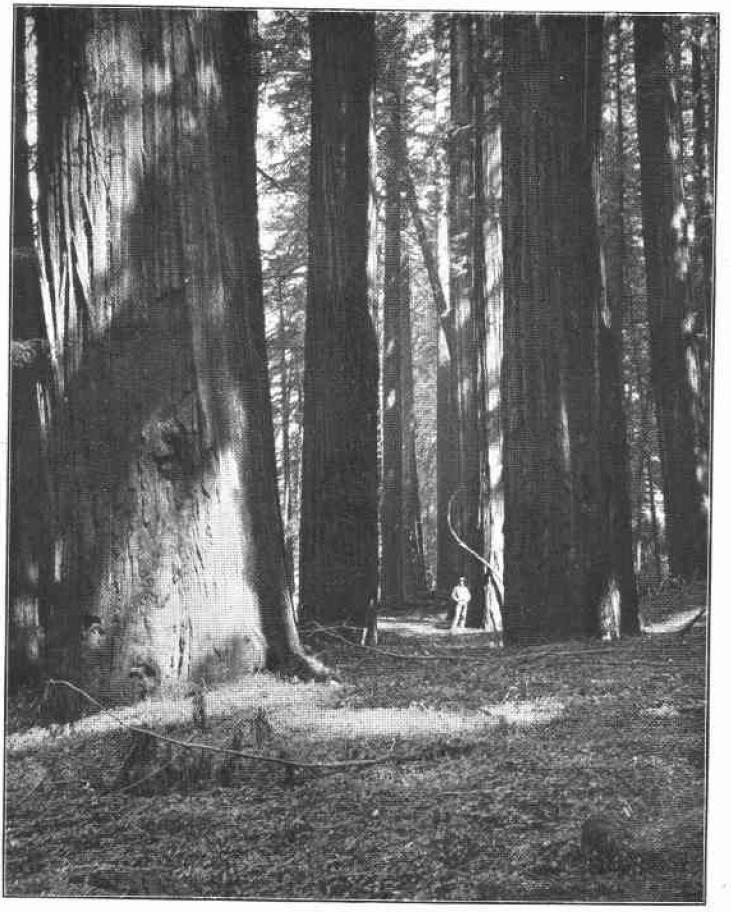

VIRGIN REDWOOD ALONG SOUTH FORK OF EEL RIVER.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF FORESTRY—BULLETIN No. 38.

GIFFORD PINCHOT, Forester.

THE REDWOOD.

I. A STUDY OF THE REDWOOD.
By RICHARD T. FISHER, *Field Assistant, Bureau of Forestry.*

II. THE BROWN ROT DISEASE OF THE REDWOOD.
By HERMANN VON SCHRENK, *Bureau of Plant Industry.*

III. INSECT ENEMIES OF THE REDWOOD.
By A. D. HOPKINS, *Division of Entomology.*

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF FORESTRY,
Washington, D. C., November 18, 1902.

SIR: I have the honor to transmit herewith a manuscript on "The Redwood," by Richard T. Fisher, Field Assistant, Bureau of Forestry, together with a discussion of "The Brown Rot Disease of the Redwood," by Dr. Hermann von Schrenk, of the Bureau of Plant Industry, and of "Insect Enemies of the Redwood," by Dr. A. D. Hopkins, of the Division of Entomology, and to recommend its publication as Bulletin No. 38 of the Bureau of Forestry.

In the summer of 1899 several prominent manufacturers of the Pacific coast requested that the Division (now Bureau) of Forestry make a study of the Redwood. They contributed $550 toward the expense of the work, and offered the hospitality of their camps to the agents who should have it in charge. The Division put a party in the field, which in six months during the years 1899 and 1900 examined nearly all the Redwood belt. Studies of old timber were made at Fort Bragg, Mendocino County; at Scotia, Humboldt County; at Ryan's Slough, near Eureka; at Vance's, on Mad River; and at Crescent City, Del Norte County. Second growth in small areas was studied at Crescent City, Trinidad, Eureka, and Arcata. For courtesies received in lumber camps at these places acknowledgment is made.

The illustrations, which include thirteen full page plates, four text figures, and two diagrams, are considered essential for a proper understanding of the text.

Respectfully,

GIFFORD PINCHOT, *Forester.*

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

TABLES.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

DIAGRAMS.

THE REDWOOD.

A STUDY OF THE REDWOOD.

By Richard T. Fisher,
Field Assistant, Bureau of Forestry.

SCOPE OF THE STUDY.

This study concerns itself with young second-growth Redwood rather than with mature trees; with lumbered areas rather than with the virgin forest. Where attention is given the old forest and methods of lumbering, it is only that a better knowledge may be gained of second growth and how to deal with it.

An attempt is made to answer the question whether it would prove profitable to hold cut-over Redwood lands for future crops. To save the young growth when the old timber is lumbered and to protect the cut-over lands from fire can not be done without cost. The problem, then, more plainly presents itself: Does the Coast Redwood reproduce itself well enough, grow fast enough, and can it be protected cheaply enough to make it profitable to hold the lands?

CONCLUSIONS REACHED BY THE STUDY.

The following facts have been determined:

That the Redwood reproduces itself abundantly by sprouts on cut-over lands, and occasionally by seed;

That in thirty years, in a fair soil and a dense stand, it will produce trees of 16 inches diameter, 80 feet high, yielding 2,000 feet board measure per acre; and

That after careful lumbering under favorable conditions it does pay to hold cut-over Redwood lands for future crops.

INTRODUCTION.

In order to deal with a tree so as to make it produce as much wood as possible in the shortest time, it is necessary to know a great deal about its silvicultural habits. This includes a knowledge of its soil and moisture requirements, the climate and altitude it prefers, its

ability to grow in the shade, and, most important of all, its rate of growth under different conditions.

Serious difficulties lie in the way of obtaining such knowledge of the Redwood. If fully exposed, the tree makes a surprisingly rapid growth; if suppressed, it may exist for a hundred years with but slight increase in diameter, only to take on new life when again exposed and to grow like a sapling. The Redwood forest is so dense that, according to the methods now in use, to lumber it is to annihilate it. Since the reproduction starts up under conditions entirely different from those that prevailed in the old forest, its rate of growth will vary. It is evident that the rate of growth of young timber can not be forecasted from that of old trees, and that trees, to furnish material for yield tables, must have been growing under the same general conditions as those trees to which the tables are to be applied.

The old Redwood will inevitably be cut. Occasionally, it is true, parks and recreation grounds may preserve, on small areas, examples of this wonderful forest growth, but generally the Redwood must be lumbered on account of its commercial value. Since it is with the Redwood as a timber tree that the present study is concerned, the question of preserving it for its beauty is necessarily outside the purpose of the discussion.

But while the old forest must be lumbered, it is important that the lumbering should be less destructive to the young trees. Difficult as logging is among the great Redwoods, it need not mean the total destruction of the forest. Better methods than those now in use must soon be found possible and profitable. In support of this prediction may be cited the case of the Mendocino Lumber Company, an account of whose operations is given in this bulletin. This company has furnished very valuable lessons in Redwood forest management, and has gone far to solve the problem of providing for second growth on Redwood lands. By exercising care in cutting, it has secured splendid stands of second growth on land which, had it been lumbered by the ordinary methods, would be now almost valueless.

FOREST DESCRIPTION.

THE REDWOOD AND THE BIG TREE DISTINCT SPECIES.

The Redwood of California (*Sequoia sempervirens*) belongs to a genus of which the Big Tree (*Sequoia washingtoniana*) is the only other species now alive. Both are allied to the Cypress (*Taxodium distichum*), and their lumber is often called by the same name, but they are botanically distinct from each other. They do not even occupy the same situations. The Big Tree occurs in scattered bodies on the west slopes of the Sierra Nevada, while the Redwood forms dense forests on the west slopes of the Coast Range.

FIG. 1.—REDWOOD SLOPE, SOUTH FORK OF EEL RIVER.

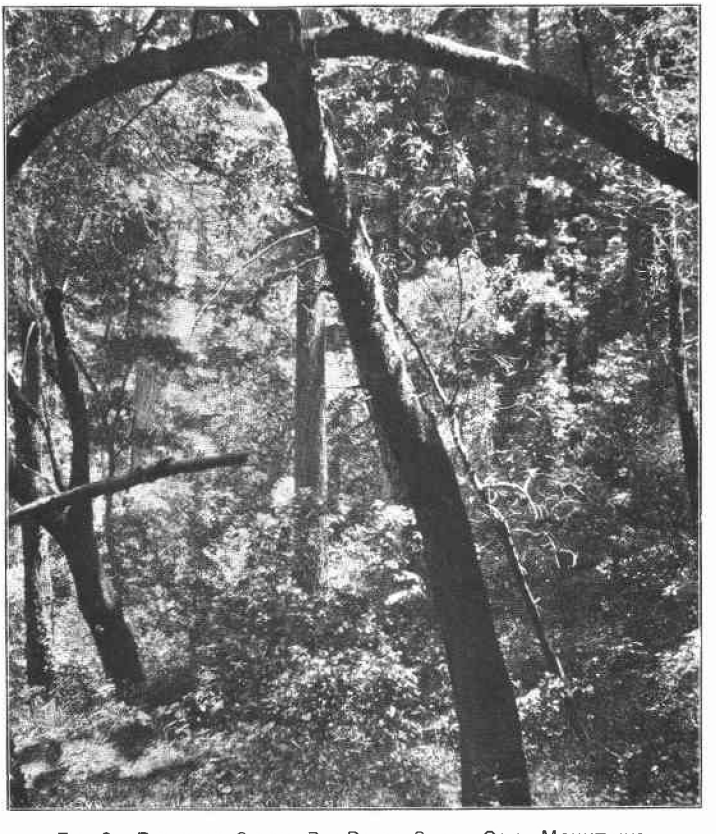


FIG. 2.—REDWOOD SLOPE, BIG BASIN, SANTA CRUZ MOUNTAINS.

FIG. 1.—REDWOOD FLAT, ALLUVIAL BENCHES, SOUTH FORK OF EEL RIVER.

FIG. 2.—REDWOOD FLAT, CRESCENT CITY.

FIG. 1.—TYPICAL FORMS OF MATURE REDWOOD, CRESCENT CITY.

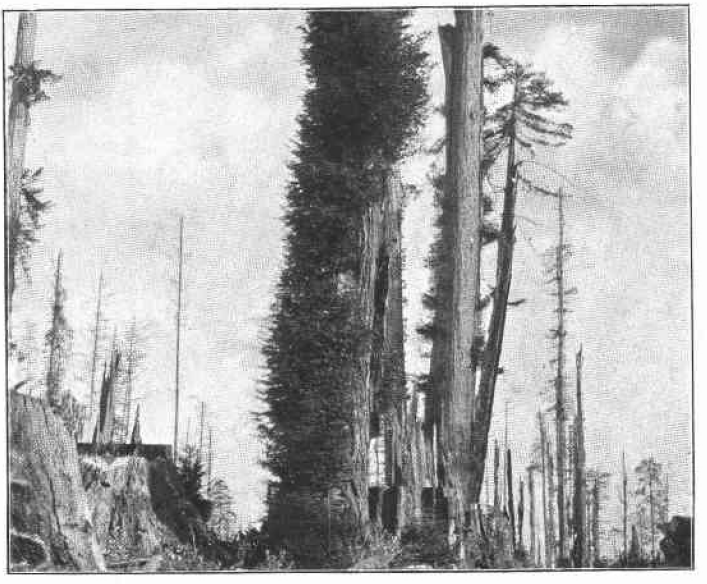


FIG. 2.—CHARACTERISTIC SPROUTING OF BROKEN REDWOOD.

FIG. 1.—SPROUTS OF ONE SEASON'S GROWTH, CRESCENT CITY.

FIG. 2.—SPROUTS 6 TO 8 YEARS OLD, CRESCENT CITY.

DISTRIBUTION OF THE REDWOOD.

