The deterioration of Beetle-Killed Douglas-Fir in Western Oregon and Washington

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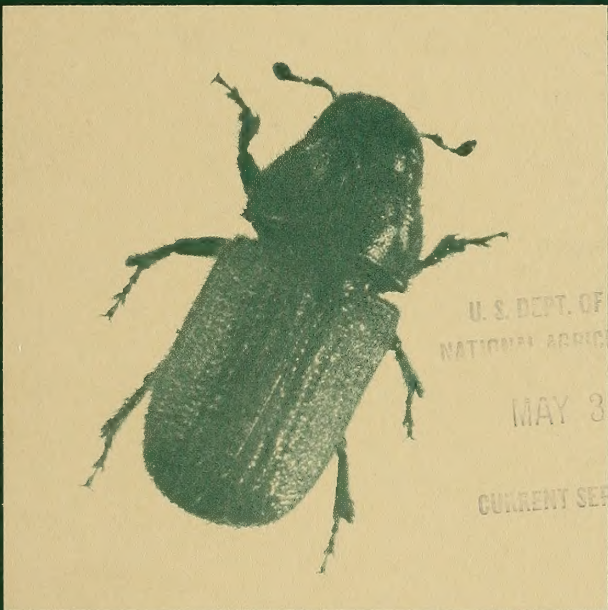

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Beetle-killed Douglas-firs near Marys Peak, Siuslaw National Forest, Oreg. Photograph taken 6 years after trees died.

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SUMMARY

The Douglas-fir beetle sporadically kills large volumes of Douglas-fir sawtimber in western Oregon and Washington. Salvage of dead timber before it deteriorates beyond economic use is often a major problem for forest-land owners and managers. A study was started in 1952 to determine how fast beetle-killed trees deteriorate, the factors influencing the rate of deterioration, and the causal agents. Preliminary reports were issued in 1952 (8) and 1954 (9).[1] The present report completes the study. Highlights of the results are:

- Volume of wood deteriorated increases steadily with time, as follows:

Years after death	Percent deteriorated	
	(Board-foot basis)	(Cubic-foot basis)
1	3	1
3	19	9
5	33	24
7	45	38
9	65	56
11	79	70

- Quantitative wood deterioration the first year following death is minor, but stain and pinhole borers reduce quality for some uses. After 3 years, the high-quality sapwood is extenisvely deteriorated. By 5 years, there is significant decay penetration of the heartwood. Deterioration is slower in the heartwood, but by 9 years the typical beetle-killed tree is a broken snag, with only a sound core remaining in the lower half of the bole. After 11 years, deterioration is usually complete except for the butt log of the largest trees.
- Rate of deterioration is strongly related to age and size of tree and, to a lesser degree, to locality – being faster in second growth than in old growth, in small trees as compared with large, and in the Cascade Range as compared with the Coast Ranges.
- Cruisers can use external tree characteristics to estimate time since death and the attendant amount of deterioration. Some tree characteristics useful in backdating are: relative proportion of small and large branches present, proportion of bole remaining (top breakage), bark slippage, and kind and size of conks.
- The red belt fungus (*Fomes pinicola*) is by far the most important agent causing deterioration. Among the insects, pinhole borers cause degrade during the first year; only minor damage results from other wood borers for about the first 5 years. Later, wood borers may penetrate deeply into otherwise sound heartwood.
- Felling breakage is related to time since death and size of tree – when expressed in terms of total number of breaks or height of the first break.
- When established logging priorities are for beetle-killed timber, maximum value will be recovered if consideration is given to: age and size of the timber, locality differences in deterioration rate, accessibility of the timber, topography as it affects felling breakage, products to be manufactured, and changing utilization standards.

[1] *Numbers in parentheses refer to selected references, p. 20.*

INTRODUCTION

The Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.) is a major killer of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) throughout the range of the host tree. Killing has been particularly severe in the Douglas-fir subregion of western Oregon and Washington. All known major outbreaks of the beetle in this subregion have been triggered by severe forest disturbances, particularly blowdown from extensive storms but also by large forest fires. Storms in the winters of 1949-50 and 1950-51 were followed by a beetle outbreak which killed an estimated 3 billion board feet of mature Douglas-fir over an area of about 4.8 million acres. A major beetle infestation also developed from blowdown from the catastrophic Columbus Day windstorm of 1962. A survey in the summer of 1965 showed that 2.6 billion board feet had been killed to that time in western Oregon. It was estimated that more than 200 million board feet of green timber adjacent to the 1933 Tillamook Burn was killed by the Douglas-fir beetle.

Major timber salvage programs were developed following these disturbances and subsequent beetle outbreaks. However, the affected areas were so large and scattered, and access roads so limited, that only a part of the timber was salvaged before it deteriorated beyond economic recovery. Forest managers and owners have asked for better information on the rate of deterioration of the affected timber in order to schedule salvage programs in accordance with other forest management and harvesting considerations.

Considerable information on the rate of deterioration of fire-killed Douglas-fir is known from the research by Kimmey and Furniss (7), and of blowdown from that by Boyce (3), Buchanan and Englerth (2), and Childs and Clark (4). But essentially nothing was known about deterioration rate of beetle-killed Douglas-fir until the study reported here was started in 1952. A preliminary unpublished report was issued in 1952 (8), and an interim Pacific Northwest Forest and Range Experiment Station research paper was published in 1954 (9). The present paper includes information from the two early reports and much additional data gathered since.

This study was possible only through the cooperation of several organizations and many individuals. The Weyerhaeuser Co. provided much of the early impetus for the investigation and participated directly by reserving study areas and giving assistance in felling and dissecting the study trees. Several National Forests in Oregon and Washington set aside groups of beetle-killed trees, some of which were felled periodically as time passed.

Special acknowledgment is made to the following individuals who participated directly in the study or contributed in a substantial way: P. G. Lauterbach and Dr. J. E. Lodewick of the Weyerhaeuser Co.; John Shallenberger of the Rogue River National Forest; and Dr. E. Wright, now retired, of the Pacific Northwest Forest and Range Experiment Station who helped initiate the study in 1952, made many of the early examinations, and coauthored the two earlier reports.

STUDY OBJECTIVES

The principal objectives of the study were:

- To provide forest managers of the Douglas-fir subregion with estimates of the amount of wood deterioration in standing beetle-killed Douglas-firs, for varying periods after death.
- To provide field foresters with photographs and descriptive guides for estimating the time trees have been dead.
- To develop estimates of breakage when felling beetle-killed Douglas-firs.
- To determine the principal fungi and insects causing deterioration.

STUDY AREAS AND METHODS

Beetle-killed trees of known date of death from 10 different areas were used. The areas were selected to sample a variety of stand and climatic conditions in the Douglas-fir subregion (fig. 1). The 10 areas represented were:

Area Name	Generalized location	Estimated stand age
		(Years)
Cispus River	Central Washington Cascades	180
Clackamas River	Northern Oregon Cascades	240
Mapleton	West-side Oregon Coast Ranges	140
Marys Peak	East-side Oregon Coast Ranges	250-350
Millicoma	Southwest Oregon Coast Ranges	180-200
North Umpqua	Southern Oregon Cascades	160
St. Helens[1]	Southern Washington Cascades	100-110
Sutherlin[1]	Central Oregon Cascades	250-300
Willamette	Central Oregon Cascades	200-225
Wind River	Southern Washington Cascades	100-110

[1] *Examined only in 1953 or 1954.*

Although it was recognized that deterioration rate usually varies according to tree age, the scope of the study did not permit systematic sampling by age classes. Arbitrarily, 160 years of age was used to separate the study trees into "second growth" and "old growth." Accordingly, the study trees at Mapleton, North Umpqua, St. Helens, and Wind River were classed as second growth and those in the other areas as old growth.

To insure that study data were recorded to consistent standards, it was necessary at the outset to define "deterioration." It was decided that any wood that could be converted into at least low-quality lumber would be classed as sound. Accordingly, blue-stained wood or wood with a few pinholes from insects was not classed as deteriorated. However, any wood that was weakened physically by decay organisms was regarded as deteriorated and unusable.

Deterioration analyses usually were made at 2-year intervals. Five trees, representing the diameter range present, were selected on each study area and felled. Early in the study, when rot penetration was superficial and varied slightly, the trees were usually bucked at 32-foot intervals. After 1954, the trees were cut at 16-foot intervals, with additional cuts if the decay pattern was highly variable (fig. 2).

