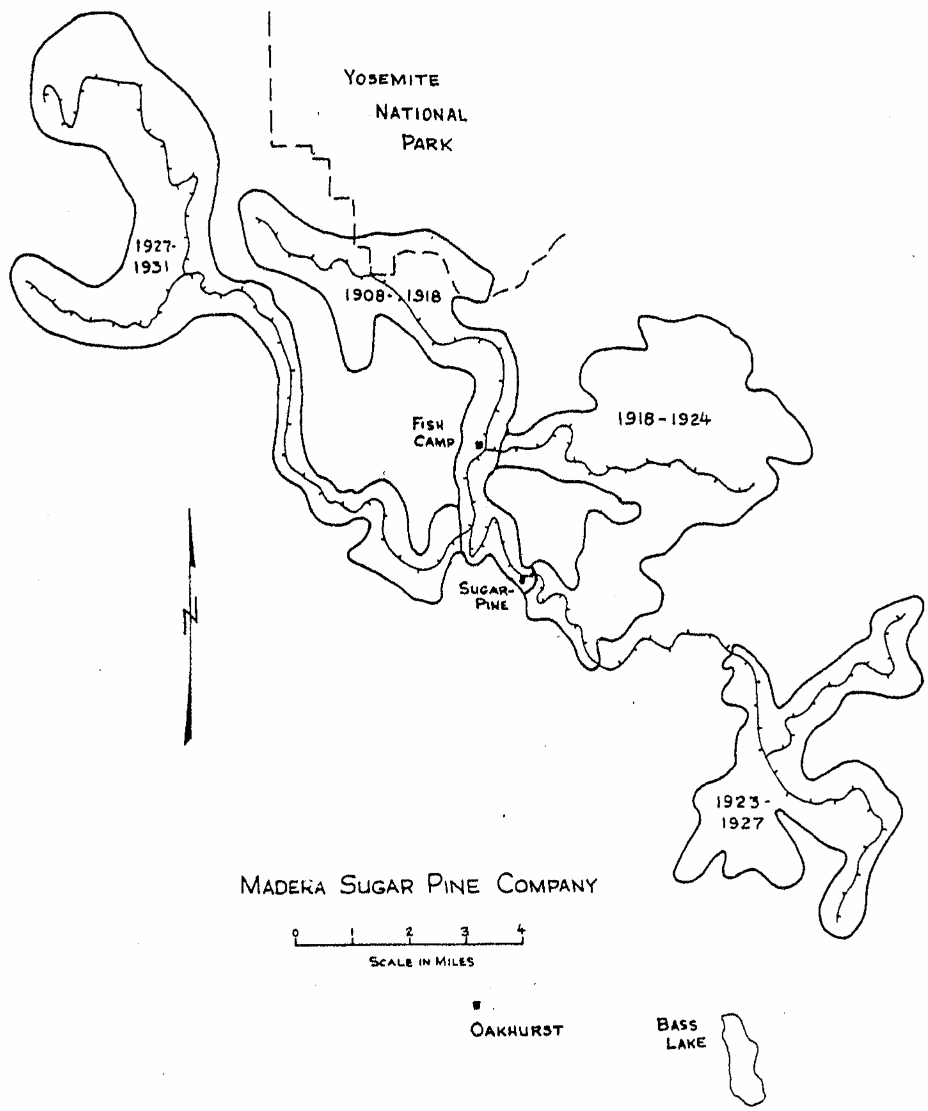

Fig. 4. The Madera Sugar Pine Co. and predecessor company operations (1908 to 1931) showing the general location of the main logging railroad line and the general locations of harvest units through time.

Madera Sugar Pine Company

The Madera Sugar Pine Company (Fig. 1) and its predecessors, California Lumber Co. (1874-1878) and Madera Flume and Trading Co. (1878-1899), operated from 1874 to 1933 near Oakhurst, Madera County, California (Fig. 4). Ponderosa and sugar pine were the principal trees taken. The company milled the harvested logs in the woods and then shipped boards to the finishing mill in Madera using a 54-mile long flume constructed of approximately 7 million board feet of lumber. The logging railroad extended about 140 miles over 30 years of operation (Johnston 1968).