The Redwood is popularly thought to occupy a strip of country 10 to 30 miles wide, from the Oregon line to the Bay of Monterey, but these boundaries do not cover its actual distribution. Two thousand acres of Redwood, in two separate groups, are growing in Oregon along the Chetco River. South of the Chetco a continuous Redwood belt begins. By way of the river valleys and lowlands it increases its width from 10 miles, at Del Norte County, to 18 or 20 miles, and keeps on unbroken to southern Humboldt County. Here, for about a township, it thins out, but becomes dense again 6 miles north of the Mendocino line, and after entering that county widens to 35 miles, its greatest width. The Redwood belt ends in Mendocino County, but isolated forests of the species are growing in sheltered spots as far south as Salmon Creek Canyon, in the Santa Lucia Mountains, Monterey County, 12 miles south of Punta Gorda, and 500 miles from the northern limit of the tree along the Chetco River.

CLIMATE AND TOPOGRAPHY.

The climate and topography that have brought about this limited distribution of the Redwood deserve attention. North and south along the coast, in nearly parallel ridges, lie the mountains of the Coast Range, steep and rising to altitudes of 1,000 to 2,000 feet. A few large rivers and many smaller streams cut through them to enter the sea, and along their courses in places are broad bottom lands and gentle slopes. West of the Coast Range the climate is even and moderate, with a range from just below freezing to 80° F., and a yearly average of from 50° to 60°. Snow lies on the tops of only the highest ridges. Thirty to 60 inches of rain falls in the autumn and winter, and in the summer sea fog bathes the coast. But east of the mountains, less than 50 miles from the sea, lie hot interior valleys, never visited by the fog, parched and rainless in the summer, and wet only occasionally by the winter rains—conditions too unfavorable to permit the growth of the Redwood.

SILVICULTURAL TYPES.

The Redwood may be considered in two types—Redwood Slope and Redwood Flat. It passes from one to the other as the ground becomes steep and dry or level and moist, and admits other species wherever the situation satisfies their requirements.

THE REDWOOD SLOPE.

The common type is the Redwood Slope (Pl. I). It occurs on the steep sides of the Coast Range, and is a mixture of Redwood, Red Fir, Tanbark Oak, and White Fir, with an occasional Madroña or Hemlock.

The Redwood is the predominant tree in the mixture, and the Red Fir ranks next.

The composition of the forest is shown in the following table, which is constructed from surveys taken in six localities. Scotia and Dyerville, since they showed similar conditions, were thrown together. In accordance with the custom of the country, timber with a diameter of 20 inches breasthigh is classed as merchantable.

TABLE 1.—*Redwood Slope.*

Locality and species.	Trees 4 inches and over in diameter breasthigh.		Trees 4 to 19 inches in diameter breasthigh.		Trees 20 inches and over in diameter breasthigh.		
	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average diameter breasthigh.
CRESCENT CITY.							*Inches.*
Hemlock	35.24	37	33.11	50	2.13	7	26
Redwood	32.71	34	9.73	15	22.98	79	71
White Fir	15.25	16	14.11	21	1.14	4	30
Red Fir	7.06	7	4.43	7	2.63	9	56
Tanbark Oak	4.94	5	4.89	7	.05	.....	21
Spruce	.78	1	.57	.....	.21	1	29
Total	95.98	100	66.84	100	29.14	100	.....
VANCE'S.							
Redwood	25.44	40	5.94	17	19.50	68	105
Hemlock	23.25	37	19.50	56	3.75	13	32
White Fir	14.87	23	9.31	27	5.56	19	35
Total	63.56	100	34.75	100	28.81	100	.....
RYAN'S SLOUGH.							
Redwood	52.24	66	24.43	79	27.81	57	81
White Fir	13.47	17	3.14	10	10.33	21	38
Red Fir	10.86	13	.76	3	10.10	21	41
Hemlock	2.95	4	2.57	8	.38	1	34
Total	79.52	100	30.90	100	48.62	100	.....
SCOTIA AND DYERVILLE.							
Redwood	46.59	72	14.76	55	31.83	85	63
Tanbark Oak	8.59	14	7.90	29	.69	2	26
White Fir	7.93	12	4.29	16	3.64	10	31
Red Fir	1.41	2	.10	.....	1.31	3	42
Total	64.52	100	27.05	100	37.47	100	.....
FORT BRAGG.							
Redwood	38.21	64	13.02	60	25.19	67	79
Red Fir	8.16	14	1.04	5	7.12	19	39
Tanbark Oak	6.22	10	4.87	22	1.35	4	26
White Fir	4.56	8	1.60	7	2.96	8	33
Hemlock	2.11	4	1.42	6	.69	2	25
Total	59.26	100	21.95	100	37.31	100	.....

The slope of the ground and the uneven height and density of the different species in mixture admit enough light to make the Redwood Slope comparatively open, so that, except where fires are frequent, there is a dense undergrowth of huckleberry, salal, Oregon grape, thimbleberry, and ferns.

Differences in altitude and the steepness of the slope cause differences in the condition of the forest. The higher the altitude and the steeper the slope, the sparser and poorer the growth becomes.

THE REDWOOD FLAT.

As the slopes become moderate, the altitude lower, the soil deeper, and the water supply better, the Redwood steadily gains on the other species and the forest becomes denser, until, on the rich flats and gulches, a second type is evolved. This is the Redwood Flat (Pl. II), and in its extreme form it has no other tree than Redwood.

The surveys for the following tables were taken on level ground, where the soil was deep and the moisture abundant.

TABLE 2.—*Redwood Flat.*

Locality and species.	Trees 4 inches and over in diameter breasthigh.		Trees 4 to 19 inches in diameter breasthigh.		Trees 20 inches and over in diameter breasthigh.		
	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average diameter breasthigh.
CRESCENT CITY.							*Inches.*
Redwood	37.10	63	12.79	42	24.31	85	84
Hemlock	19.16	32	16.02	52	3.14	11	28
Spruce	3.02	5	1.93	6	1.09	4	31
Total	59.28	100	30.74	100	28.54	100	.....
SCOTIA AND DYERVILLE.							
Redwood	50.50	.....	14.31	.....	36.20	.....	76

The Eel River stands are the extreme form of the Redwood Flat, and the tree here attains its greatest known height and clear length. On the benches that line the stream the Redwood possesses all the growing space, and casts a shade so dense that no ground cover except oxalis and occasional tufts of sword fern will grow beneath it.

While the heaviest stands and the best timber are found on the Redwood Flat, this type comprises a very small percentage of the Redwood forest, being confined mainly to narrow strips along the streams, occasional coastal plains, and the river deltas. The "rough country," as the Redwood slopes are called, so far exceeds the Redwood flats in extent that the proportion of the former to the latter is about 50 to 1.

CHARACTERISTICS OF THE REDWOOD

HEIGHT AND DIAMETER.

The Redwood grows to a greater height than any other American tree, but in girth and in age it is exceeded by the Big Tree of the Sierras. On the slopes 225 feet is about its maximum height and 10 feet its greatest diameter, while on the flats, under better conditions, it grows to be 350 feet high, with a diameter of 20 feet.

AGE OF THE REDWOOD.

Most of the Redwoods cut are from 400 to 800 years old. After the tree has passed the age of 500 years it usually begins to die down from the top and to fall off in growth. The oldest Redwood found during this investigation began life 1,373 years ago.

FORM AND DEVELOPMENT.

The tree, when normal, has a straight, slightly tapered bole, clear for more than a hundred feet, and a crown of horizontal branches that may occupy from a third to a half of its total length. (Pl. III, fig. 1.) Although without a taproot, it is well adapted to securing water in dry ground. The roots strike downward at a sharp angle, and are so large and so numerous as to form a compact mass of wood, in shape like an inverted funnel. The bark of the tree offers such a remarkable resistance to fire that except under great heat it is not combustible. It is of a reddish-gray color, fibrous in texture, and gives to full-grown Redwoods a fluted appearance.

The Redwood assumes a wide variety of shapes, and the normal is not its common form. In the old forests the crown may consist of a few long, flat limbs or of a mass of little bushy branches reaching from the ground to the top of the tree. (Pl. III, fig. 2.) Many Redwoods grow burls on the trunk that are 10 feet long, and some carry curious protuberances called "hanging necks," which droop and are open at the ends. Most of these irregularities in the tree are caused by the healing of its hurts. A windfall may break off the crown; immediately the broken limbs sprout and replace a part of what was lost. The fireproof sheathing of bark may be scraped away in a place and a little of the sapwood burned; the spot grows over and a burl may result. Fire may burn one of the branches and leave a charred snag behind; sapwood grows over the snag and forms a hanging neck. However badly the tree may be injured, if enough live wood is left it will heal the injury.

SOIL MOISTURE THE FIRST REQUISITE.

The Redwood requires little of the soil except that it be moist. The prevailing formation from Port St. George to Mendocino County,

where the tree grows, is a sandstone, complicated at different places with a later stratum, and the soil has a clayey to sandy consistency, greasy when wet, yellowish in color, and with a capacity for holding much water. Moisture available for the roots is the first need of the Redwood, as any hilly tract of forest will show. Wherever a small gully, or bench, or basin is so placed as to receive an uncommon amount of seepage, or wherever a creek flows by, there the trees are sure to be largest. Even if the soil be not rich, but merely gravel, and it contain much moisture, the Redwood will grow more abundantly there than on richer but drier ground.

THE REDWOOD FOLLOWS THE FOGS.

While moisture of the soil affects the development of the Redwood, moisture of the atmosphere regulates its distribution. The limits of the sea fogs are just about the limits of the tree. The fogs, unless scattered by the winds, flow inward among the mountains. Western exposures receive most of the mist they carry, except those higher ridges above their reach, which support, in consequence, only a scattering growth of Redwood. Eastern and southern slopes, where the sun is hot and the mists strike only occasionally, show few Redwoods, and these are short and limby.

THE QUALITY OF THE WOOD VARIES.

The wood of the Redwood varies greatly. The softest and best trees usually grow in the bottoms; the "flinty" timber occurs on the slopes. But this rule does not always hold good. Such fine tracts as those on the Crescent City flats show all sorts of unexpected and unaccountable differences in the quality of the timber. A soft, fine-grained tree will be found close beside one "flinty" and less valuable. Even the practical logger is never sure until he cuts it what kind of lumber a Redwood will yield. The tree's vitality is so great, it endures so may vicissitudes, and suffers from so many accidents in the centuries of its existence, that the grain of its wood becomes uneven in proportion as its life has been eventful. Most Redwoods become windshaken, or, if they escape this, the wood fibers formed under different rates of growth sometimes set up a tension so great that when the log is sawed the wood splits with a loud report.

THE LARGE REDWOODS OUTNUMBER THE SMALL ONES.

The Redwood forest is of the selection type; that is, it contains trees of widely varying ages in a single mixture, and keeps itself stocked by reproduction under its own shade. But while in the usual selection forest of other species the young trees far outnumber the mature ones, in a virgin Redwood forest as much as 72 per cent of the trees have been found to be above 20 inches in diameter.

REPRODUCTION BY SUCKERS AND BY SEEDLINGS.

Careful examination has proved that sucker and seedling share in the reproduction of the Redwood forest; but they share unequally, for the proportion of suckers to seedlings is as 100 to 1. The limited number of seedlings is due both to the quality of the seed and to the opportunities for germination afforded it. The habit of perpetuating itself by sprouts seems to have weakened the vitality of the Redwood's seed. Mr. P. Rock, of the horticultural staff at Golden Gate Park, says that under the best conditions only 15 to 25 per cent of Redwood seed will germinate. The seed requires more light than the forest usually affords it, and suckers cast so dense a shade as to crowd it out even when it does germinate.

Plates IV and V show how quickly Redwood will reproduce itself from sprouts. In Pl. IV, fig. 1, is represented the growth of the first few months after the slashing was logged and burned. Such shoots are as soft and juicy as asparagus. In Pl. IV, fig. 2, is seen the size and development reached in six to eight years. In Pl. V, fig. 1, are shown suckers which have passed the age of twenty-five years, and which have begun to take on a forest form. The parent stump is visible in the rear. Pl. V, fig. 2, shows a characteristic clump of mature Redwoods, surrounding and concealing the parent stem, but revealing unmistakably their identity as sprouts.