Three methods were used during tree dissections to record sound and deteriorated volumes:

1. In 1952 and 1953, the tree measurements and rot data were plotted on U.S. Forest Service Form 558a and the volumes computed in cubic feet from planimeter measurements. Board-foot volumes were computed by the Scribner Decimal C scale with no deductions made for shake, heart rot, butt rot, or other defects present before the tree was killed by the beetles.
2. In 1958, a scale diagram was made of each log cross section after it was cut; the gross, decayed, and sound areas of the log ends were drawn to scale. The decayed and sound areas were then measured by planimeter on the diagrams and the respective volumes for each log computed by Smalian's formula. Board-foot volumes were again computed by the Scribner Decimal C scale from diagram measurements. After one season, this method was abandoned because it was too time consuming, although it provided accurate log and tree volume data.
3. In 1960 and 1962, a "four-diameter" method was used to record the field data. Beginning at a point on the perimeter of

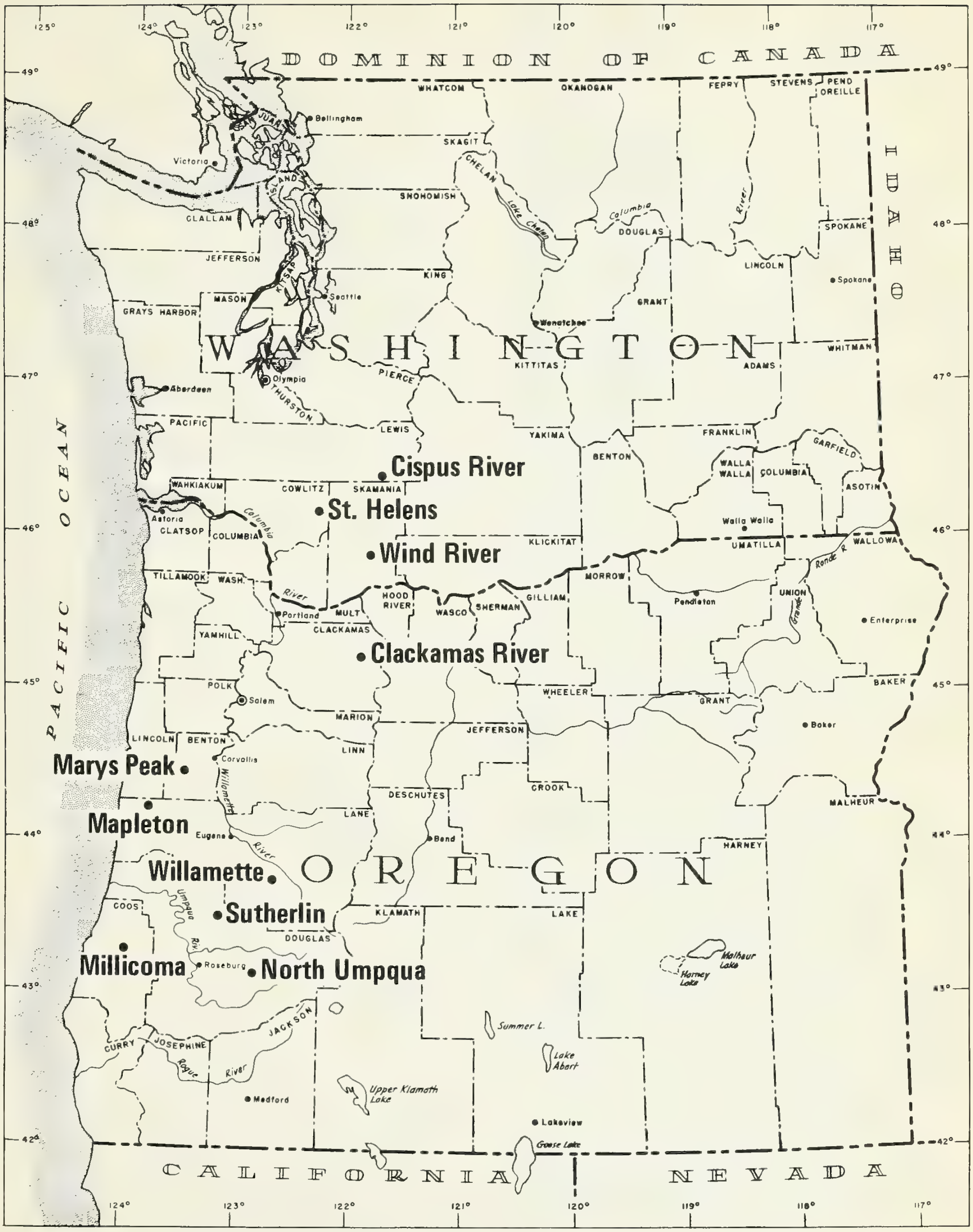


Figure 1. Location of beetle-killed Douglas-fir study plots.

Figure 2.
Field procedures for obtaining deterioration data.

the log end (usually the point of maximum rot penetration), a diameter reading was made – noting the total diameter, and the diameter of the sound wood area. Three additional readings were made in the same way at successive 45^{o} angles from the initial measurement. The readings were averaged and used to compute the gross, decayed, and sound wood cubic volumes for each log by Smalian's formula. Board-foot volumes were computed by the Scribner Decimal C scale using the same diameter measurements. A comparison of the scale diagram method and the four-diameter method showed that individual tree volumes differed by each method, but the overall totals were not significantly different on a statistical basis (P=0.01).

Throughout the study, isolations from wood samples were made on 2 percent malt agar to determine the fungi associated with the progressively deteriorating trees. Prior to 1958, random samplings were made; during the 1958 dissections, one sample was taken from each cut from all felled trees; and in 1960 and 1962, three replicate samples were taken from each cut but from one tree only at each locality.

Field records were taken on penetration of and damage to logs by wood-boring insects. Sections of infested logs were also caged to rear borer larvae to the adult stage for positive identification, but relatively few of the borers completed development under laboratory conditions.

Near the end of the study, felling breakage was assessed. The location and extent of each felling break was recorded for later analysis. However, breakage was ignored in computing deterioration volumes.

To develop guides for determining how long standing beetle-killed trees have been dead, both photographic and visual descriptions were made. Permanent photo points were established, and photographs were taken at 2-year intervals. Field glasses were used as needed. Data were recorded on the appearance and retention of foliage, twigs and small branches, large branches, bark (intact, cracking, sloughing), top breakage, and the incidence of fungus fruit bodies.

RESULTS

Deterioration Related to Number of Years Dead

The progression of deterioration (primarily decay) during the 11-year study period is shown in table 1 and figures 3, 4, and 5. Because of variation in the size, number, and locality of trees dissected at the 2-year sampling intervals, these data show some annual departures from an otherwise straight-line relationship between passage of time and amount of wood deterioration. However, the trend over the 11-year study period is consistent. Deterioration advanced from about 3 percent at the end of the first year to almost 79 percent at 11 years on a board-foot basis, and from 1 to 70 percent on a cubic-foot basis.

The **first year** following death, loss usually is confined to sapwood degrade from wood-staining fungi and pinhole borers (ambrosia beetles). Occasionally some incipient decay may occur, making the sapwood somewhat brash.

By the end of the **second year** after death, sapwood rots are well established with significant wood loss, particularly in second-growth trees.

The progression of decay in trees dead longer than 2 years can perhaps best be visualized by study of the diagrams in figure 6.

After **3 years**, the top one-third of the bole and a small band near the ground are the only

Table 1. **Average rate of deterioration of beetle-killed Douglas-fir in western Oregon and Washington**[1]

Number years dead	Number trees dissected	Average d.b.h. per tree	Average gross volume per tree	Total gross volume	Total deterioration volume	Deterioration	Average gross volume per tree	Total gross volume	Total deterioration volume	Deterioration
		Inches	Board-foot measure (Scribner)			Percent	— Cubic-foot measure —			Percent
1	18	26.2	1,221	21,970	720	3.3	205	3,688	52	1.4
2	46	34.1	2,711	124,710	23,040	18.5	421	19,358	2,272	11.7
3	7	21.0	561	3,930	760	19.3	123	861	75	8.7
4	8	23.9	971	7,770	1,350	17.4	169	1,353	163	12.0
5	14	26.4	1,347	18,860	6,180	32.8	220	3,085	750	24.3
6	5	25.4	1,042	5,210	1,580	30.3	177	884	221	25.0
7	33	31.6	2,156	71,160	32,230	45.3	329	10,862	4,167	38.4
8	18	23.0	830	14,940	11,260	75.4	132	2,381	1,460	61.3
9	36	29.7	1,589	57,200	36,905	64.5	251	9,049	5,076	56.1
10	7	21.1	641	4,490	4,490	100.0	110	767	703	91.7
11	23	29.8	1,649	37,930	29,880	78.8	253	5,829	4,067	69.8
	215	29.0	1,712	368,170	148,395	40.3	270	58,117	19,006	32.7

[1]Basis: 215 trees from 10 areas; volume to an 8-inch top.