Madera Sugar Pine harvested any tree that contained at least one merchantable log. Trees that were not merchantable, because of size or value, were left standing and were often damaged during logging activities.

Timber production increased from the 1880's into the 1920's and declined thereafter. Madera Sugar Pine produced 11 million board feet in 1883 and by the mid-1880's was producing 15 million board feet each year. In 1903, the company anticipated producing about 35 million board feet by cutting 1,000 acres each year of their 22,000 acres of timberland. By about 1925, the firm's timber supply was exhausted and for the last six years of operation, timber was cut from National Forest inventories. Production over the last 33 years of operation exceeded 1 billion board feet (Johnston 1968), and total production over the life of the company approached 1.5 billion board feet.

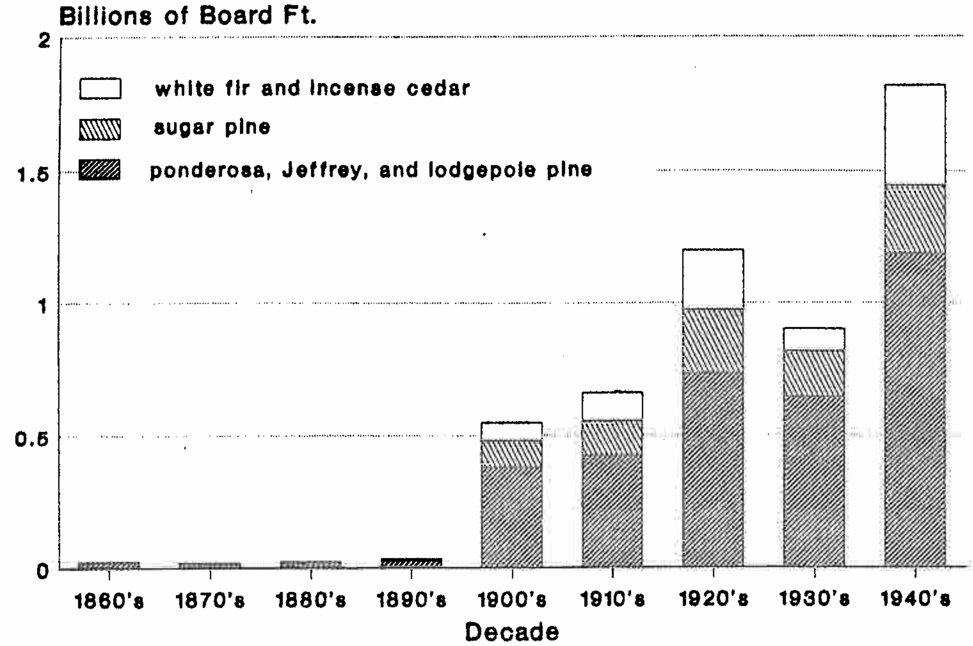

Fig. 5. Mean annual timber production by decade for ponderosa pine, mixed conifer, and white fir forests of the Cascade and Sierra Nevada ranges of California (1861-1950).

Effects of Historical Logging Operations

Historic Volumes of Timber Standing and Harvested

California currently has approximately 2.6 million acres of ponderosa pine, 9.3 million acres of mixed conifer, 0.7 million acres of Jeffrey pine, and 0.7 million acres of lodgepole pine or a total of 13.3 million acres of these forests (Calif. Dep. For. and Fire Prot. 1988). Information on historical timber volumes is generally lacking. However, Berry (1917) reported standing volumes for the sugar and yellow pine region (the area generally described by the distributions of sugar, ponderosa, and Jeffrey pine) in California for about 1915 but unfortunately, did not indicate the methods used for the calculations. Approximately 100 billion board feet of ponderosa and Jeffrey pine, 40 billion board feet of sugar pine, and 50 billion board feet of white and red fir were present in the pine region at about 1915 (Berry 1917). By 1953, there were approximately 70 billion board feet of ponderosa and Jeffrey pine, 30 billion board feet of sugar pine, and 60 billion board feet of white and red fir sawtimber present in California (Calif. Forest and Range Exp. Stn. 1954). The values are not directly comparable because it is probable that different inventory methods were used and the land bases on which the volumes were estimated, may not be equal. These data however suggest that ponderosa pine, Jeffrey pine, and sugar pine have declined relative to white and red fir and the total volume of sawtimber of these species has also declined. Between 1915 and 1950, white and red fir probably increased relative to the pines because of changes in the fire regime and timber harvest, and the total amount of sawtimber has declined because more acres were in young stands after a century of timber harvest.