YIELD OF REDWOOD STANDS.

The yield of virgin Redwoods on the northern flats is from 125,000 to 150,000 board feet per acre. Farther south it is much less. About Humboldt Bay it is from 50,000 to 75,000 feet per acre; and on slopes like those in Sonoma County, from 20,000 to 30,000 feet. The amount of timber got out of a Redwood forest is only a small proportion of what the stand contained. At least a quarter of the timber is destroyed in felling and in the burning that follows, and of what remains all the broken and misshapen logs are left on the ground.

TOLERANCE, OR SHADE-ENDURING QUALITIES.

The seed of the Redwood will not germinate in shaded places; the small seedling demands plenty of light. The crown is almost as thin and open as that of the larch—another sign that the tree is not naturally shade-enduring. In a mixed stand the Redwood's branches die off more rapidly than those of its companions, and the crown bends eagerly to the places where the light enters the forest canopy. But in spite of these signs of its sensitiveness to light, the Redwood forms one of the densest forests that grow.

The reason for this is that the stand is chiefly maintained by suckering from old trees. Supported and nourished by full-grown roots and stems, young trees grow under shade that would kill the small seedling.

The sprout manages to survive year after year by connection with its parent, and to make a slight increment of wood. When an old tree is felled, more light is let in, more nourishment made available, and the sprout shoots up with all its native vigor.

The sprout will endure an astonishing amount of shade. In stands of second growth, so dense that not a ray of sunlight can enter, saplings 6 or 8 feet high are to be found growing from stumps, bare of branch or foliage except for a few inches of pale green crown at the top. In very dark, damp places in the virgin forest one may find clumps of shoots as white as sprouts from a potato in a cellar.

The tolerance of the Redwood sprout depends somewhat on soil moisture. On the bottoms the tree is enabled to stand so much shade that other species are usually driven out of competition for the ground. On the hills, where there is less moisture and more light, the Redwood generally gives way to the less tolerant Fir and to such drought-enduring species as Tanbark Oak and Madroña.

ENEMIES OF THE REDWOOD FOREST.

The enemies of the Redwood are few, and it suffers from them less than other trees. The wind can scarcely uproot it, insects seem to do it little harm, and fungi seldom affect it. Even fire, the great enemy of all trees, though it may occasionally kill whole stands of young Redwood growth, is unable to penetrate the fireproof sheathing of shaggy bark with which the old trees protect themselves.

FIRE.

For centuries fires have run through Redwood forests. They have killed young growth, made "goose pens" by burning out the litter from between the roots, and scarred the bark of the older trees; but the Redwood has suffered less from fires than has any other species. In the damp northern part of the Redwood belt the forest is too wet to burn. Farther south, during August and September, while the trade winds are blowing and the land is dry from lack of rain, fires are frequent. Even then, unless the conditions are exceptional, the fires are seldom dangerous. But if the dry season has been unusually long and the wind is very high, and a fire is driven down from the bald hills into the heavy timber of the flats and gulches, the flames may gain such headway as to sweep from the forest all the younger trees and the underbrush. Ridge fires commonly clear the ground of underbrush and occasionally kill small trees. In September, 1900, a ridge fire occurred near Occidental, Sonoma County, where the forest of Redwood, Fir, and Tanbark Oak is thin and scattering, with dense, dry underbrush. The wind drove the flames over the ground as fast as a man could run; fences, bridges, and farm buildings were burned; young timber was killed and the growth of the old timber checked.

Complete recovery from such a fire is slow. The leaf mold is burned off and the soil is made naked as a road. The large Redwoods will sprout again from their stumps; but the rest of the space, once occupied by Fir and Oak, will be covered first by buck brush and blue blossom, until, after years, the Fir and Oak return.

The common cause of fire in the forest is the carelessness of campers and settlers, who leave their camp fires burning. Sparks from the brush fires of logging camps occasionally start a blaze in the timber, and lightning may be responsible for a few forest fires.

WIND SELDOM UPROOTS THE REDWOOD.

When a strong wind follows a long rainy season, Redwoods exposed on high ridges may sometimes be blown down, but no considerable tracts of forest are ever overthrown.

SPECIES IN MIXTURE.

Of the trees which grow with the Redwood in the forest the following are the most important:

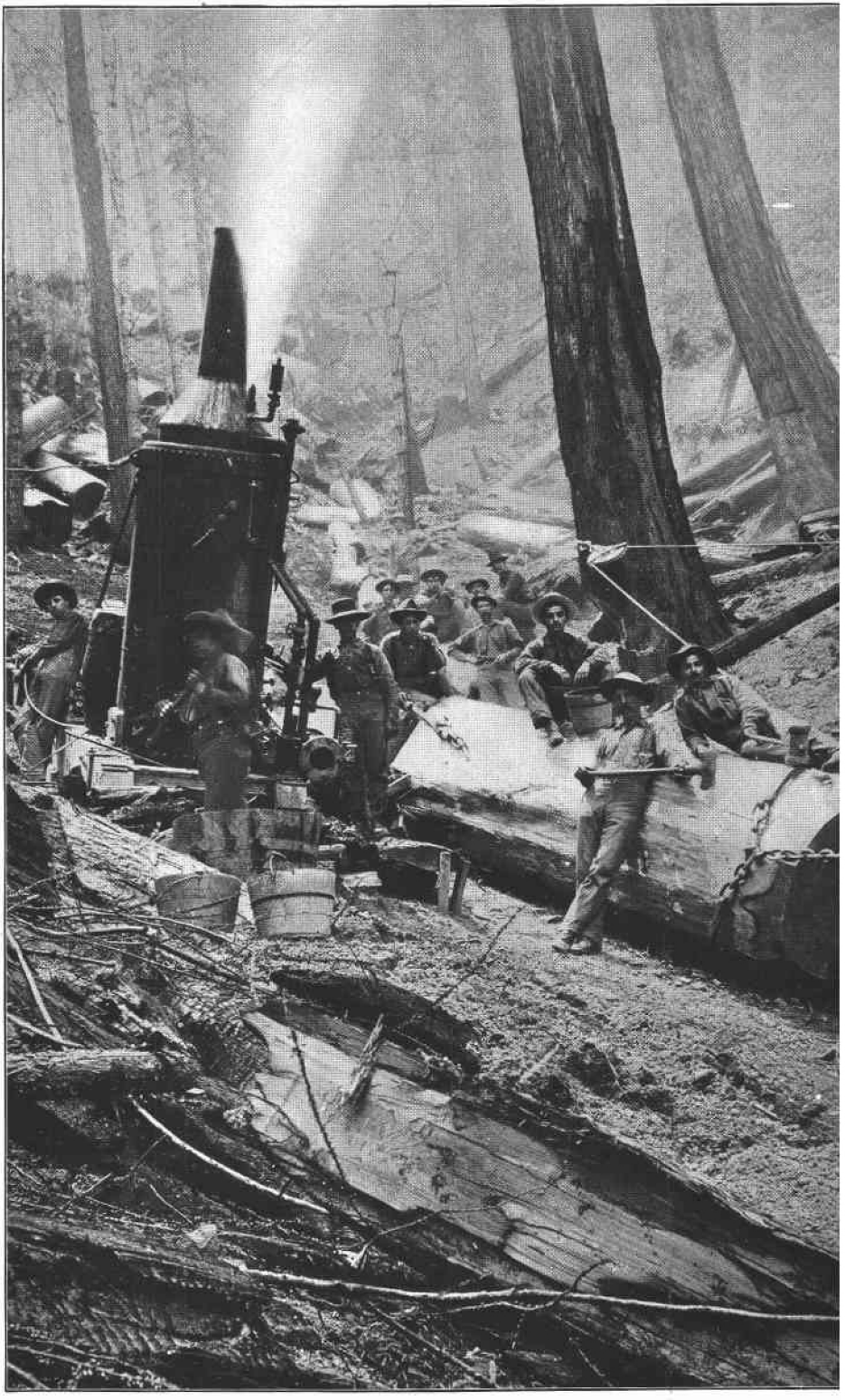
Red Fir, *Pseudotsuga taxifolia* (Lam.) Britt.
Tanbark Oak, *Quercus densiflora* Hook. & Arn.
Sitka Spruce, *Picea sitchensis* (Bong.) Trautv. & Mayer.
Port Orford Cedar, *Chamaecyparis lawsoniana* (Murr.) Parl.
Giant Arborvitae, "Red Cedar," *Thuja plicata* Don.
Western Hemlock, *Tsuga heterophylla* (Raf.) Sargent.
Lowland Fir, "White Fir," *Abies grandis* Lindl.
Pacific Yew, *Taxus brevifolia* Nutt.
California Torreya, *Tumion californicum* (Torr.) Greene.
Knobcone Pine, *Pinus contorta* Loud.
California Laurel, "Pepperwood," *Umbellularia californica* (Hook. & Arn.) Nutt.
Madroña, *Arbutus menziesii* Pursh.
Cascara Buckthorn, "Cascara Sagrada," *Rhamnus purshiana* de C.
Red Alder, *Alnus oregona* Nutt.
Gowen Cypress, *Cupressus goveniana* Gord.

These trees are usually beaten in the struggle for growing space by the Redwood, which is climatically the most favored, but each species finds places here and there where the conditions enable it to hold its own. Red Fir, or Oregon Pine, the most abundant and important of the trees in mixture, occurs with Redwood everywhere except on damp flats and in gulches. It grows best on medium soil, on ridges and high flats where the forest is comparatively open. On some fine tracts, as in Del Norte County, it constitutes 75 per cent of the stand. Next to Redwood, it is the most used of the timber trees on the coast, and in Mendocino County forms from 10 to 20 per cent of the output of the mills.

FIG. 1.—SPROUTS 25 YEARS OLD, CRESCENT CITY.

FIG. 2.—MATURE SPROUTS IN VIRGIN TIMBER, CRESCENT CITY.

REDWOOD LOGGING. "FALLERS" MAKING THE UNDERCUT, CASPAR, MENDOCINO COUNTY, CAL.



REDWOOD LOGGING. THE YARDING DONKEY AND YARDING CREW, CASPAR, MENDOCINO COUNTY, C

FIG. 1.—LOGGED SLOPE ON BIG RIVER.

FIG. 2.—SLOPE SIMILAR TO ABOVE, SHOWING SUBSEQUENT REPRODUCTION OF FIR AND REDWOOD.

LUMBERING: ITS HISTORY AND EXTENT.

The Spaniards, near San Francisco Bay, were the first to log the Redwood forests, but their cuttings were very small. Late in the eighteenth century a Russian colony cleared a tract of Redwood, which has since grown up to good timber and again been cut over; but no considerable amount of logging was done until long after the Russians had left. About the year 1850 small mills started up in Santa Clara and Santa Cruz counties, at Albion, and at the mouth of Big River, in Mendocino County, at Arcata and Eureka, on Humboldt Bay, and at Trinidad. At first the mills on Humboldt Bay cut chiefly Red Fir and Sitka Spruce, as Redwood was not valued; and the other mills cut very little Redwood, since the tree was without a market and the mill men were handicapped by the lack of improved machinery. In those days logs were usually driven to the mill in the rivers, and the strong freshets carried many out to sea. As soon as the growth of San Francisco and the settlement of the southern counties developed a market, more companies and better methods came in. Logging railroads superseded driving, and donkey engines did the work of teams. By the early nineties mills were employing about the same number of men as now (1900) and had about their present equipment.

PRESENT OPERATIONS.

Redwood lumbering is now narrowed to northern counties in California. In Santa Cruz County all the large stands of Redwood will be made into a park. In Marin County Redwood has long since dwindled to a few isolated groves, used mostly as picnic grounds. In Sonoma County Redwood holdings are reduced to a few scattered claims. Large operations begin in Mendocino County. The ten sawmills in this county had in 1900 cleared 150,000 acres, or 25 per cent of the total acreage, including the largest and best stands. In Humboldt County the mills had cleared 65,000 acres, and in Del Norte County two mills had cleared 3,000 acres. It is unsafe to estimate what proportion of the original stand these cuttings represent.

QUALITIES OF THE WOOD.