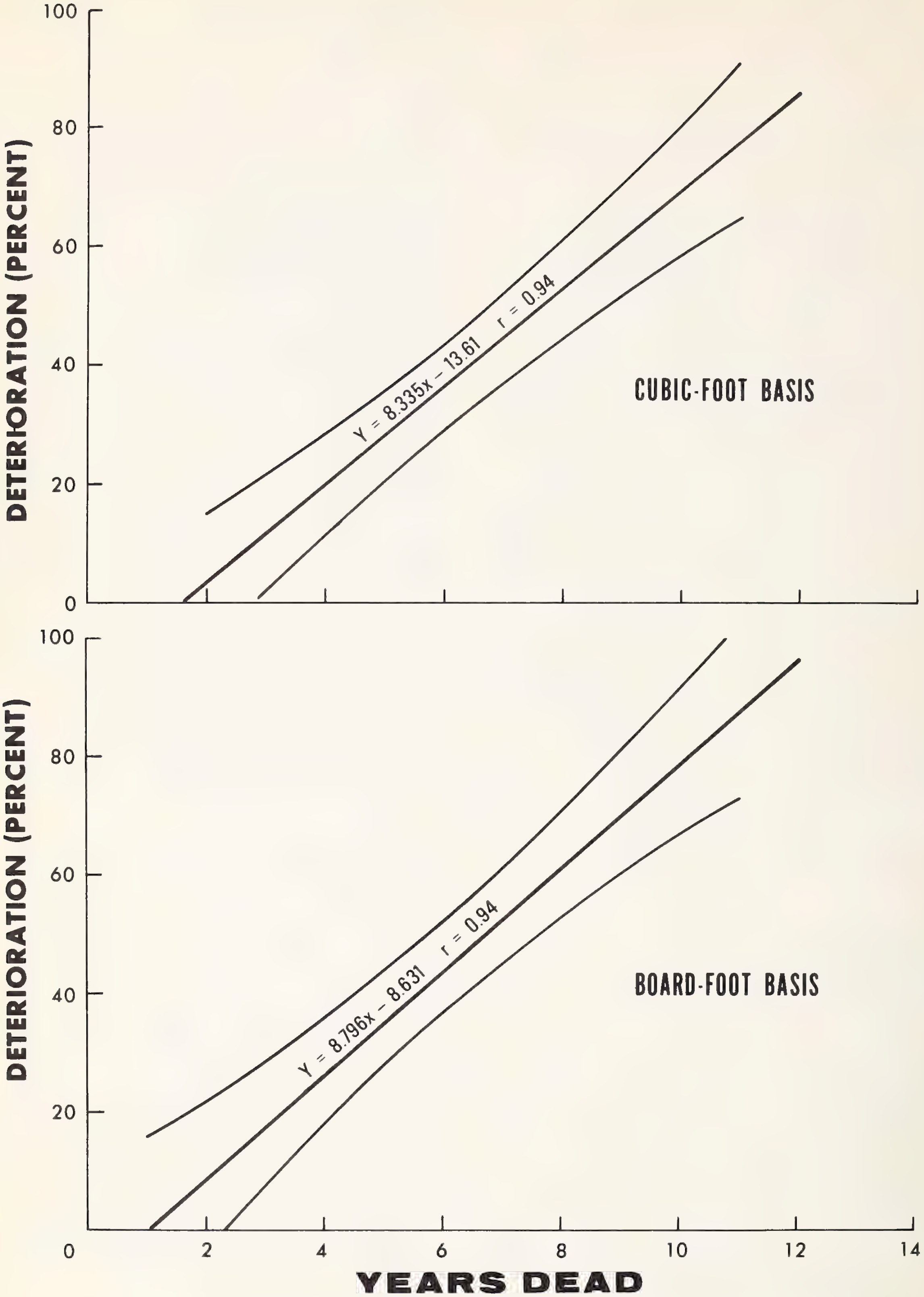


Figure 3. Relationship of board-foot and cubic-foot deterioration to number of years dead.

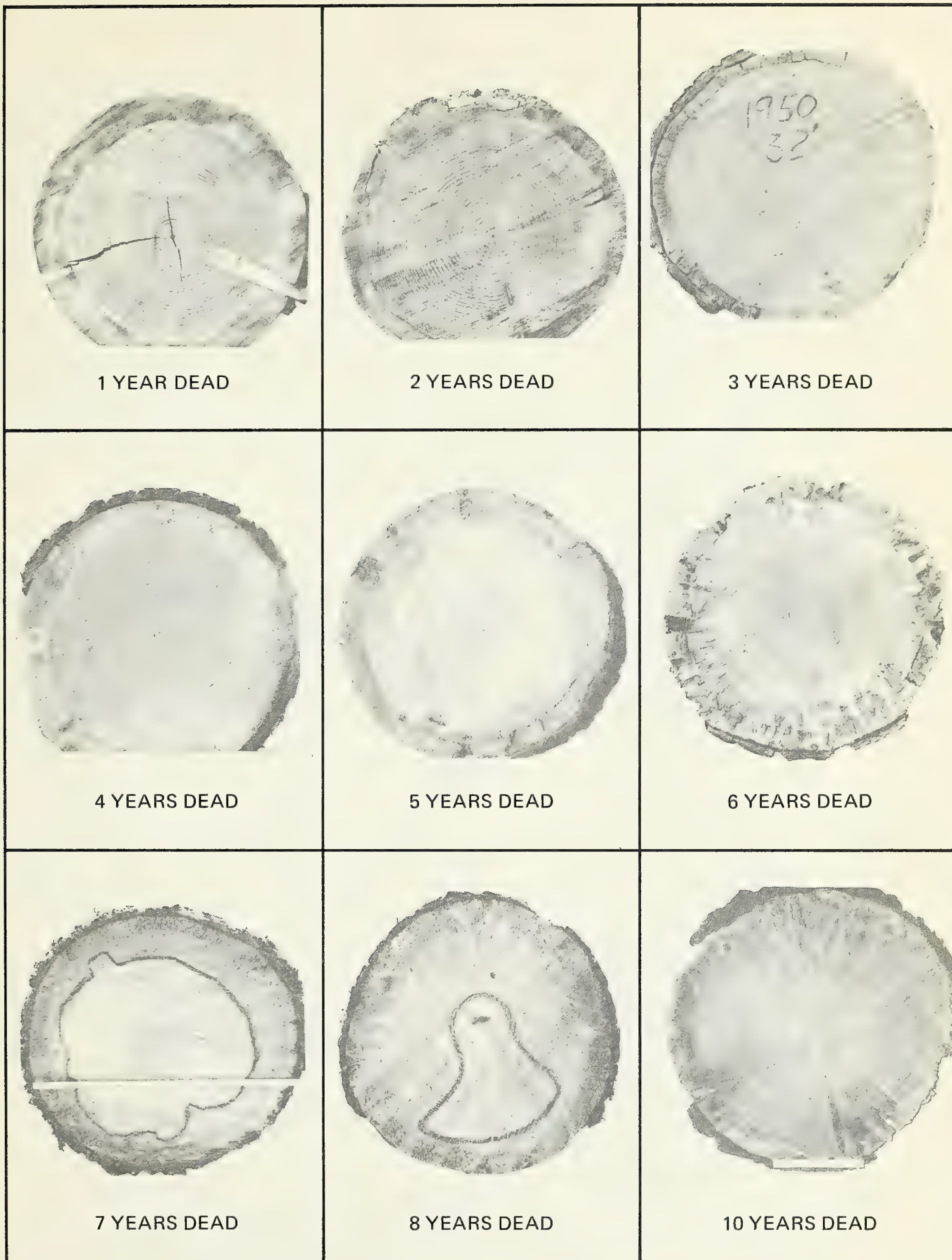


Figure 4. Typical deterioration in trees dead 1 to 11 years. (All cuts made 32 to 60 feet above ground.)