May (1953) indicated that the total reported production of timber in California from about 1850 to 1950, exceeded 100 billion board feet composed of about 34.6 billion board feet of ponderosa pine, 9.2 billion board feet of sugar pine, 7.6 billion board feet of California white fir, and 1.5 billion board feet of incense-cedar; the remaining production was primarily redwood and Douglas-fir. Timber harvest increased greatly after 1900 until the Depression years of the 1930's and then increased greatly during and after World War II (Fig. 5).

Geographic Extent. Show and Greeley (1926) noted that approximately 51,000 acres per year were being harvested in the 1920's, however, they did not attempt to estimate the total number of acres harvested up to that date nor did they indicate

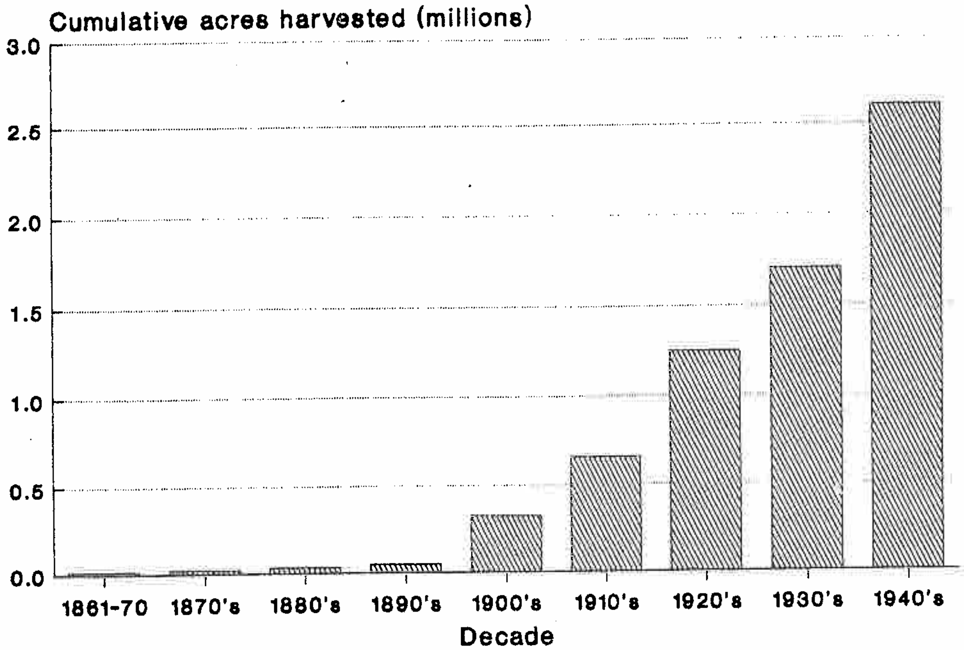

Fig. 6 Estimated cumulative acres harvested by decade for ponderosa pine, Jeffrey pine, and white fir forests of the Cascade and Sierra Nevada ranges of California (1861-1950).

the total production from the 51,000 acres. An estimate of the number of acres of forest may be calculated by dividing the total harvest (number of board feet) by the average production of an acre of forest (production is defined as the commercial output of finished lumber from the mill measured in board feet). Assuming an average production of 20,000 board feet per acre for all of these forest types, insignificant harvest of "young-growth" forest, and that historical acreages of these vegetation types did not differ much from current values, approximately 2.7 million acres were harvested before 1950 or about 20 percent of the current total (Fig. 6). Harvested areas were scattered throughout the pine region (Fig. 1). These figures did not necessarily take into account large amounts of wood used for ties and timbers by logging railroads nor did they necessarily account for pulpwood for paper or the take of fuelwood. The use of fuelwood for heating and cooking, and especially as fuel for all of the steam-powered equipment, must have been extensive.