Redwood possesses qualities which fit it for many uses. In color it shades from light cherry to dark mahogany; its grain is usually straight, fine, and even; its weight is light; its consistency firm, yet soft. It is easily worked, takes a beautiful polish, and is the most durable of the coniferous woods of California. It resists decay so well that trees which have lain five hundred years in the forest have been sent to the mill and sawed into lumber.

12478—No. 38—03——2

RESISTANCE OF LUMBER TO FIRES AND INSECTS.

The wood is without resin and offers a strong resistance to fire, as is indicated by the record of fires in San Francisco, where it is much used. Insects seldom injure it, because of an acid element its lumber contains. In sea water, however, the marine teredo eats off Redwood piling as readily as other timber.

USES FOR REDWOOD.

Redwood is used for all kinds of finishing and construction lumber, for shingles, railroad ties, electric-light poles, paving blocks, tanks, and pipe staves. It is an excellent wood for all these purposes. As a tie its average life, under heavy traffic, is six to eight years; as shingles it will last as long as forty years. The chief difficulty in working Redwood lies in the seasoning process. The tree absorbs so much moisture that the butt logs will sink in water. Left in the sun, they require three or four years to dry.

COST OF LUMBERING.

The manufacture of Redwood lumber is costly and difficult. From the felling of the tree to the delivery of the finished product unusual problems and expenses beset the mill man. Most of the land where the Redwood grows is rough and hilly, and from 100 to 250 miles from the main market, which can be reached only by sea. None but the big companies can operate with any profit, and each plant has usually to own a complete outfit. This includes the mill and accompanying buildings, about 10 miles of railroad track, two locomotives, three to six donkey engines, several logging camps (including all the rigging and tools that go with them), and perhaps a pair of steam schooners. The men employed number from 150 to 300. Yet, even on such a scale, the business is very uncertain. On account of the sparseness of the settlement, labor is scarce and high and taxes are severe. The most prosperous companies are those which have developed a town with their business. They run a general store, raise most of their own supplies, and sometimes have a local sale for their common lumber and for firewood.

Redwood lumber is at present not highly profitable to mill men. It costs, according to the accessibility of the timber and the price of labor, from $3 to $5.50 a thousand feet, board measure, to log—that is, to deliver at the mill; from $3 to $3.50 to saw; from 25 to 50 cents to load, and from $2.50 to $4 to ship to the city. These items, with the expenses of the city offices and sales, bring up the average total to $10.75, or in many cases, with insurance, taxes, interest on capital, stumpage, and accidents reckoned in, about $12.

WHERE THE LUMBER GOES.

The market is uncertain and limited. Redwood must depend for its sale on the demand of San Francisco, Los Angeles, and the southern counties of the State. Occasional cargoes go to Australia, Honolulu, South America, and the Orient; but this outlet is restricted by the necessity for costly reshipment at San Francisco, since seagoing vessels can not load everywhere on the coast. For five years prices have remained $11 to $13 for rough, and $18 to $25 for clear, merchantable Redwood. This leaves little room for profit. It would appear that so useful a wood should find a ready sale in the East; but at present Eastern buyers do not appreciate its good qualities, and high freight rates have helped to keep it out of Eastern markets.

DESTRUCTIVE LUMBERING METHODS.

Redwood lumbering is expensive and difficult. Steam is used throughout the process. On the flats and bottoms, where the trees average from 5 to 15 feet in diameter, the stand is very dense, and to get Redwood out of the forest without breaking other trees is not an easy task. Choppers who can save a good percentage of the wood in the trees felled must be experienced men. If the tree is not felled so as to strike throughout most of its length at the same time, the brittle wood will break and splinter badly. To prevent this, a "lay-out" is usually leveled for the tree to fall on. Even then the whole of the crown and at least a fourth of the bole are demolished and strewn upon the ground. The mass of broken branches may lie shoulder deep, and the logs must be got out from this tangled wreckage.

After the choppers have done their work, the "ringers" and "peelers" follow. They peel the bark from the logs and let it lie with the broken branches, which soon dry and are then set afire. When bark and branches are consumed the logs lie free, and the logger can put sawyers and swampers to work, and move in his yarding donkey engine and rigging. Many small trees used by the yarding crew to set blocks are unavoidably girdled; the rest are in constant danger from the moving logs, which work this way and that, plow into the earth, and butt into the young trees until scarcely one of them is left unharmed.

After the yarding crew has done its work the log's progress to mill is over land already slashed and burned. Three or four logs are coupled together, attached to an endless cable, and hauled to the railroad track by a bull-donkey engine, which stands on a landing at the end of the skid road and winds in a wire rope on a drum. Then, with block and tackle, worked either by the train locomotive or a smaller donkey engine, the logs are loaded upon trucks and hauled to the mill pond. (Pls. VI and VII.)

CUT-OVER LANDS: POSSIBILITY OF SECOND GROWTH.

During the fifty years in which the Redwood has been lumbered, several hundred thousand acres of timber have been cut over. The good lands have been put into cultivation under fruit or grain, or, where mills have had a large and permanent force of men to feed, the mill owners have turned their cut-over lands into pasture for the raising of cattle.

The chance for the reproduction of the tree has been small. On the farms the stumps are either grubbed out or shorn of their suckers every year; on pasture lands, burning and the cattle have prevented reproduction; and those lands not used after lumbering have also been subjected to fire. As year by year the Redwood forests have dwindled, it has come to be pretty generally believed that the tree is doomed to extinction.

The popular idea that the Redwood has no chance of survival is not well founded; the possibilities of second growth are much better than they appear. While most of the lumbered areas have been kept bare by lack of protection, there are tracts where accidentally favorable conditions have allowed the sprouts to develop, and here the real vigor of the Redwood second growth is apparent.

VALUABLE SECOND GROWTH.

On the northernmost slashings near Crescent City, which is perhaps the most isolated of all the lumber regions on the coast, there is one small tract among acres of unpromising brush and stumps where the growth of sprouts has been unimpeded, and there a stand exists which averages 12 to 16 inches on the stump and is 60 to 80 feet in height. Only the very best of the virgin timber may be profitably lumbered in this place, and the second growth is not cut. A hundred miles south, near Humboldt Bay and Eureka, are tracts of young growth only ten years older than those at Crescent City, which have a market value. Men who have found their old claims grown up to sticks 20 inches through and a hundred feet long have sold the trees for piling, for which they are locally considered almost as good as Red Fir. A good many mill men in Eureka believe that the Redwood sucker will in time and under the proper conditions produce valuable timber; but they say that the wood of the sprout is too soft and brittle—"brashy" they call it—not taking into account that it has not been grown in dense stands and has not had time to harden.

This soft timber can be used. In Sonoma County, where the country is well settled, Redwood was never so dense as farther north; but there has been a better chance for reproduction and there is a better market. Sonoma County second-growth Redwood is cut to as low a diameter as 10 inches, and the mills are making money at the business. The timber is sappy, but it makes good box boards and good lumber.

This contrast between the indifference with which second-growth Redwood of large size is regarded in Crescent City and the readiness with which much smaller stuff is used in Sonoma County, where there is a market for it, is significant. It is one of the signs which go to show that second growth has a future, and that better times for the Redwood are near at hand.

A BETTER MARKET NECESSARY.

The important matter is that the market should improve; and the market is improving. The northern country is opening up; railroads are entering where the large trees grow, and buyers are learning more about the good qualities of the Redwood lumber. All this makes it the more worth while to the lumberman to plan for a second crop on his Redwood lands.

A STUDY OF SECOND-GROWTH REDWOOD.

To learn the rate of growth of second-growth Redwood a study was made of some of the largest of such stands. The investigation began with the timber near Crescent City. In that place logging operations have so far been confined to the coastal plains between the sea and Smith River, a plain once forested with a heavy growth of Redwood, Spruce, and Hemlock.

THE TRACT AT CRESCENT CITY.

The second growth studied near Crescent City was on the crest of a small rise, just above sea level, where the original stand of timber was cut off in 1873–1875. The trees covered 6 acres; they had suffered no burning since the first crop was logged, and there had been no other interference with the reproduction. The age of the stand was 25 to 30 years.

TRACTS AT EUREKA AND ARCATA.

Two small tracts were studied near Eureka and Arcata. They were on good soil, 200 to 300 feet above sea level, on rolling ground. At Eureka 20 per cent of the forest was Red Fir; at Arcata 15 per cent was Red Fir and White Fir. The Eureka stand was 35 years old; that at Arcata, 40 to 45 years.

THE REDWOOD'S FIGHT FOR THE GROUND.

The stands at Crescent City, Eureka, and Arcata represent the best conditions for the growth of suckers. When the old Redwood is cut the stumps sprout abundantly; a few Spruces and Hemlocks seed up the gaps; and these three species, with the help of small shrubs, soon form a dense thicket. In a few years the Spruce and Redwood and other fast-growing trees, like Alder, begin to overtop and shade out the brush and small plants; the dead vegetation deposits a leaf muck,

or humus, which enriches the soil, keeps it moist, and makes growth more rapid. As the crowns grow up, in the struggle for light and room most of the weak or intolerant trees die off. The Hemlocks survive and partly keep up, because they can stand a good deal of shade, but the Willows and Alders become restricted to the openings. It happens, therefore, that wherever the suckering has been thick enough at first, Redwood finally dominates all the other species and occupies most of the ground.

THE TRACT AT TRINIDAD.

A fourth tract, which showed more typical conditions and the kind of situation characteristic of most of the Redwood belt, was found at Trinidad. The topography there is a broad coastal terrace, rising gently from the sea cliffs and cut by the canyons of several small streams. About 2 miles inland the terrace rises to an altitude of 500 feet, and the soil becomes coarse and poor. The tract of second-growth Redwood stands on a plateau-like divide between the two gulches. The age of the stand is 25 years.

THE VALUATION SURVEYS.

Valuation surveys were run at Crescent City, Arcata, and Trinidad. The results are given in the following table:

TABLE 3.—*Valuation survey of second-growth Redwood.*

Locality and species.	Trees 2 inches and over in diameter, breasthigh.		Trees 2 to 13 inches in diameter, breasthigh.		Trees 14 inches and over in diameter, breasthigh.		
	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average diameter breasthigh.
ARCATA.							*Inches.*
Redwood	192.10	80	162.70	79	29.40	84	17
White Fir	34.10	14	30.30	15	3.80	11	15
Spruce	11	5	10.20	5	.80	2	14
Red Fir	3.30	1	2.30	1	1	3	17
Total	240.50	100	205.50	100	35	100	.....
CRESCENT CITY.							
Redwood	234.33	55	204	53	30.33	75	16
Spruce	104.33	25	99.66	26	4.67	12	17
Hemlock	86	20	80.67	21	5.33	13	17
Total	424.66	100	384.33	100	40.33	100	.....
TRINIDAD.							
Redwood	401.6	66	399.20	75	2.40	12	14
Red Fir	134.4	22	120.40	23	14	70	15
Hemlock	62	10	.....	.....	.....	.....	.....
Spruce	7.6	1	7.20	1	.40	2	14
Pine	5.6	1	2.40	1	3.20	16	15
Total	611.2	100	529.20	100	20	100	.....

HOW THE TABLES WERE MADE.

In the tables which follow, trees 14 inches and over in diameter are assumed to be merchantable. This is done because a 14-inch tree is the smallest that will contain a log which is salable by the Spaulding Rule, and because it is the smallest tree used by the mills.

The volume tables are based on stem analyses, obtained by measuring 450 trees at Crescent City, 50 at Eureka, and 50 at Arcata.

To find the volume per tree in board measure, all the trees analyzed, beginning with those that contained a log 12 feet long and 10 inches in diameter at the small end inside the bark, were scaled, and the results for each diameter plotted in a curve. The table of merchantable volume given here was derived from the curve. It gives the average volume in board feet and the height of each tree for diameters from 14 to 27 inches, inclusive.