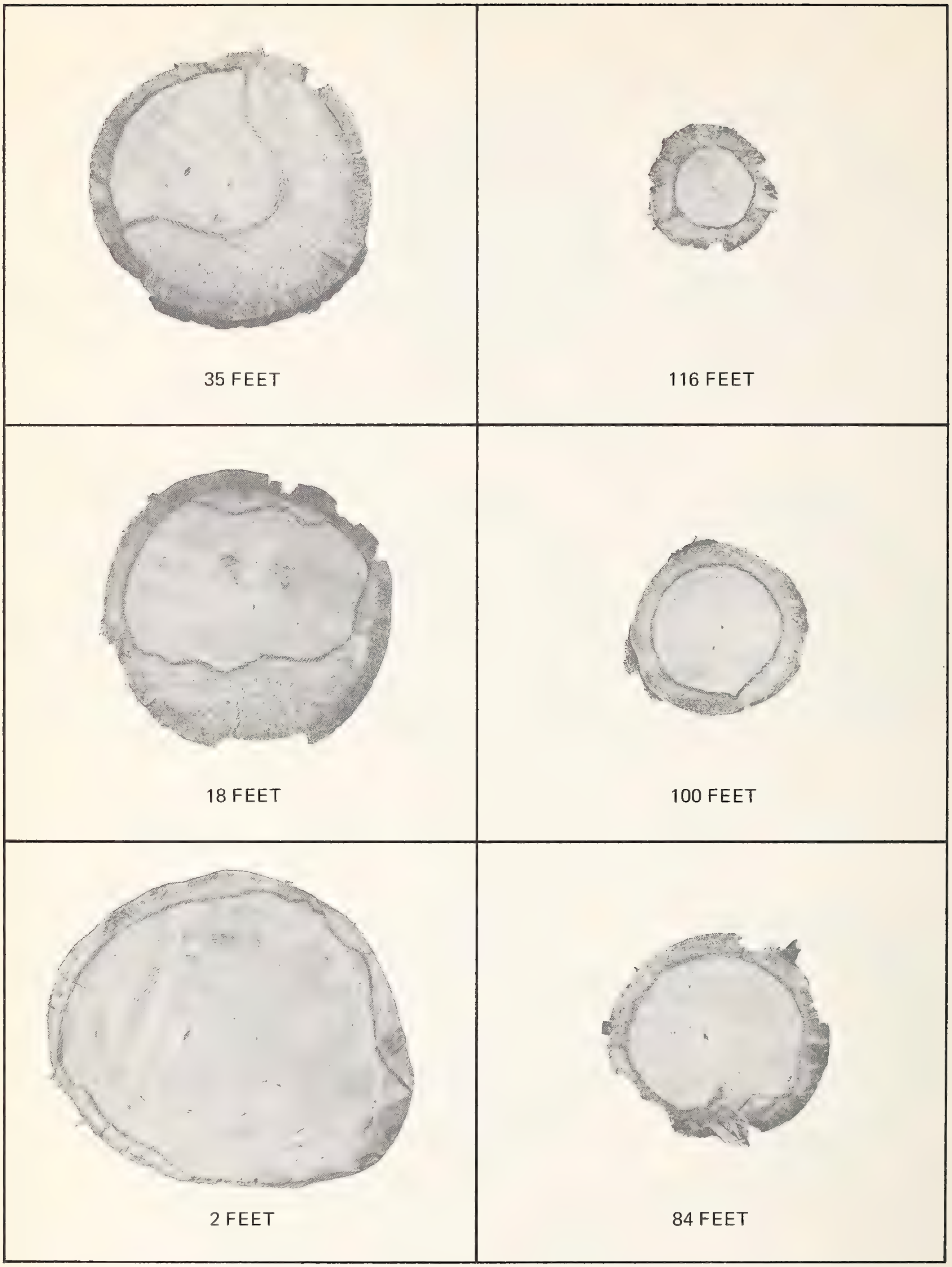


Figure 5. Typical pattern of decay from bottom to top of beetle-killed Douglas-fir (dead 8 years).

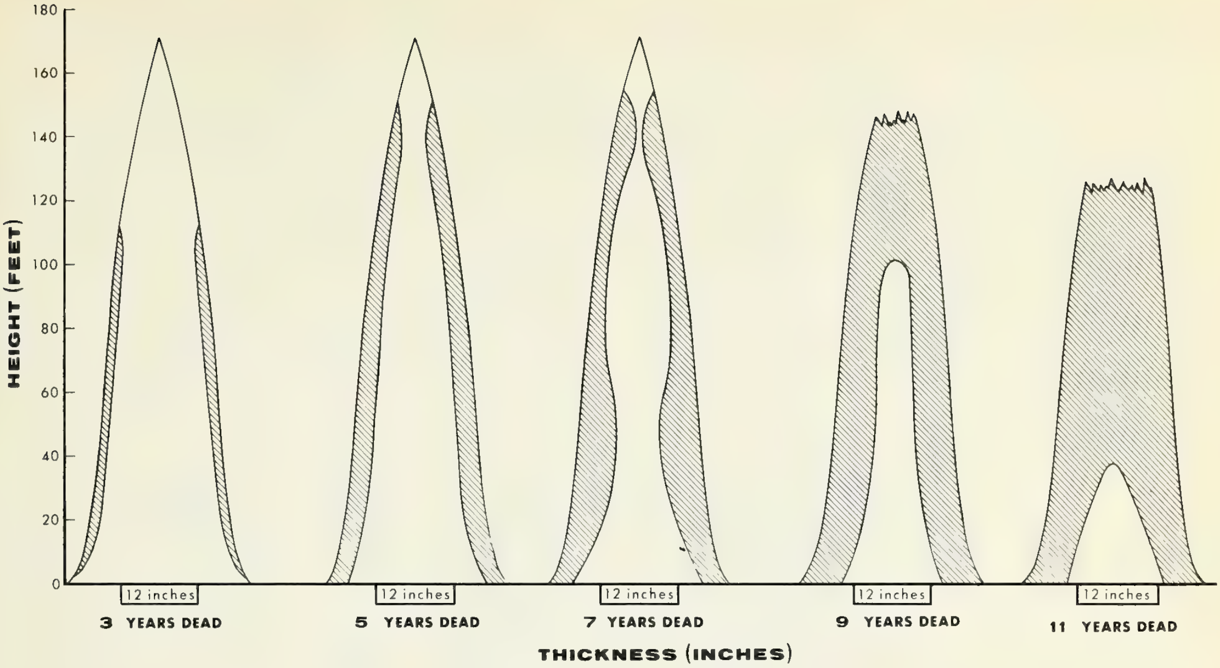


Figure 6. Progressive pattern of decay in a typical beetle-killed Douglas-fir.

sound portions of the tree. Almost two-thirds of the sapwood has been lost to decay. Differential deterioration of the bole usually is attributed to lack of Douglas-fir beetle attacks in the undecayed areas and to conditions unfavorable for decay (cool and wet at the base, hot and dry at the top). The wood in the undecayed top of the snag usually is very dry and casehardened.

After **5 years**, almost all of the sapwood is decayed, except for a small portion at the extreme top, and significant deterioration of the heartwood has begun. In general, radial penetration of decay is about equal throughout the snag. Economical salvage for lumber or plywood usually is not possible from second growth; old growth may still have considerable usable volume.

After **7 years** a different pattern of decay appears. Radial penetration of decay is deep in the lower bole, decreases about midbole, and deepens again in a zone 20 to 30 feet from the top. The areas of deep penetration are setting the stage for the next phase of deterioration – snag breakage. Salvable volume usually will be limited to the lower half of old-growth trees and is usable only for rough lumber or pulp.

After **9 years**, the typical beetle-killed tree is a snag with a broken top, and the heartwood is completely decayed except for an inner core in the lower half of the bole. Some salvable volume, perhaps usable only for pulp, might be recovered from very large trees.

After **11 years**, deterioration is essentially complete. A second break may have occurred below the first. A cone of sound wood remains in the butt log of very large trees. However, trees dead this long are unlikely to be recovered profitably, except where logging and wood utilization conditions are highly favorable.

Deterioration by Geographic Locality and Tree Age

Table 2 summarizes, by years dead and locality, the deterioration in all trees dissected on the 10 study areas. From the deterioration measurements, observations during the study, and experience by lumbermen, it is apparent that deterioration varies by tree age and locality. For example, the 250- to 350-year-old trees at Marys Peak in the Oregon Coast Ranges, which averaged 34.9 inches d.b.h., still had about 40 percent of their original cubic volume 11 years after death. Trees in the

Clackamas River drainage in the northern Oregon Cascade Range were nearly as old (240+ years) and large (26.5 inches d.b.h.) but had only about 15 percent of the original cubic volume 11 years after death. Although statistical proof is lacking, the authors feel that, for a given latitude, deterioration is more rapid in the Cascades than in the Coast Ranges. It seems reasonable that deterioration is more rapid during drier summer conditions in the Cascades. The cool, damp conditions in the Coast Ranges, particularly on the western slopes, appear to reduce the rate of decay as compared with interior areas.

The effect of tree age on rate of deterioration is suggested by comparison of deterioration in 140-year-old beetle-killed trees at Mapleton and 250- to 350-year-old trees at Marys Peak (table 2). After 9 years, 36 percent of the original cubic volume was decayed at Marys Peak, whereas, for the same period, the younger (and smaller) trees at Mapleton were 66 percent decayed. The two areas are near the

Figure 7.

Typical crown condition of some beetle-killed Douglas-firs after varying lengths of time since death.