Stand-Level Species Composition and Structure. The composition of the ponderosa pine, Jeffrey pine, mixed conifer, and California white fir forests has changed as a result of historic harvest practices combined with the change in fire regime and livestock grazing. Both ponderosa pine and sugar pine have declined at many locations relative to incense-cedar and especially, white fir. In some localities, sugar pine has almost disappeared. However, the decline of sugar pine cannot be ascribed entirely to the historic logging period. Almost all sugar pines are susceptible to white pine blister rust (*Cronartium ribicola*) considered to be the most destructive disease of trees of all ages (Fowells 1965). White pine blister rust was introduced from Europe and is most damaging to smaller-sized five-needle pines on moist sites especially in northern California (Arvola 1978).

The change in the fire regime also has permitted encroachment of California white fir and incense-cedar into the forest. In the understory, the dominant perennial grasses have declined in contrast to woody shrubs. Opening the stands by logging permitted the establishment of many species of shrubs. The reduction in fire frequency reduced shrub mortality and unmanaged livestock grazing, early in the century, depleted many grasses.

The structure of harvested areas has also been altered. In areas that were harvested during our period of study, the resulting forest is now generally composed of younger and smaller trees with a few older, larger trees that were left at the time of harvest. Natural pine stands generally had relatively open canopies and were composed of small groups of even-aged trees associated with other even-aged groups of varying ages. This natural pattern was apparently the result of frequent, low-intensity fires and unpredictable and rare periods of successful seedling establishment. Harvested areas often have the appearance of having only a few age classes, the result of the widespread opening of the stand by logging, and the canopies are more closed. Dense stands of young growth pines are widespread in the forest.

Landscape-Level Structure. Historic logging operations generally harvested relatively large blocks of land in a rather sequential manner (Figs. 2, 3, and 4). This procedure initially resulted in large blocks of forest that had varying numbers of large trees depending on whether stands had been partially cut, to permit a second harvest in the not-to-distant future, or had been cut to maximize economic return. However, through time the forest has matured and now some of these lands support relatively large blocks of maturing forest with remnants of the virgin forest that were not harvested.

CONCLUSIONS

Historic logging has substantially altered the forests of the Cascade and Sierra Nevada Ranges. Large expanses of the forest, at least 20 percent of the pine and mixed conifer forest in California was harvested by 1950, have been subjected to this treatment. Shifts in species composition have occurred and the structure of the forest has changed. However, harvest did not usually result in a patchwork of small openings. Rather, historical logging operations gradually altered relatively large blocks of land in a consecutive manner. It is difficult to quantify the direct effects that logging had on the forest because fire prevention and suppression and intensive livestock grazing also affected the composition and structure of the forest. These actions compounded the changes caused by logging.

LITERATURE CITED

APPLEGATE, E. I. 1938. Plants of the Lava Beds National Monument, California. American Naturalist 19:334-368.

ARVOLA, T. F. 1978. California forestry handbook. California Department of Forestry, Sacramento, CA. 233 pp.

AYRES, R. W. 1958. History of timber management in the California National Forests 1850-1937. U.S. Department of Agriculture, Forest Service, San Francisco, CA. 86 pp.

BERRY, S. 1917. Lumbering in the sugar and yellow pine region of California. U.S. Department of Agriculture, Washington, DC, Department Bulletin No. 440. 99 pp.

BISWELL, H. H. 1989. Prescribed burning in California wildlands vegetation management. University of California Press, Berkeley. 255 pp.

CALIFORNIA DEPARTMENT OF FORESTRY AND FIRE PROTECTION. 1988. California's forests and rangelands: growing conflict over changing uses. California Department of Forestry and Fire Protection, Forest and Rangeland Resources Assessment Program, Sacramento. 348 pp + appendices.