TABLE 4.—*Merchantable volume of Redwood timber.*

Diameter breast-high.	Merchantable volume.	Total height.	Diameter breast-high.	Merchantable volume.	Total height.
Inches.	*Board feet.*	*Feet.*	*Inches.*	*Board feet.*	*Feet.*
14	52	69	21	186	88
15	62	72	22	188	91
16	74	75	23	226	93
17	90	78	24	267	95
18	108	81	25	316	97
19	130	83	26	430	99
20	156	86	27	496	101

The yield per acre of merchantable timber at Crescent City and Arcata is given in the following table (No. 5). The figures were found by multiplying the number of trees per acre in each diameter class, as found in the valuation survey tables, by the figure corresponding to that diameter class in the table of merchantable volume. Only Crescent City, Eureka, and Arcata showed trees large enough to be scaled on the standard chosen. At Eureka the culling of the forest for piling had left nothing on which to base an estimate of yield per acre.

TABLE 5.—*Merchantable yield of Redwood per acre.*

Diameter breast-high.	Crescent City.		Arcata.	
	Average number of trees per acre.	Merchantable yield.	Average number of trees per acre.	Merchantable yield.
Inches.		*Board feet.*		*Board feet.*
14.....	17.7	920.4	13.5	702.0
16.....	6.0	444.0	7.0	518.0
18.....	2.7	291.6	4.4	475.2
20.....	1.5	234.0	2.0	312.0
22.....	1.0	188.0	1.1	206.8
24.....	1.0	267.0	.5	133.5
26.....	.3	129.0	.2	86.0
Total ..	.....	2,474.0	.....	2,433.5

Table 6 shows the number of pile feet in trees of diameters from 18 to 28 inches, inclusive. It was obtained from stem analyses taken at Crescent City, Arcata, and Eureka. Assuming that nothing which will not furnish a log 30 feet long and 10 inches in diameter at the small end is available for piling, the smallest tree to contain a pile was found to be 18 inches in diameter breasthigh. The table follows:

TABLE 6.—*Pile length of Redwood.*

Diameter breast-high.	Pile length.	Diameter breast-high.	Pile length.
Inches.	*Feet.*	*Inches.*	*Feet.*
18	30.5	24	49.0
19	33.5	25	52.0
20	37.0	26	54.5
21	40.0	27	57.5
22	43.0	28	60.0
23	46.0		

Diagrams 1 and 2 show the relations between age and height, and between age and diameter, of the Redwood examined at Crescent City, Eureka, and Trinidad.

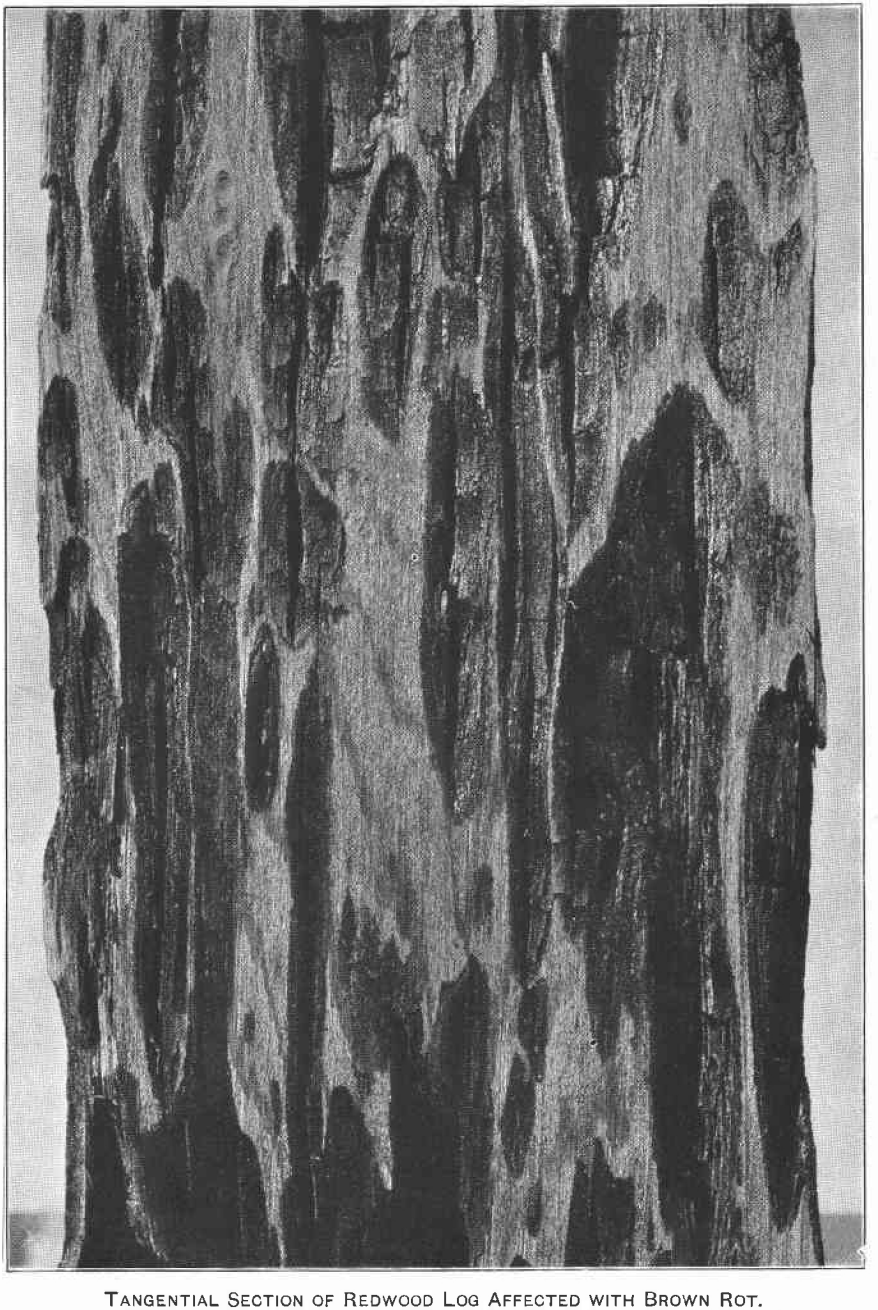
FIG. 1.—SECOND-GROWTH REDWOOD AT EUREKA, 30 TO 35 YEARS OLD.

FIG. 2.—SECOND-GROWTH REDWOOD AT MENDOCINO, 40 TO 45 YEARS OLD.

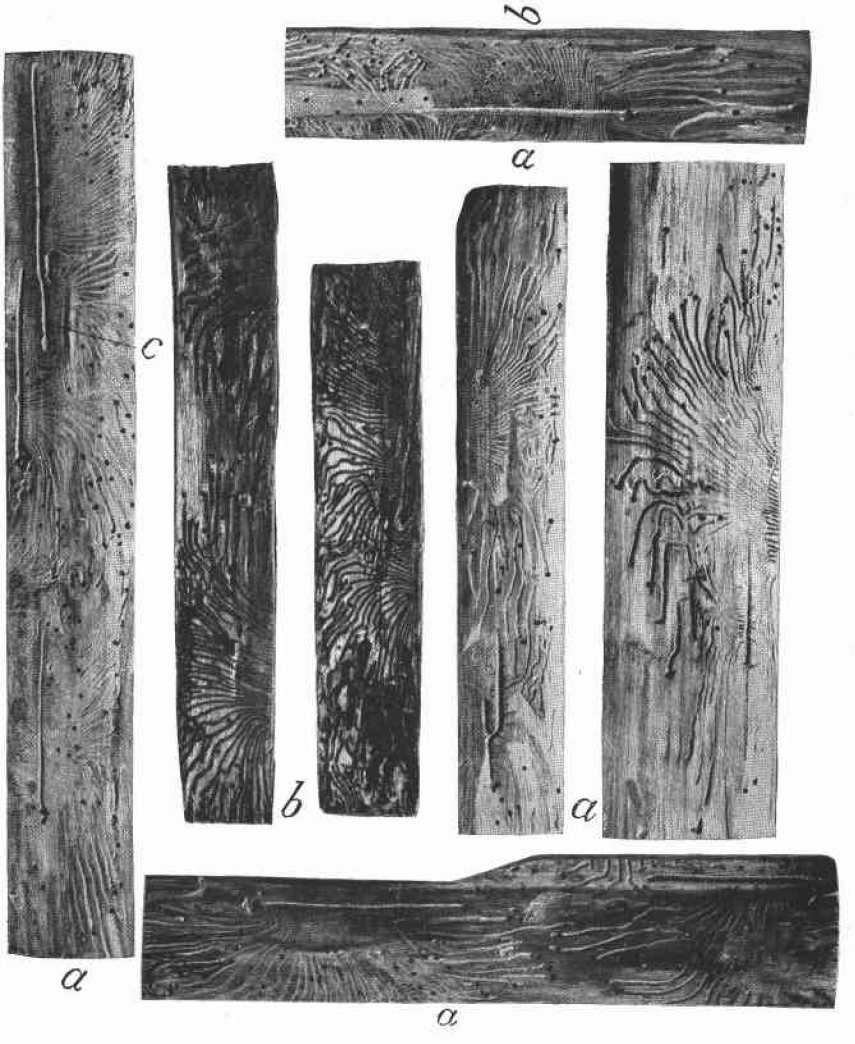
FIG. 1.—DISTRIBUTION OF POCKETS OF DISEASED WOOD.

FIG. 2.—POCKETS OF DISEASED WOOD IN VARIOUS STAGES.

SECTIONS OF REDWOOD LOGS, SHOWING BROWN ROT.



TANGENTIAL SECTION OF REDWOOD LOG AFFECTED WITH BROWN ROT.



WORK OF THE REDWOOD BARK-BEETLE.

a, Surface of wood grooved by primary galleries and larval mines; *b*, bark with galleries and mines through inner layer; *c*, primary or egg gallery (original).

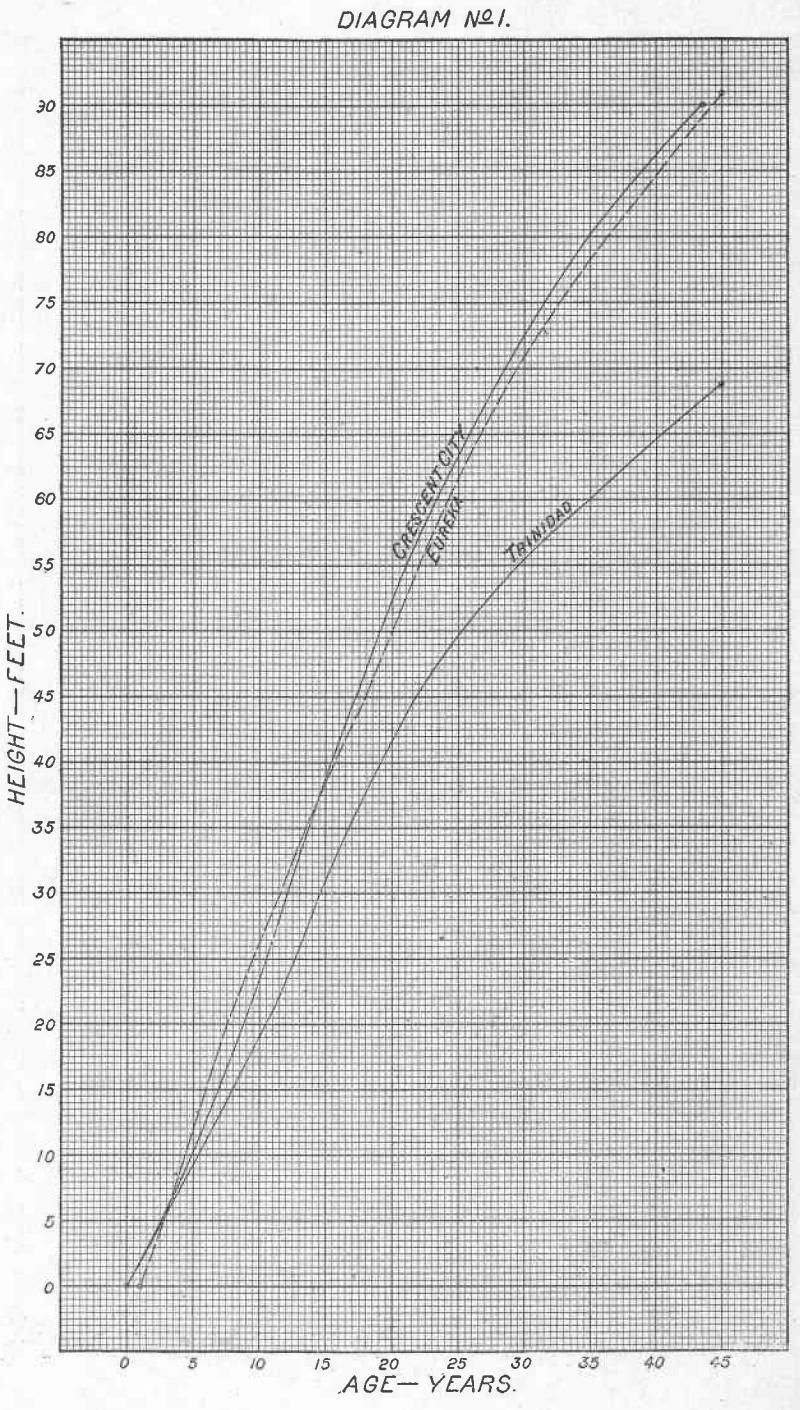


DIAGRAM No 1.
HEIGHT — FEET.
AGE — YEARS.
CRESCENT CITY
EUREKA
TRINIDAD
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90

DIAGRAM Nº2.