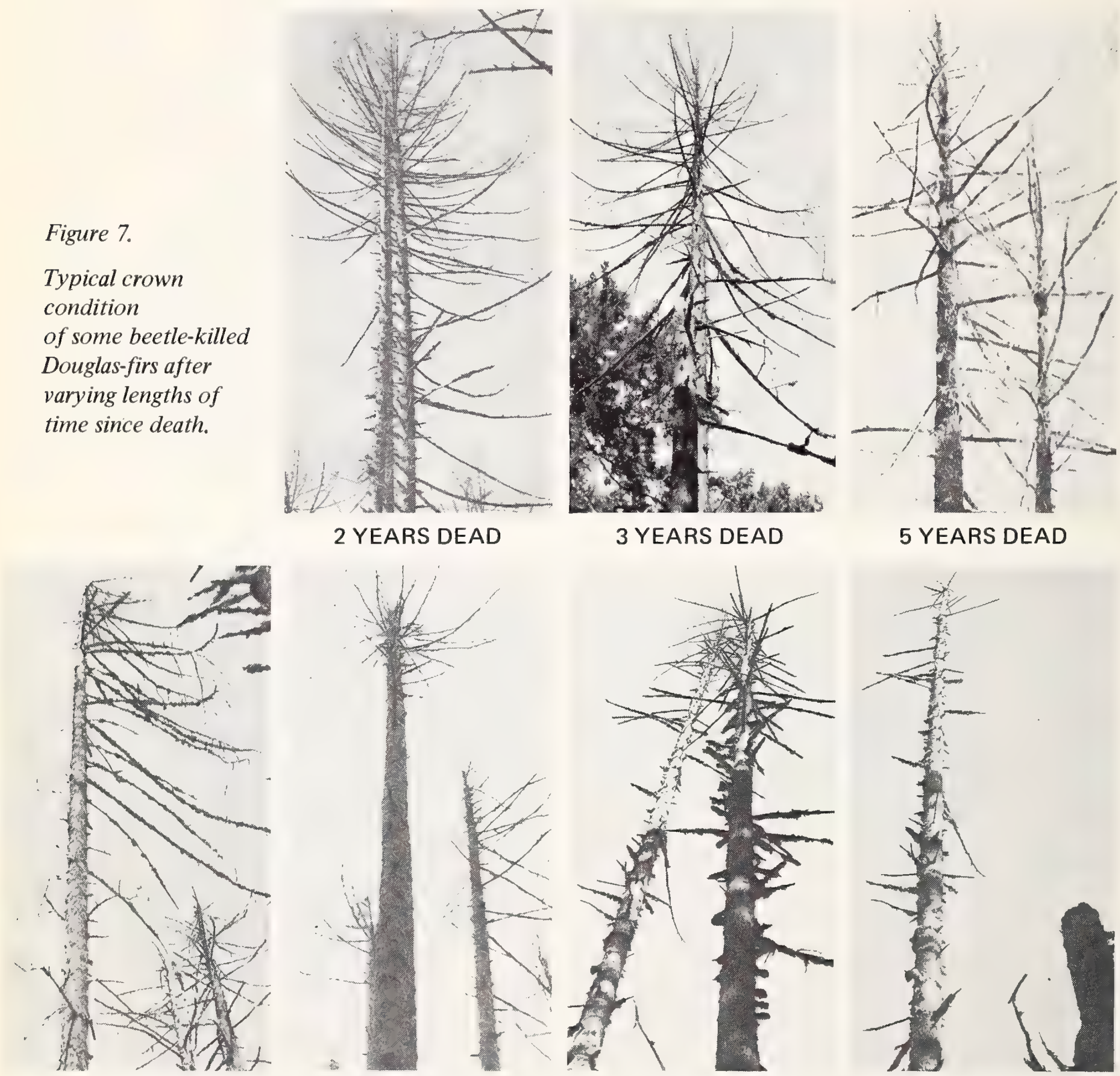


Table 2. **Progression of deterioration in beetle-killed Douglas-fir on 10 areas in western Oregon and Washington (volumes to 8-inch top)**

Area and age of stand	Years dead	Trees analyzed	Gross volume	Volume deteriorated		Gross volume	Volume deteriorated	
	Number	Number	Board feet (Scribner)	Board feet (Scribner)	Percent	Cubic feet	Cubic feet	Percent
Cispus (central	8	5	5,030	3,800	75.5	847	511	60.3
Washington Cascades),	9	2	2,170	1,800	82.9	373	262	70.2
180 years	10	3	2,090	2,090	100.0	349	315	90.3
Clackamas (northern	7	5	6,290	3,640	57.9	970	496	51.1
Oregon Cascades),	9	5	6,400	5,150	80.5	1,014	689	67.9
240 years	11	5	6,590	6,000	91.0	1,021	860	84.2
Mapleton (west-side	7	3	4,320	2,850	66.0	694	385	55.5
Oregon Coast Ranges),	8	2	5,190	3,430	66.1	784	447	57.0
140 years	9	5	9,290	6,860	73.8	1,389	917	66.0
Marys Peak (Oregon	7	5	17,960	5,900	32.9	2,572	703	27.3
Coast Ranges),	9	5	12,670	5,320	42.0	1,897	690	36.4
250-350 years	11	5	11,840	8,140	68.7	1,811	1,078	59.5
Millicoma (southern	1	7	13,750	390	2.8	2,187	38	1.7
Oregon Coast Ranges),	2	20	44,360	8,720	19.6	7,333	878	12.0
180-200 years	3	7	3,930	760	19.3	861	75	8.7
	4	8	7,770	1,350	17.4	1,353	163	12.0
	5	10	15,490	5,220	33.7	2,528	695	27.5
	6	5	5,210	1,580	30.3	884	221	25.0
	7	10	25,920	11,310	43.6	4,109	1,471	35.8
	9	5	11,500	6,860	59.7	1,801	927	51.5
	11	4	6,840	6,050	88.5	1,053	810	76.9
North Umpqua (southern	7	5	7,760	4,520	58.2	1,179	607	51.5
Oregon Cascades),	9	5	6,080	5,190	85.4	1,047	790	75.5
160 years	11	5	6,210	4,910	79.1	985	698	70.9
St. Helens (southwestern	5	4	3,370	960	28.5	557	55	9.9
Washington Cascades),	8	6	1,500	1,360	90.7	251	182	72.5
100-110 years	9	2	520	395	76.0	83	41	49.4
Sutherlin (central Oregon Cascades), 250-300 years	2	12	70,110	11,390	16.2	9,978	1,004	10.1
Willamette (central	7	5	8,910	4,010	45.0	1,338	505	37.7
Oregon Cascades),	9	5	7,180	4,300	59.9	1,198	599	50.0
200-225 years	10	1	930	930	100.0	157	140	89.2
	11	4	6,450	4,780	74.1	959	621	64.8
Wind River (southern	1	11	8,220	330	4.0	1,501	14	.9
Washington Cascades),	2	14	10,240	2,930	28.6	2,047	390	19.1
100-110 years	8	5	3,220	2,670	82.9	499	320	64.1
	9	2	1,390	1,030	74.1	247	161	65.2
	10	3	1,470	1,470	100.0	261	248	95.0
Total		215	368,170	148,395	—	58,117	19,006	—

Table 3. **Exterior crown and bole indicators for estimating how long beetle-killed Douglas-firs have been dead**[1]

Indicator	Length of time since death				
	1 year	2-3 years	4-5 years	6-8 years	9-10 years
Foliage	All present to all gone; any present is red	0-5 percent present	Absent	Absent	Absent
Twigs and small branches (less than ¾ inch in diameter)	Intact	60-90 percent present; only very small branchlets dropping	40-75 percent present; fewest in areas with frequent snow and ice (e.g., Cascades)	0-15 percent present	0-5 percent present
Large branches intact (¾ inch and over)	Intact	Intact	50-90 percent present; fewest in southern Oregon Cascades	30-60 percent present	10-50 percent present
Bark	Intact	Intact	Intact, except for minor cracking in top 5-10 feet; seldom seen from ground	Some cracking and sloughing in top 25 feet of unbroken boles; none in broken boles	Considerable cracking and sloughing in top 50 feet of unbroken boles; some near tops of broken boles
Top	Intact	Intact	Some breakage in top one-fourth of crowns of smaller trees, particularly in southern Cascades	Upper one-half of boles of approximately 50 percent of trees broken off	Upper two-thirds of 75 percent of trees broken off. Remainder with some breakage, except a few very large old trees
Fungi (fruiting bodies)	Blue stain; fresh *Polyporus volvatus* conks	*P. volvatus* conks dried up; rudimentary *Fomes pinicola* conks (yellowish color) beginning to appear in bark crevices	*P. volvatus* conks largely sloughed off; *F. pinicola* conks are bracket-shaped, with reddish margins	*F..pinicola* conks often very large; conks of miscellaneous species may be present	Same as for 6-8 years; conks somewhat larger

[1]Source: Approximately 190 tagged trees examined biannually for a 10-year period.