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION. 1954. Forest statistics for California. U.S. Department of Agriculture, California Forest and Range Experiment Station, Berkeley, CA. Forest Survey Release 25. 66 pp.

COX, T. R. 1974. Mills and markets: a history of the Pacific Coast lumber industry to 1900. University of Washington Press, Seattle. 364 pp.

FITCH, C. H. 1900*a*. Classification of Lands--Sonora quadrangle, California. Pages 569-571 in Twenty-first annual report, Part V. U.S. Geological Survey, Washington DC.

FITCH, C. H. 1900*b*. Classification of Lands--Yosemite quadrangle, California. Pages 571-574 *in* Twenty-first annual report, Part V. U.S. Geological Survey, Washington DC.

FOWELLS, H. A. 1965. Silvics of forest trees of the United States. U.S. Department of Agriculture, Forest Service, Agricultural Handbook No. 271. Washington, DC. 762 pp.

JOHNSTON, H. 1968. Thunder in the mountains. Trans-Anglo Books, Corona del Mar, CA. 128 pp.

LAUDENSLAYER, W. F., H. H. DARR, and S. SMITH. 1989. Historical effects of forest management practices on eastside pine communities in northeastern California. Pages 26-34 *in* A. Tecle, W. W. Covington, and R. H. Hamre, tech. coords. Multiresource management of ponderosa pine forests. U.S. For. Serv. Gen. Tech. Rep. RM-185.

MARSHALL, R.B. 1900. Classification of Lands--Sonora quadrangle, California. Pages 574-575 in Twenty-first annual report, Part V. U.S. Geological Survey, Washington DC.

MAY, R. H. 1953. A century of lumber production in California and Nevada. U.S. Department of Agriculture, California For. and Range Exp. Stn., Berkeley, Forest Survey Release No. 20. 33 pp.

MUNGER, T.T. 1917. Western yellow pine in Oregon. U.S. Department of Agriculture, Washington, DC, Department Bulletin No. 418. 48 pp.

NILES, R., and D.E. SUPERNOWICZ. 1990. History of the California Door Co. and the Diamond-Caldor Railway. U.S. Department of Agriculture Forest Service, Eldorado National Forest, Placerville, CA. 21 pp.

POLKINGHORN, R. S. 1984. Pino Grande--logging railroads of the Michigan-California Lumber Co. Trans-Anglo Books, Glendale, CA. 176 pp.

SHOUP, L. H., and S. BAKER. 1981. Speed power, production, and profit: railroad logging in the Goosenest District, Klamath National Forest, 1900-1956. U.S. Department of Agriculture Forest Service, Klamath National Forest, Yreka, CA. 202 pp.

SHOUP, L. H., and S. BAKER. 1987. Speed power, production, and profit: railroad logging in northeastern Siskiyou County, 1900-1956. Siskiyou County Historical Society, Yreka, CA. The Siskiyou Pioneer 5:1-107.

SHOW, S. B., and W. B. GREELEY. 1926. Timber growing and logging practice in the California pine region. U.S. Department of Agriculture, Washington, DC, Department Bulletin No. 1402. 75 pp.

SHOW, S. B., and E. I. KOTOK. 1924. The role of fire in the California pine forests. U.S. Department of Agriculture, Washington, DC, Department Bulletin No. 1294. 80 pp.

SIGNOR, J. R. 1982. Rails in the shadow of Mt. Shasta. Howell-North Books, Burbank, CA. 262 pp.

SUDWORTH, G. B. 1900. Stanislaus and Lake Tahoe Forest Reserves, California, and adjacent territory. Pages 505-561 in Twenty-first annual report, Part V. U.S. Geological Survey, Washington DC.

SUPERNOWICZ, D. 1981. The lumber industry of El Dorado, Amador, and southern Placer Counties 1848-1950. U.S. Department of Agriculture Forest Service, Eldorado National Forest, Placerville, CA. 75 pp.

ZIVNUSKA, J. A., P. COX, A. POLI, and D. PESONEN. 1965. The commercial forest resources and forest products industries of California. California Agricultural Experiment Station Extension Service Publ., University of California, Berkeley. 122 pp.