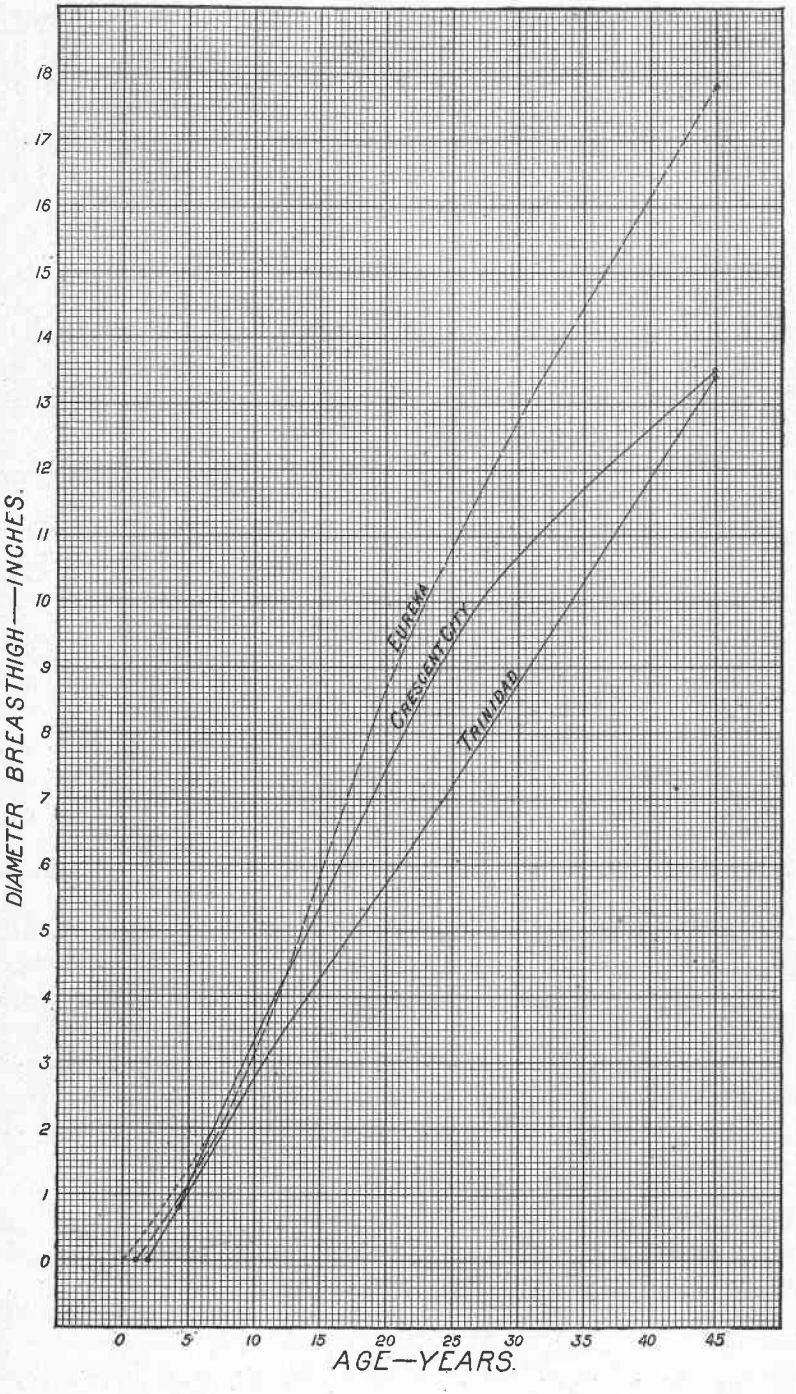

DIAMETER BREASTHIGH—INCHES.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
EUREKA
OREGON GIANT
TRINITY
0
5
10
15
20
25
30
35
40
45
AGE—YEARS.

Table 7 shows the relation between sapwood and heartwood for diameters of from 4 to 22 inches, inclusive. The amount of sapwood varies both with the diameter and the age. This table was constructed from measurements of trees taken at Crescent City, Eureka, and Arcata, which were used in the volume table, and of 400 trees at Trinidad too small to be used in the volume table.

TABLE 7.—*Width of sapwood and diameter of heartwood.*

Diameter breast-high.	Eureka.		Arcata.		Crescent City.		Trinidad.	
	Width of sapwood.	Diameter of heart-wood.	Width of sapwood.	Diameter of heart-wood.	Width of sapwood.	Diameter of heart-wood.	Width of sapwood.	Diameter of heart-wood.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
4	1.70	0.6	1.50	1.0	1.65	0.7	1.55	0.9
5	1.90	1.2	1.60	1.8	1.70	1.6	1.70	1.6
6	2.05	1.9	1.70	2.6	1.80	2.4	1.75	2.5
7	2.10	2.8	1.80	3.4	1.90	3.2	1.80	3.4
8	2.20	3.6	1.90	4.2	2.00	4.0	1.85	4.3
9	2.25	4.5	1.90	5.2	2.10	4.8	1.90	5.2
10	2.30	5.4	1.95	6.1	2.15	5.7	1.95	6.1
11	2.35	6.3	2.00	7.0	2.25	6.5	2.00	7.0
12	2.40	7.2	2.05	7.9	2.30	7.4	2.05	7.9
13	2.40	8.5	2.10	8.8	2.40	8.2	.....	.....
14	2.45	9.1	2.10	9.8	2.45	9.1	.....	.....
15	2.50	10.0	2.10	10.8	2.50	10.0	.....	.....
16	2.55	10.9	2.15	11.7	2.60	10.8	.....	.....
17	2.60	11.8	2.15	12.7	2.65	11.7	.....	.....
18	2.65	12.7	2.20	13.6	2.70	12.6	.....	.....
19	2.70	13.6	2.20	14.6	2.80	13.4	.....	.....
20	2.80	14.4	2.20	15.6	2.85	14.3	.....	.....
21	2.90	15.3	.....	.....	.....	.....	.....	.....
22	3.00	16.0	.....	.....	.....	.....	.....	.....

WHERE THE TABLES APPLY.

The tables given in this bulletin furnish the most accurate knowledge of the Redwood's growth now available. The Crescent City, Eureka, and Arcata figures are applicable to Redwood flats, where the ground is low and moist. The Trinidad tables may be applied to all that great body of Redwood of the slope type which occupies high lands and steep slopes.

CONCLUSIONS.

THE SIMPLEST MANAGEMENT THE BEST.

The narrow profits of Redwood lumbering prevent any but the simplest systems of forest management. Excellent results can, however, be accomplished by inexpensive methods.

WHAT ONE COMPANY HAS DONE.

An interesting case of conservative Redwood management is found in Mendocino County, where the Mendocino Lumber Company has

consistently logged with an eye to the future value of its holdings. The forest is the usual ridge-timber type of Redwood, Red Fir, and Tanbark Oak, varied with occasional bottom-land stands of pure Redwood; and the practice has been to cut no trees under 20 inches in diameter (Pl. VIII). The trees left standing have in a few years so restocked the ground with Redwood suckers and Fir seedlings that at a distance the hillsides look well wooded. In most places the stand is thick enough to insure clear trunks and render the danger from fire much less than it would have been under the usual system of laying bare the land.

The result has been in every way worth the effort. It cost next to nothing to make the experiment, for the trees left standing had no market value.

Instead of bare ridges washed by rain and run over by fires, there is now a young forest, which keeps the soil moist and firm and feeds the water into the streams so gradually as to cause an even flow. The land is becoming more and more valuable as the forest grows.

These advantages were gained at the trifling expense of using care to save the small trees in logging. On some areas, where the old stand was heavy, there is young Redwood only 45 years old that is 20 to 30 inches on the stump and nearly 100 feet high (Pl. IX, fig. 2). This timber is already marketable as piles. The whole area of the Mendocino Lumber Company will again bear timber and regain much of its former value.

The Mendocino Lumber Company's management of its Redwood is worthy of careful attention. The example it has set is especially to the point, because it shows a practical and cheap method of dealing with a difficult problem. At little expense and trouble the company has assured itself of future crops of timber, and has thereby considerably increased the selling price of its cut-over lands. The conditions under which these results were brought about were not exceptional, but average; they prevail throughout a greater part of the Redwood belt.

Something more than what the Mendocino Company has done may be necessary in some cases. For example, something might be spent in protecting the cut-over lands from fire until the young growth can protect itself. But whatever is done must be done with a sharp eye to the cost.

THE BROWN ROT DISEASE OF THE REDWOOD.

By HERMANN VON SCHRENK,
Bureau of Plant Industry.

The Redwood is one of a group of trees of ancient lineage, all of which are singularly free from fungus diseases. A number of parasitic fungi, such as *Leptostroma sequoiæ* Cook & Harness., and *Stricta versicolor* Fr., attack the living leaves and branches; but they occur so rarely, and then only in such small numbers, that they are practically insignificant. Dr. Farlow states that "more than thirty species have been recorded on *Sequoia sempervirens*," none of which is known to cause serious disease. In Europe, where the Redwood has been grown for many years as an ornamental tree, a species of Botrytis frequently attacks the young branches.

Redwood timber possesses lasting qualities scarcely equaled by any other wood. Although very light and porous, it has antiseptic properties which prevent the growth of decay-producing fungi. So far as is now known, none of the ordinary wood-rotting fungi grow in Redwood timber. This is an exceedingly valuable property, which should extend the use of the wood for all kinds of construction purposes.

It is because of its resistance to most forms of decay that the Redwood reaches such a great age. A remarkable fact to be noted is that the innermost rings of most of the trees are as sound now as when first formed.

Only one disease of the trunk is now known, commonly called butt, brown, or pin rot. The wood at the base of the trunk of diseased trees is filled with many pockets of dark brown, almost black, wood, irregular in form, though usually twice as broad as they are long, and ranging in size from mere specks to masses several inches in diameter (Pl. XI). They may join at the ends very much as they do at the sides. At first the individual masses of diseased wood are separated from one another by lamellæ of sound wood, and the line of division is sharply defined (Pl. X, fig. 2). In later stages of the disease the dividing lamellæ are changed into brown wood, thereby causing two or more masses to unite (Pl. X, figs. 1 and 2). The bases of the older trunks affected by this disease may be masses of brown decayed wood.

The brown wood is very brittle and has all the properties of charcoal. Under a little pressure it will crumble into a fine powder. As the wood decays, it shrinks considerably. This reduction in volume causes large cracks to appear in the brown wood, and in some instances the diseased wood separates entirely from the sounder wood and lies loose in the pocket.