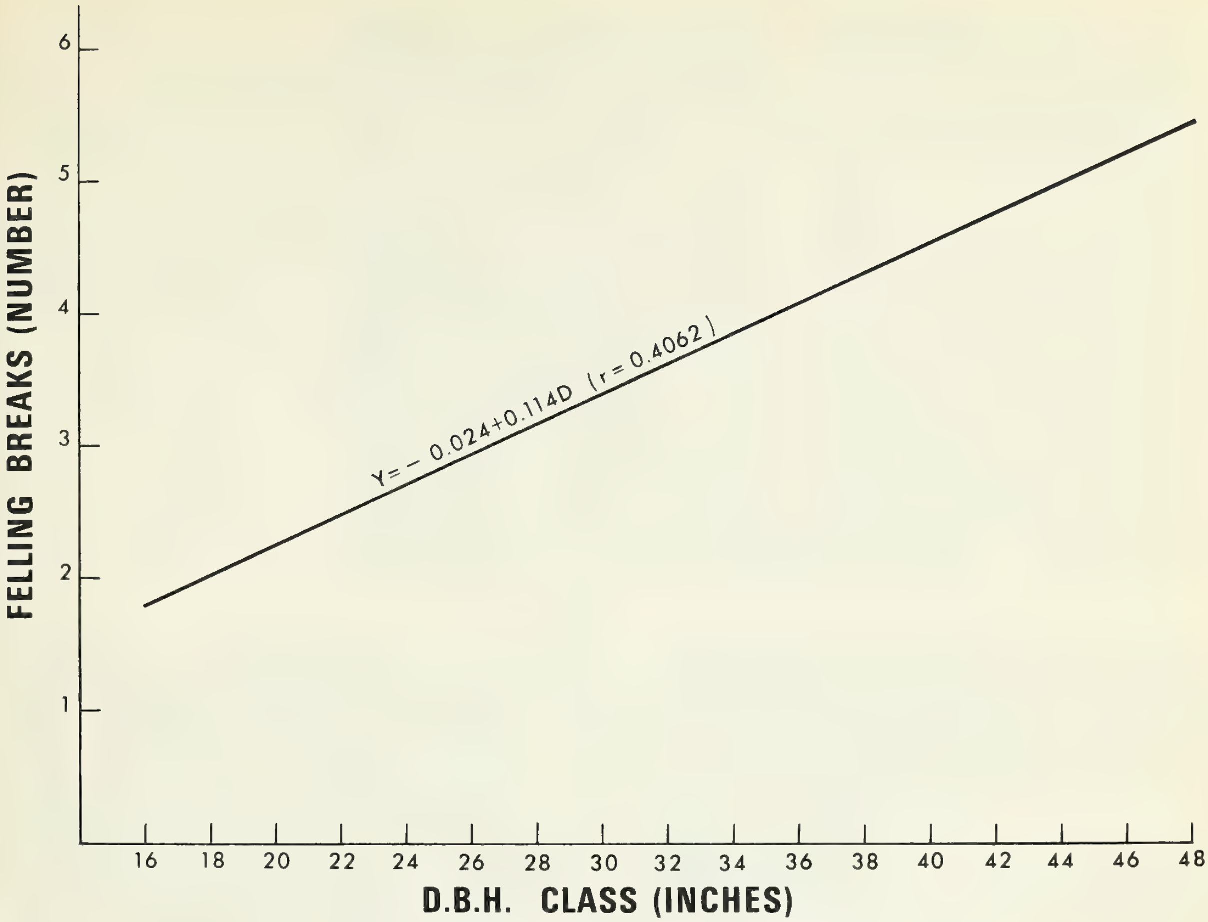


Figure 8. Number of felling breaks as related to d.b.h.

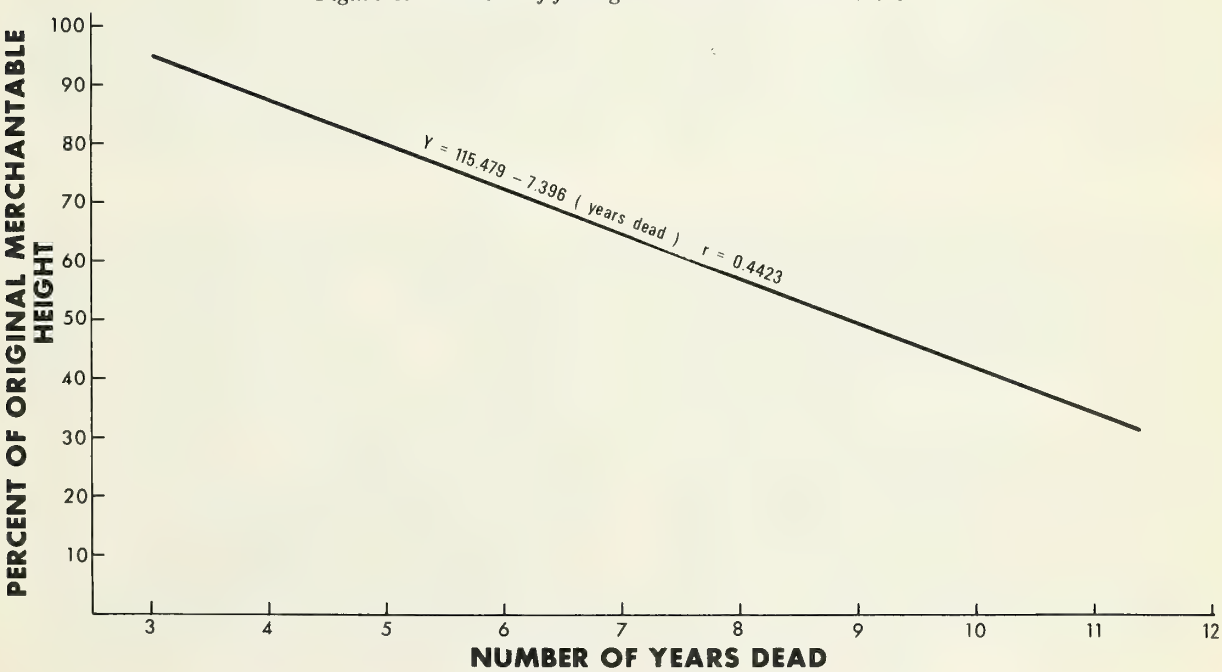


Figure 9. Height of first felling break as related to number of years dead.

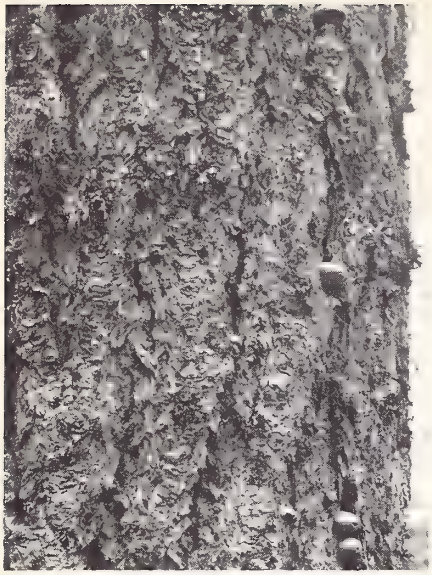


Figure 10. Fungus fruiting bodies commonly found on beetle-killed Douglas-firs.

A. Polyporus volvatus *conks 1 year after death of tree.*

B. P. abietinus *conks 2 years after death of tree.*

C. Fomes pinicola *conk developing on log 2 months after cutting (tree dead 8 years).*

D. F. pinicola *conks first appearing in bark crevice 3 years after death of tree.*

E. *and* **F.** F. pinicola *conks about 3 and 7 years old, respectively.*

same latitude and both are in the Coast Ranges, although Marys Peak is on the somewhat drier, warmer eastern slope.

Estimating How Long Trees Have Been Dead

Figure 7 illustrates the appearance of seven sample trees dead from 2 to 10 years; and table 3 gives a descriptive summary of the various indicators of the time of death, based upon periodic examinations of 190 tagged trees.

Estimating time of death for the first 5 years can be done rather precisely, after which it becomes increasingly difficult. The first few years following death, inspection of the amount of dead foliage, fine branches, large branches, and size of *Fomes pinicola* (Swartz) Cke. conks enables the observer to estimate the time of death within 1 or 2 years, and thereby estimate the amount of remaining merchantable volume. For trees dead more than 5 years, the most reliable indicators are the proportion of branches remaining, the amount of top break (i.e., proportion of bole still intact), and the size (age) of *F. pinicola* conks.

The observer should adjust his estimates according to locality and tree age and size. On the average, the general appearance of beetle-killed trees in the Cascades of southwestern Oregon declined most rapidly of those studied – which was also true of the internal deterioration as discussed earlier. Trees in the Oregon Coast Ranges remained intact longest. It appears that crowns of trees subject to frequent ice and snow storms break up sooner than those in the coastal rain belt. Large old-growth trees remain intact longer than second-growth trees.

If the observer uses figure 7 and table 3 to estimate when trees died and then refers to table 2 to determine the remaining merchantable volume, he should arrive at an assessment suitable for most purposes.

Estimating Felling Breakage

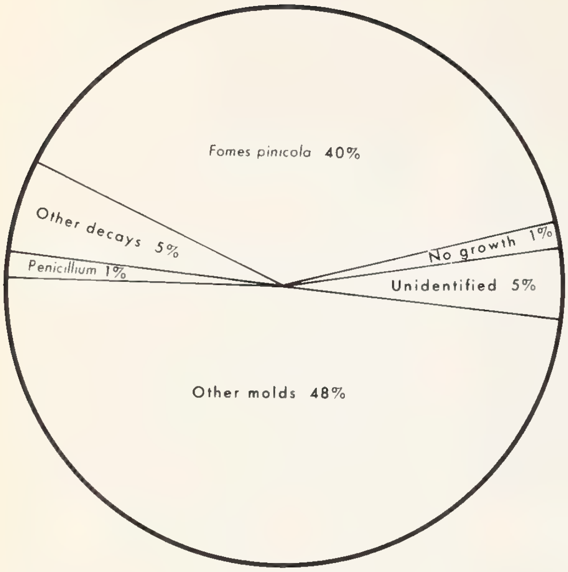
Felling breakage of beetle-killed Douglas-fir is a composite expression of the internal condition of the snag, the faller's skill, and topography of the impact site. Because of these variables, felling breakage in terms of volume loss was omitted from computations in this study. Instead, only the number and height of breaks were computed and are shown as two regression curves. The first regression curve (fig. 8) relates the number of felling breaks to snag diameter; the second curve (fig. 9) relates the height of the first felling break (as a percent of the original merchantable height) to the number of years the tree has been dead. Both curves are needed to estimate the breakage for a given snag.

An example of how to use these curves in estimating the number and height of breaks: Assume a 26-inch-d.b.h. snag dead for 7 years with an original merchantable height of 100 feet. The regression line from figure 8 indicates that the probable number of felling breaks will be three. Figure 9 indicates that the first felling break (for 7 years dead) will be at 64 percent of the original merchantable height (100 feet), or 64 feet.