The decay starts in the inner rings of the heartwood and extends outward gradually until all the heartwood is pitted (Pl. X, figs. 1 and 2). Several instances have been found where small pockets had formed in the sapwood. The brown rot starts at the ground and extends from the roots upward into the trunk for distances varying from 3 to 50 feet, and in some cases probably higher. As a rule, though, it does not go farther than 10 to 15 feet in the butt, so that by cutting off a butt log of about that length sound wood can generally be reached. The brown rot is found in older trees only, so far as observed by the writer, and seems to develop very slowly.

At present no one fungus can be determined to be the cause of this disease. Under the best conditions it is a matter of great difficulty to ascertain the cause of a disease which affects the roots and butts of trees; but in the case of the Redwood the immense size of the tree and its thick bark and formidable buttresses render an accurate determination of the disease which affects it impossible without long study. There are many saprophytic fungi which grow on the dead bark and in and about the roots of the Redwoods, but in the present incomplete state of our knowledge it would be hazardous to connect any one of them with this disease.

Reference may be made to the close resemblance of the brown rot to the pin rot of *Libocedrus decurrens*. The diseased wood of the Incense Cedar is filled with brown pockets which closely resemble those of the Redwood. These pockets occur in the tops of the trees, however. The fungus causing this disease is *Polyporus libocedris*,[a] so far found only on Libocedrus. It may be that it causes the rot of the Redwood. The fact that the Redwood disease occurs in the base of the trees ought to furnish no objection to such an assumption, since there are other cases where the same fungus attacks one tree in the crown and another nearer the ground—*Trametes pini*, for instance, which causes the disease of most of the pines in the tops of the trees, attacks *Pinus monticola* very close to the ground.

The brown rot has so far been reported as rather prevalent in northern California. Near Fort Bragg and Crescent City the writer found it in a good many old trees. It probably occurs throughout the Red wood belt.

Brown rot is not so serious as to cause alarm; it does practically lit-

[a] von Schrenk, H. A disease of Taxodium known as Peckiness; also a similar disease of *Libocedrus decurrens*. Rep. Mo. Bot. Garden, 11:2, 3, 1900.

tle harm. The disease may possibly develop in timber that was partly decayed when cut from the tree, although in several cases observed such timber was used for posts or ties and did not deteriorate further. Where strength is not the first requirement, wood in the early stages of decay may be classed in a low grade for posts or ties.

Measures for preventing decay in Redwood are impracticable.

DECAY IN REDWOOD POLES.

As this bulletin goes to press the writer is in receipt of samples of decayed Redwood taken from telegraph poles in California that were set in 1877. They were 12 inches square at the butt and were set 5 feet into the ground. About half of them showed signs of decay this year; half of this number had decayed from the outside in, while the other half showed rot within the poles. Many poles that were broken off by a windstorm had been decayed to a depth of several inches.

The decay very closely resembles the red rot. The diseased wood is red-brown, brittle, and porous. In cases where the decay started on the outside, the spring wood cells were attacked first, leaving the summer cells practically intact. In the decayed wood many colorless hyphæ traverse the walls, and here and there are found groups of colored spores. No fruiting organs of any fungus occurred on the samples sent.

PREVENTION.

The decay of poles of the Redwood can probably be retarded considerably by thoroughly drying the poles before setting them. Careful inspection will often show, at the butt end, signs of the brown rot disease of the living tree. Poles from such trees should not be used. Dry poles can be coated with some preservative substance, which will probably retard decay considerably. Tests are now under way with the Redwood to determine the best method for preventing this rot.

EXPLANATION OF PLATES.

PLATE X. Cross sections of Redwood logs (Fort Bragg, Cal.), showing brown-rot disease. Fig. 1 shows distribution of pockets. Since the log lies partly in a stream, only a part of the section is exposed. Fig. 2 shows a small part of a section with pockets in various stages.

PLATE XI. Tangential section of Redwood log, showing the decayed wood in long pockets.

INSECT ENEMIES OF THE REDWOOD.

By A. D. HOPKINS,
In Charge of Forest Insect Investigations, Division of Entomology.

In 1881 Mr. Henry Edwards described a pitch worm as very destructive to *Sequoia sempervirens.*[a] In 1899 the writer found two species of bark beetles living in the bark of recently felled trees.[b] In 1900 the Division of Entomology obtained information from Mr. J. E. Norton, through a lumber firm in San Francisco, indicating that Redwood lumber was immune from attack by termites, or white ants;[c] and this was verified by experiments conducted in the Philippine Islands by Mr. D. N. McChesney, as reported by Capt. George P. Ahern, Chief of the Philippine Forestry Bureau.[d]

This embraces about all that has been published relating to Redwood insects.

These insects and their work may be described in more detail as follows, the small type indicating information from other authors and ordinary type that based on the writer's observations, whether previously published or not:

THE SEQUOIA ÆGERINIAN, OR REDWOOD PITCH WORM.

(*Vespamima sequoiæ* Hy. Edw.)

This relative of the common peach-tree borer is described by Henry Edwards[a] and other writers[e] as very destructive to Redwood.

Mr. Beutemüller says:

> According to Hy. Edwards this species is devastating the pine forests in Mendocino County, California, and is particularly destructive to the Big Tree (*Sequoia sempervirens*), *Pinus ponderosus*, and *Pinus lambertiana*. The eggs are laid in the axils of the branches, the young caterpillar boring in a tortuous manner about its retreat, thus diverting the flow of sap and causing large resinous nodules to form at the place of its workings. These nodules gradually harden, the branch then dies, and the tree at last succumbs to its insignificant enemies. Hundreds of fine trees in the forests of the region are to be seen in various stages of decay. The moths make their appearance in June and July, during which period the eggs are deposited. The

[a] Papilio, vol. i (1881), p. 181; also Bul. U. S. Ent. Comm. No. 7, Appendix.
[b] Bul. 31, N. S., Div. Ent., U. S. Dept. Agr., pp. 7, 19, 20.
[c] Bul. 30, N. S., pp. 95, 96.
[d] As quoted in Bul. 33, Bur. Forestry, p. 20.
[e] Beutemüller, Am. Mus. Nat. Hist., vol. i, part vii, pp. 263, 264.

larvæ begin to form their cocoons in December and January, being an evidence that the insect is double brooded. The larvæ when fully grown line the channel in the resinous nodules with silk, forming a sort of cocoon, in which they transform to pupæ.

This insect was observed by the writer in September, 1902, in the vicinity of Del Monte, Cal., where it occurred in the matured larval stage in large masses of pitch on the trunks of living Monterey Pine. According to information from Mr. Lee, the gardener in charge of the Del Monte grounds, it does considerable damage to the tree.

The work of probably the same insect was also observed in the same grounds on Lawson's Cypress, causing deformities on the main trunk and branches.

REMEDY.

In comparatively small areas it would not be difficult to dig the worms out of the pitch with a knife during the fall and winter months. This would serve to greatly reduce their numbers and to prevent serious depredations in future. In the case of larger areas of forest trees there is, so far as known, no practical remedy.

CEDAR BARK-BEETLES.

There is a certain class or genus of bark-boring beetles which, so far as has been determined in different countries, inhabits only the cedar and cedar-like trees. Owing to this habit they may properly be termed cedar bark beetles. They belong to the order Coleoptera, family Scolytidæ, and genus Phlœosinus. Two species of this genus were found by the writer in living and partly living bark of recently felled Redwoods near Guerneville, Cal., in April, 1899.

The Redwood Bark-Beetle.

(*Phlœosinus sequoiæ* Hopk. MSS.)

This is a common species, which heretofore has been confused with a much less common one described by Dr. Le Conte under the name *cristatus*. It is a medium-sized, stout, black beetle (fig. 1), the male and female of which bore through the outer bark and excavate long, nearly straight burrows or galleries through the inner living or dying bark and surface of the wood, as shown in the illustration, Plate XII. The eggs are closely placed along each side of the gallery in little notches excavated for the purpose. These soon hatch into minute white grubs, which immediately commence to feed upon the inner layers of bark and outer layers of wood. They continue to feed thus, extending meanwhile their food burrows, and increase in size until they attain their full growth as grubs (larvæ). Then they enter the wood for a short distance and excavate a cavity or kind of cell, in which they change to the inactive or pupal stage. Here they remain

until their legs and wings are fully developed, when, as fully matured adults, they bore their way out through the wood and bark, producing the shot-hole condition, as shown in the illustration.

It is known that the Redwood bark-beetle flies early in April and attacks the living bark of recently-felled trees, but as yet we have no positive evidence that it attacks standing living trees. The fact, however, that a near relative, the Lawson's Cypress bark-beetle, will attack and kill trees, indicates that under specially favorable conditions this species may do likewise. Therefore any unhealthy condition of the young or old trees in which the leaves toward the top turn yellow and reddish brown should be examined for traces of the beetle's work in the bark and at the base of living twigs.

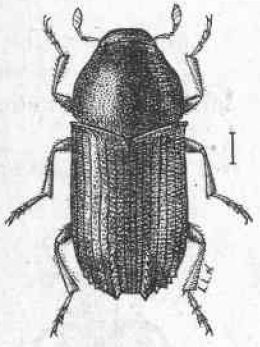


FIG. 1.—The Redwood bark beetle: adult—enlarged (original).

REMEDY.

If it should be found that this beetle is attacking living trees, its known habit of infesting recently-felled trees suggests that it might easily be controlled by cutting and barking all infested trees between the 1st of September and the 1st of December, and by providing a few trap trees to attract those beetles that escape. This may be accomplished by felling a few trees in December. Then after the adults have entered the bark in the spring and the larvæ (grubs) are about half-grown, or before they enter the surface of the wood, if the bark is stripped from all the infested parts of the trunk and larger branches, the broods will be destroyed. It will not be necessary to burn the bark thus removed, because the drying of the inner surface will kill the young stages, while some of the natural enemies of the beetle which would otherwise be destroyed by burning might survive to be of service in reducing the numbers of those which are not attracted to the trap trees or which breed in the standing timber. The tops and smaller branches, which can not conveniently be barked, should be burned, but they should first be left until the broods are nearly developed, in order that the parasites and other natural enemies may have time to develop and emerge to continue their good work. It would be best if this material were burned just before the beetles begin to emerge.

The life history of the Redwood bark-beetle has not been worked out, but the insect is probably double-brooded, the first brood emerging about the middle of summer and the other the following spring. If this is true, it is of the greatest importance to protect, so far as possible, the natural enemies of the first brood, in order that they may continue their depredations on the second brood.

Evidence was found at Guerneville, in the vacant brood galleries in bark that had been infested the previous summer, that many of the broods had been destroyed by minute wasp-like parasites and predaceous enemies. It is probable that the natural enemies of other species of the same genus will attack it, especially those of the Lawson's Cypress bark-beetle.

Lawson's Cypress Bark-Beetle.

(*Phlœosinus cupressi* Hopk. MSS.)

This is the other species found by the writer in Redwood at Guerneville, Cal. It was also found, about the same time, in a recently dead Monterey Cypress in Golden Gate Park, and in a small, dying Japanese Cypress[a] in the University grounds at Berkeley.

The general character of this beetle (fig. 2) and of its work is similar to that of the preceding beetle, except that it is a smaller, less shining insect, and that the larvæ do not enter the surface of the wood to change to the adult, but undergo their transformation in their burrows in the inner bark.

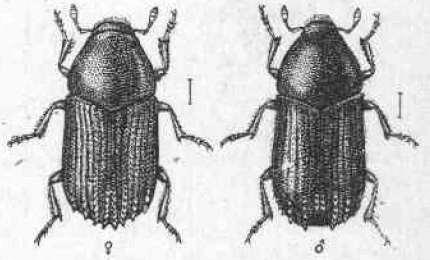


FIG. 2.—The Lawson's Cypress bark-beetle: adults, male and female (original).

The adult's habit of attacking and killing trees and of feeding on the bark of living twigs is a characteristic which has not been observed in any other species of the genus. Recently an article relating to this insect was published by Mr. Carroll Fowler,[b] under the above common name and the technical name *Phlœosinus punctatus* Lec.[c] Mr. Fowler's account of this beetle and its destructive work is as follows:

During the past year our attention has been repeatedly brought to the sickly condition of many of our Lawson's Cypress trees. This is one of our common and most handsome ornamental trees, and therefore the way in which they are dying is a matter of no small concern to many parties.

The first indication one has that the tree is diseased is in the unhealthy appearance of the upper leaves. These turn brown and die, and gradually those below take on a similar appearance, until they are all killed. If the trunk and branches are examined, it will be noticed that they are thickly punctured with small holes. Then if some of the bark is cut, it will be found to be dead in many places, especially near the top of the tree, not infrequently extending entirely across the branch. There will also be noticed small burrows just under the surface, and if it is in the winter there may usually be found at one end of each burrow a small white grub or dark-

[a] Identified by Professor Davy as *Cryptomeria*.

[b] Rept. Univ. of Cal. Agric. Exp. Sta., 1898–1901, Part I, pp. 80, 81.

[c] The writer has examined the specimens on which this identification was based, and finds that it is quite different from *P. punctatus*, a common enemy of the Giant and other Western cedars.

brown beetle. This beetle is one of the engraver beetles, so called on account of the appearance of the system of burrows. The central tunnel is made in the sapwood by the mother beetle, which deposits eggs at frequent intervals. The larvae hatching from these eggs bore off at right angles. When the beetles are numerous the trees are frequently encircled, so that the food supply is cut off. The attack is usually begun at the top of the tree, and extends downward from year to year.

This family of beetles generally attacks trees that are not in a very healthy condition, although when they become very numerous they take to healthy trees. Such has proven to be the case with the Lawson Cypress beetle. Those trees which have suffered most severely from drought lately have been most severely injured by the pest, while those in the same locality which have been kept thrifty are in many instances almost free.

After these borers have once gotten into a tree there is no way in which they can be killed without injury to the tree. Where the attack is severe the trees should be cut down and burned during the winter while the insects are in their burrows. They begin to eat their way out as early as March, although some appear much later; hence the destruction should be done earlier than this. Trees only slightly affected need not be destroyed, since by fertilization with Chile saltpeter and frequent watering they may be gotten into such a healthy condition as to withstand, and in a measure resist, attack. Professor Hilgard has by this means saved some of his trees, which were beginning to show marked signs of injury. Prompt measures should be taken against the insect, not only to save the trees attacked, but also to prevent the numbers from becoming so great as to cause them to spread to healthy trees.

Dr. Hilgard informs the writer that his experiments with Chile saltpeter were very successful indeed, and that he believes little harm would result from the attack of this insect if the trees were kept in a healthy, vigorous condition.

Early in September of this year the writer had an opportunity to make some additional observations on the habits of this beetle at Del Monte and in the famous Monterey Cypress grove at Cypress Point, Cal. These observations indicate quite clearly that the Monterey Cypress is the original food plant, and that the common use of this tree for hedges and ornament in private grounds and parks throughout western California has enabled the beetle to extend its range from its original restricted home, and thus to acquire the habit of attacking other species of Cypress and the Redwood. This change of habit and extended range of distribution, as has been demonstrated by many of our worst insect pests which have come from other countries and other sections of our own country, involves variation in normal habit, and even in structure, which renders a species that is comparatively harmless in its original home most destructive under the influence of new environments.

An examination of the Cypress grove showed no sign that this beetle had attacked standing trees, although it was found to be exceedingly common in the bark of broken branches and storm-felled trees. The natural enemies of the broods occurred in great numbers, and up to the date of writing the number of adult parasites which have emerged from sections of branches placed in breeding jars has been exceedingly large.

An examination of Lawson's Cypress, which had been transplanted in the park at Del Monte, showed that the Lawson's Cypress bark-beetle has the common habit of boring into the living bark at the base of perfectly healthy twigs (fig. 3, *a*). It was also found that this injury would often result in the death of the lateral and deformity of the central twigs (fig. 3, *b*), while in many cases the wound would be covered with gum (fig. 3, *c*) and heal without any serious harm. This is conclusive evidence that the beetle attacks healthy plant tissue of the Lawson's Cypress. This was further verified by specimens of

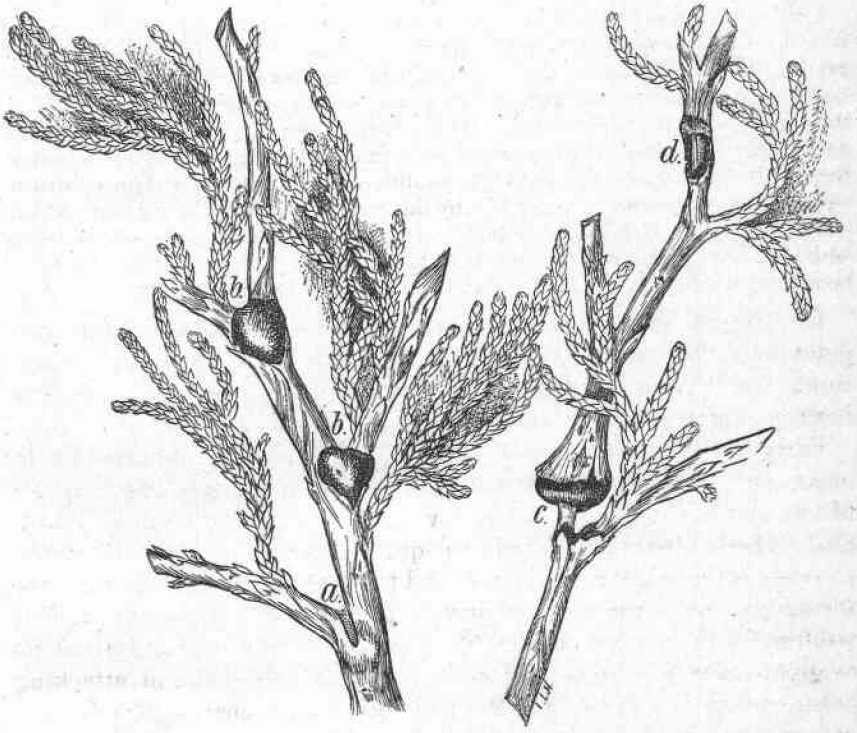


FIG. 3.—Work of the Lawson's Cypress bark-beetle in twigs of living trees: *a*, burrows at base of twig; *b*, *b*, wounds covered with gum; *c*, deformed twig; *d*, wound where twig has died and fallen (original).

wood from a Lawson's Cypress said to have been killed by the beetle, which were kindly submitted to the writer by Professor Woodworth, entomologist of the California experimental station at Berkeley. An examination of this specimen showed in the healed-over wounds made by the beetles that at least two successive annual attacks on the living bark had been made before the tree died. Nevertheless, the annual rings of wood showed nearly a normal growth and indicated an otherwise healthy condition up to the year in which the tree died. It would therefore appear that while the insect breeds normally only in the felled or otherwise injured trees, it is capable of attacking healthy

trees and of causing the death of transplanted Monterey, Lawson's, and other species of Cypress. The fact that it has been found in Redwood renders it an enemy of especial interest in this connection, and one which should be carefully watched.

Recent observations by the writer near Mill Valley, California, and along the railroad leading up the western slope of Tamalpais, of an unhealthy condition of the tops of second-growth Redwood, suggest that this heretofore unnoticed trouble may be due to the work of the Lawson's Cypress, or the Redwood, bark-beetle. It is reported that much of the Lawson's Cypress in the country mentioned has recently died. If this has been caused by the Lawson's Cypress bark-beetle, as it probably has, the same insect may be to blame for the diseased condition of the Redwood.

REMEDY.

The maintenance of a healthy, vigorous growth by the application of Chile saltpeter or other fertilizers which may hereafter be found especially useful for this purpose, in addition to irrigation during severe drought, as suggested by Dr. Hilgard, is undoubtedly a most excellent provision against attack, and wherever practicable should be adopted. Otherwise, where forests of Redwood or other trees are infested or threatened by an invasion of this enemy, the recommendations for cutting and barking infested trees and for providing trap trees for the control of the Redwood bark-beetle should be adopted.

PARASITES.

The parasite reared from Monterey Cypress bark infested by this beetle was submitted to Mr. William H. Ashmead, the recognized authority on this class of insects, who found that it is a Cecidostiba sp. The abundance of this parasite, in what is evidently the normal home of the beetle, suggests that this species may very profitably be introduced into localities where the beetle is carrying on its destructive work on the same or other trees. This could easily be accomplished if medium-sized branches were cut from trees in the original grove during February, left there until thoroughly infested with broods of the beetles and their parasites, then, just before time for the parasites to emerge, cut into sections about 1 foot long and taken without delay to the desired localities and there placed among the tops of the felled trees. The parasites would then emerge and readily find their victims. Any efforts of this kind, however, should be made by an entomologist, or under his supervision.

THE MONTEREY CYPRESS BARK-BEETLE.

(*Phlœosinus cristatus* Lec.)

This is another Cedar bark-beetle which is closely allied to the preceding, and is the true *cristatus*, with which several other species have heretofore been confused.

In February, 1893, specimens of this insect and its work were sent to the Division of Entomology by Mr. J. Dickee, Riverside, Cal., with a statement that it was doing great damage to Cypress hedges in Contra Costa County, Cal. Nothing further is known of its habits, but it is possible that it may also attack the Redwood. (Fig. 4.)

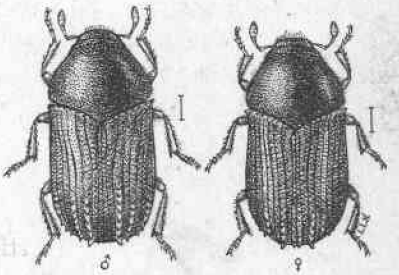


FIG. 4.—The Monterey Cypress bark-beetle: adults, male and female—enlarged (original).

The other species of insects found by the writer in Guerneville, Cal., in Redwood, may be briefly mentioned as follows:

Phymatodes decussatus Lec. This long-horn beetle (Cerambycid) was reared from a section of a small dead tree, and the larva of probably the same insect was found in the bark of a dying tree.

Callidium janthinum Lec. A dead adult of this well-known enemy of Cedar was found on the bark of a log, where it had evidently bred.

IMMUNITY OF REDWOOD FROM ATTACK BY TERMITES OR WHITE ANTS.

Probably the first officially published record of the relation of Redwood to the wood-destroying termites of tropical regions was that which appeared in Bulletin No. 30, new series, Division of Entomology, U. S. Department of Agriculture (1901), p. 95. This reference is quoted as follows:

> December 13, 1900, we received a communication through a firm of lumber merchants of San Francisco, Cal., which appears to indicate that the California Redwood lumber is immune to the attack of white ants or termites. Through the firm in question we received a letter from Mr. J. E. Norton, dated December 4, relating to the resistance of this wood to the so-called Manila white ant of Annia. His letter is in substance as follows:
>
> "In the latter part of 1898 I secured from a transport a piece of Redwood lumber in a yard at Manila. The spot was damp, and various pieces of timber all around showed evidence of the existence of the ant in abundance. This piece lay undisturbed for a period of five or six months, and when examined was found as sound as when put there, not having been attacked by any insects. The Chinaman, owner of the lumber yard, was still doubtful and undertook to get it eaten by putting it in different places under different conditions, such as on top of pieces already inhabited, between boards, and underneath piles, and finally, after three months, put the sample on exhibition in his office with the following placard: 'Madera Colorado de California, no se comen Annai.'

"The quartermaster's lumber yard had piled for some four or five months a quantity of Redwood, which upon my departure in October was still free from ants.

"John MacLeod, of Manila, has a room in one of his houses finished in Redwood, constructed over fifteen years ago, and to this day three-fourths of the original amount remains still in good condition, one-fourth having been worn out and replaced by other lumber."

Reference is made in Bulletin No. 33 of the Bureau of Forestry (p. 20) to certain experiments conducted in Manila, P. I., by Mr. D. N. McChesney, as reported by Capt. George P. Ahern, Chief of the Philippine Forestry Bureau, in which it would appear that Redwood, Incense Cedar, and Western Hemlock were not attacked, while Douglas Spruce, Bull Pine, and Engelmann Spruce were seriously injured.

The reader is referred to Circular No. 50, second series, Division of Entomology, U. S. Department of Agriculture, by C. L. Marlatt, for a general description of white ants, their habits and work.

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