Fungi and Insects Causing Deterioration

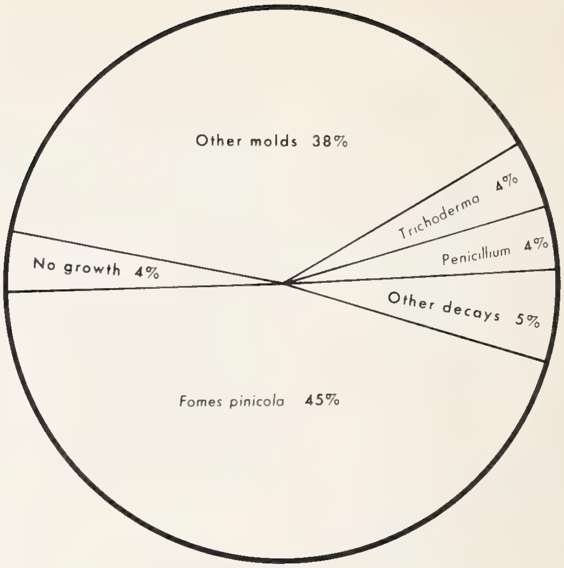
Fungi. – Wood-destroying fungi are by far the most important causes of deterioration of beetle-killed Douglas-fir. Stains (caused primarily by *Ceratocystis* spp. fungi) appear very soon in the sapwood after the Douglas-fir beetle attacks a tree. The spores of these fungi are borne on the bodies of the beetles. The stains, usually categorized as "blue stains," spread rapidly throughout the sapwood of the dying tree. The first year following death, they are the only fungi causing degrade of the wood, primarily in the form of discoloration, although affected wood is somewhat more brash than normal wood.

Sapwood decays become more important the second year after tree death and increase in importance until about the fourth year, when the sapwood in most beetle-killed trees is essentially destroyed. The most important cause of sapwood decay is *Fomes pinicola*, the common red belt fungus familiar to most foresters (fig. 10, C, D, E, and F). Other decays affecting the sapwood to a lesser degree are *Polyporus volvatus* Pk. (fig. 10A) and *Polyporus abietinus* (Dicks.), ex Fr. (fig. 10B). *P. volvatus* conks frequently appear on beetle-killed trees the year following death,



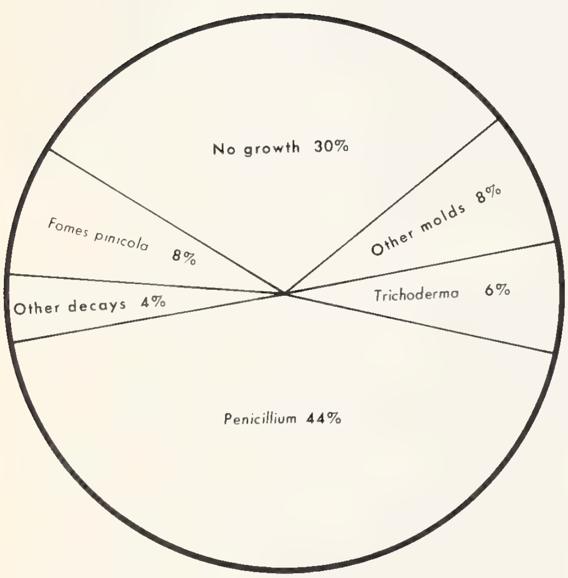
1958

TREES DEAD 6-7 YEARS



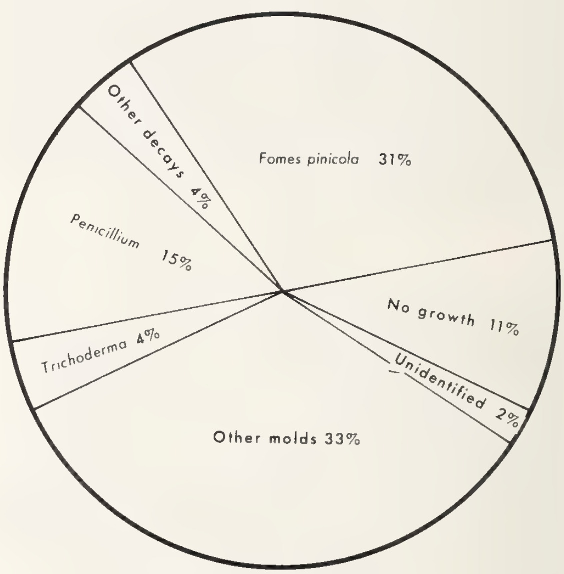
1960

TREES DEAD 8-9 YEARS



1962

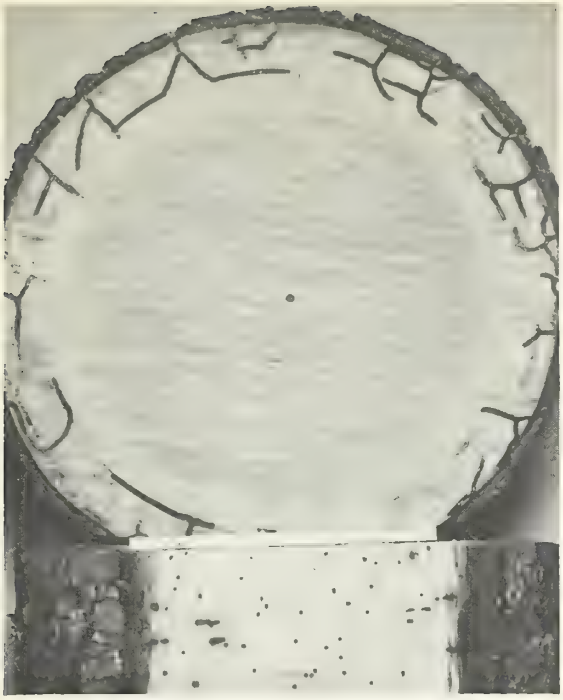
TREES DEAD 10-11 YEARS



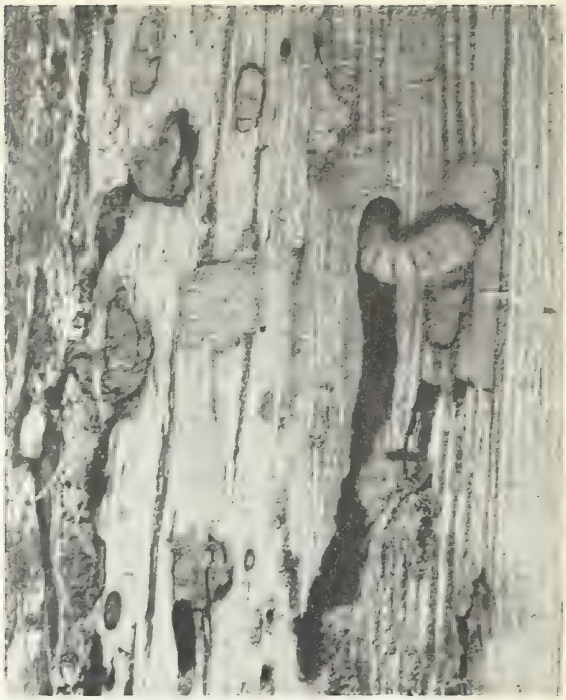
TOTAL

TREES DEAD 6-11 YEARS

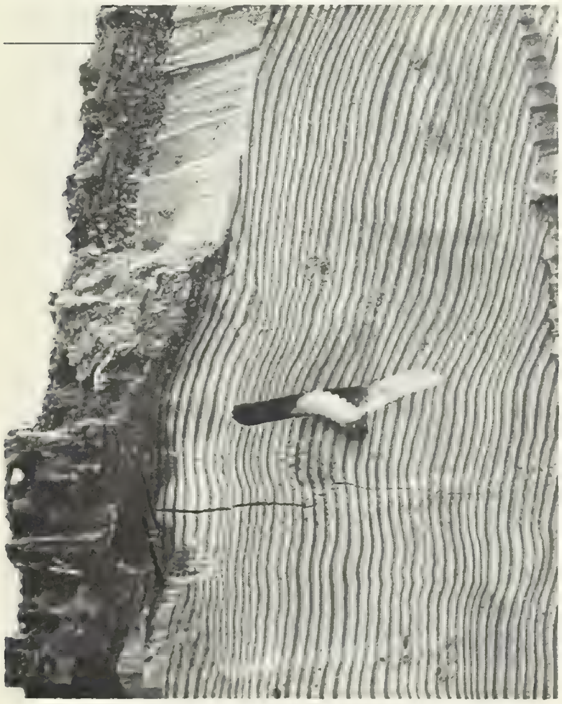
Figure 11. Decay fungi, and wood-inhabiting molds and stains isolated from beetle-killed Douglas-fir.



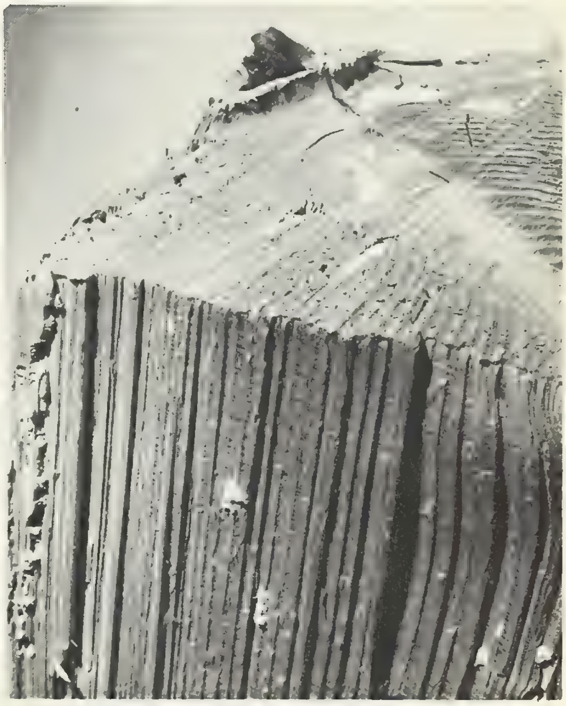
A. *Galleries of ambrosia beetles which mine in sapwood first year following death of tree (Weyerhaeuser photo).*



B. *Roundheaded borer working in decayed sapwood of tree dead 3 years.*



C. *Roundheaded borer penetrating about 4 inches into otherwise sound heartwood of tree dead 5 years.*



D. *Flatheaded borer damage extending to near center of otherwise sound heartwood of tree dead 7 years.*

Figure 12. Damage by wood-boring insects.

but they usually dry up and drop off in about 2 years. *F. pinicola* conks first appear in bark crevices of killed trees in about 3 years. Knowing when these various conks appear is helpful in backdating the time of tree death.

The only fungus cultured from decayed heartwood was *F. pinicola,* which was prevalent in all trees dissected. This fungus invades the heartwood about 4 years after tree death and advances steadily until it reduces all the wood to a characteristic brown, crumbly consistency.

Of a total of 534 attempted isolations, 31 percent were identified as *F. pinicola* (fig. 11). Other wood-destroying fungi accounted for 4 percent of the total, while *Penicillium, Trichoderma,* and other wood-inhabiting molds accounted for 52 percent of the isolates. Unidentified cultures (2 percent) and no growth (11 percent) complete the picture.

Insects. – The Douglas-fir beetle, which kills the trees, mines only in the cambium. Except for loosening the bark and serving as the carrier of fungal spores, it causes no damage to the wood. Ambrosia beetles and borers (fig. 12) are the only insects causing significant wood damage.

The first year following tree death, a flatheaded borer, *Melanophila drummondi* (Kirby), and a roundheaded borer, *Tetropium velutinum* Lec., heavily infest the phloem. These borers do little if any damage to the wood but loosen the bark and hasten the entry and progress of rots. Ambrosia beetles, or pinhole borers, mainly *Trypodendron bivittatum* (Kirby) and *Gnathotrichus retusus* Lec., also heavily attack the sapwood of many trees the first year after death (fig. 12A). Attacks are mainly in the first log; the insect galleries and accompanying stain penetrate well into the sapwood, causing degrade if the tree is to be converted to lumber or plywood. If the tree is converted to chips, the loss is minor. Damage by ambrosia beetles is more serious if logs are exported. Some countries refuse entry unless logs are fumigated, which is costly.

From about the **second to fifth year** after tree death, several species of wood borers attack the sapwood (fig. 12B). However, rot usually has already penetrated beyond their area of attack, and little real insect damage results. Borer species found in infested sapwood include two or more species of horntails (*Xeris* spp.), the flatheaded borers *Buprestis aurulenta* L. and *B. langi* Mann., and roundheaded borers of the genera *Xylotrechus* and *Neoclytus.*

Borers in the heartwood cause considerably more damage than those in sapwood because they frequently penetrate well beyond the rot (fig. 12, C and D). The most common roundheaded borers were: *Leptura obliterata* Hald., *Arhopalus productus* (Lec.), and *Asemum atrum* Esch. A few instances of damage by the very large roundheaded borer or "timber worm," *Ergates spiculatus* Lec., were found in partly decayed heartwood.

DISCUSSION AND RECOMMENDATIONS

Historically, Douglas-fir beetle outbreaks in western Oregon and Washington have been very large – sometimes covering several million acres and killing billions of board feet of merchantable timber. The rapid and extensive killing creates many problems in salvaging and utilizing the timber before it deteriorates. The size of the salvage job usually dictates that it be done over several years and that certain priorities be set in order to recover maximum values. Factors affecting logging priorities include age of the timber, geographic locality, accessibility, end product, changing utilization, and nearness to old burns. These and the possibility of advance felling to reduce losses will be discussed in order.

Age of the Killed Timber

Second-growth Douglas-fir deteriorates considerably faster than old growth. This fact is well known in the timber industry, although the magnitude of the difference may not be fully realized. Two reasons for differences in deterioration rates are the greater percentage of sapwood in young trees and the growth rate. Sapwood, which deteriorates much faster than heartwood, may comprise 40 percent or more of young trees, whereas it is often less than 15 percent in old growth. In the present study sapwood averaged 21.6 percent for all trees (fig. 3). In their study, Kimmey and Furniss (7) showed that fire-killed Douglas-fir with wide growth rings deteriorated much faster than those with narrow rings.

Geographic Locality

As pointed out previously, deterioration is faster in the Cascades than in the Coast Ranges, and in the southern part of the Douglas-fir subregion as compared with the north. This may be of significance to large timberland owners who are unable to conduct salvage concurrently on all their lands.

Accessibility of the Killed Timber

Gaining access to beetle-killed timber is a problem on undeveloped areas. Experience has been that the killed timber often is seriously deteriorated by the time roads into remote areas are financed, engineered, and built. While major cost and prompt effort are usually justified to reach beetle-kill areas, strong emphasis should also be placed on immediate salvage of killed timber adjacent to existing roads. By so-doing, a maximum of high-quality, nondeteriorated timber can be removed.

Consideration should be given to gaining access first to those areas where the beetle-kill is heaviest and logging easiest. In steep country, breakage in felling killed timber increases sharply.

End Product of the Salvage Timber

The intended use of the salvage material might well have a large bearing on where and what to log first. For example, killed timber that is planned for conversion to high-grade plywood or finish lumber should be logged sooner than timber destined for low-grade lumber or chips. The "rind" of clear sapwood remains almost entirely sound for the first year following death of a tree, but by the end of the third year it is usually almost completely destroyed, leaving a relatively knotty core unsuitable for high-quality products.

Changing Utilization Standards

The deterioration volume estimates in this report are based on present utilization standards. The kinds and quality of material that can be profitably removed from the woods vary throughout the Douglas-fir subregion – depending on difficulty of the logging show, distance to mills, end product for the logs, marketing demand, and other factors. However, it has become increasingly possible to log low-quality, partly deteriorated material profitably. If this trend continues, the wood recovery estimates in this report will doubtless prove conservative.

From the logging priority standpoint, a forest manager might choose to delay salvaging a particular area of low-quality beetle-killed timber because a chip plant was scheduled to be in operation in a few years. Instead, he might concentrate the current salvage effort in an area of high-quality timber where the beetle-killed trees were most suitable for plywood or lumber.

Proximity of Beetle-Kill to Old Burns

Furniss and Kimmey reported in their study of fire-killed timber (7) that there was a correlation between amount of borer damage and nearness to old burns. No observations were made in this regard in the present study, but it seems probable that borer damage would also be greater in beetle-killed timber near old burns, previous beetle outbreak areas, major blowdown, and slashings. Logging priorities should be influenced accordingly.

Felling in Advance of Roading and Logging

Some owners could consider felling beetle-killed timber in inaccessible areas soon after death – even though it may be impossible to log them for several years. Two reasons for doing this are decreased felling breakage and slower deterioration rate. Unquestionably, this practice would reduce breakage considerably, and the felling job would be much safer. Whether deterioration would actually be slower if the trees were felled is not known. The difference probably would be small, if any, except perhaps in wet coastal areas where coverage by dense vegetation and moss seems to slow deterioration.

So far as is known, no timber operators have actually used this procedure, but it should be considered where economic and utilization conditions are favorable.

In summary, we suggest that forest managers keep in mind the following recommendations when setting priorities for salvaging beetle-killed Douglas-fir:

1. Salvage second growth before old growth.
2. Schedule salvage in the southern part of the Douglas-fir subregion ahead of that in the north, and in the Cascades ahead of that in the Coast Ranges.
3. Salvage first the areas where beetle-kill is heaviest and logging easiest.
4. Salvage killed timber that is intended for conversion to high-quality lumber or plywood sooner than timber to be used for low-grade lumber or chips.
5. Recognize changing utilization standards and product demands in salvage schedules.
6. Give priority to killed timber adjacent to old burns, major blowdowns, and other disturbances, to minimize damage by wood borers.
7. Consider falling trees as soon as possible after they are beetle-killed – even though they may not be logged for some time – to reduce felling breakage, and possibly deterioration.

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Wood deterioration on a board-foot basis advanced from 3 percent 1 year after death to 79 percent after 11 years. Rate of deterioration is strongly related to age and tree size. Felling breakage is related to time since death and tree size. The fungus Fomes pinicola is the most important agent of deterioration. Salvage logging priorities should be influenced by age and size of timber, locality, accessibility, topography, and products to be manufactured.

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