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Laminated Root Rot Damage in a Young Douglas-Fir Stand

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Abstract

Damage occurring from the disease laminated root rot *{Phellinus weirii* (Murr.) Gilbertson) on two 10-acre plots in a young (40-year-old) stand of Douglas-fir was studied for 25 years. After 25 years, nearly 5 percent of the basal area was killed by the disease. Stand damage caused by vegetative spread of the fungus was significantly related to previous mortality from the disease and to slower net growth during that period. Nonproductive stand openings caused by the disease occupied over 11 percent of one plot and over 7 percent of the other. Although additional losses can be anticipated before harvest, severe losses are not expected in this stand before commercial maturity.

Keywords: Root rot, *Phellinus weirii.*

Introduction

Phellinus weirii (Murr.) Gilbertson was first described by Murrill (1914) as *Poria weirii,* the cause of butt rot in western redcedar *Thuja plicata* Donn ex D. Don). The fungus was not found on other species until 1929, when it appeared in young Douglas-fir *{Pseudotsuga menziesii* (Mirb.) Franco) on Vancouver Island (Bier and Buckland 1947). Since then, *P. weirii* has been found in the Pacific Northwest on all conifers of commercial importance (Buckland and Wallis 1956).

In 1951, the Pacific Northwest Forest and Range Experiment Station, Division of Forest Pathology (then a part of the Bureau of Plant Industry), began a series of studies to determine the importance of *P. weirii* in the Pacific Northwest. About 200 acres of permanent plots were established to determine the rate of damage in Douglas-fir stands infested with P. *weirii.* Unfortunately, many of the stands available for study at that time were beyond what today would be considered rotation age. Nevertheless, a few plots were established in young stands. This paper describes

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stand development over a quarter century on two 10-acre plots established in an infested 40-year-old Douglas-fir stand in southwestern Washington. Guidelines formulated from observations on these plots and plots in other stands will provide a basis for better management of infested stands.

The Study Area

The study area is located in the Wind River Ranger District of the Gifford Pinchot National Forest, about 8.5[2] miles northwest of Carson, Washington (long. 121°57', lat. 45°48'N). Plots were established in 1951 (Martha Flat) and 1952 (Martha Creek) when the trees in the stand were about 40 years old. The preceding stand had been clearcut and burned before 1910, but a few widely scattered old-growth Douglas-fir could still be found. Site index was judged to be 105 in 1949, based on 25 trees dissected in the area. Average age of dominants and codominants was 39 years and height 60 feet. Height measurements in 1976 indicate a higher site index; 12 trees selected on the two plots averaged 64 years and 110 feet, indicating a site index near 130 (McArdle et al. 1949). Stand characteristics are summarized in table 1.

Table 1—Basal area, number of stems, and average diameter of conifers at plot establishment (age 40) and last measurement (age 65) based on trees greater than 3-inch diameter at breast height (d.b.h.)

Plot	Age	Basal area per acre	Stems per acre	Average d.b.h.
	Years	Square feet	Number	Inches
Martha Flat	40	144	508	7.2
	65	207	299	11.3
Martha Creek	40	156	548	7.2
	65	199	265	11.7

Douglas-fir is the predominant tree species, but some western hemlock *{Tsuga heterophylla* (Raf.) Sarg.), western white pine *{Pinus monticola* Dougl. ex D. Don), and grand fir *{Abies grandis* (Dougl. ex D. Don) Lindl.) are present. Hardwoods, principally red alder *{Alnus rubra* Bong.), bitter cherry *{Prunus emarginata* Dougl. ex Eaton), and bigleaf maple *(Acer macrophyllum* Pursh), occur sporadically throughout the stand.

[2]Metric equivalents are on page 15.

Establishment of Plots

Plots were located in areas known to have laminated root rot (P. *weirii)* and were readily accessible for study. The Martha Flat plot (fig. 1) is on nearly level ground at about 1,100-foot elevation. The Martha Creek plot (fig. 2) has a gentle to moderate slope with variable but generally northern aspect and an average elevation of 1,150 feet. The Martha Flat plot is 10 by 10 chains, gridded at 2-chain intervals, thus breaking the plot into 25 blocks of 0.4 acre. The Martha Creek plot is similarly composed of 25 blocks of 0.4 acre but is irregular in shape to avoid a road and topographic features that change the character of the stand. Grid intersections are marked with 4-foot cedar stakes and location *of* gridlines by bark blazes and paint on the "line" side of nearby trees.

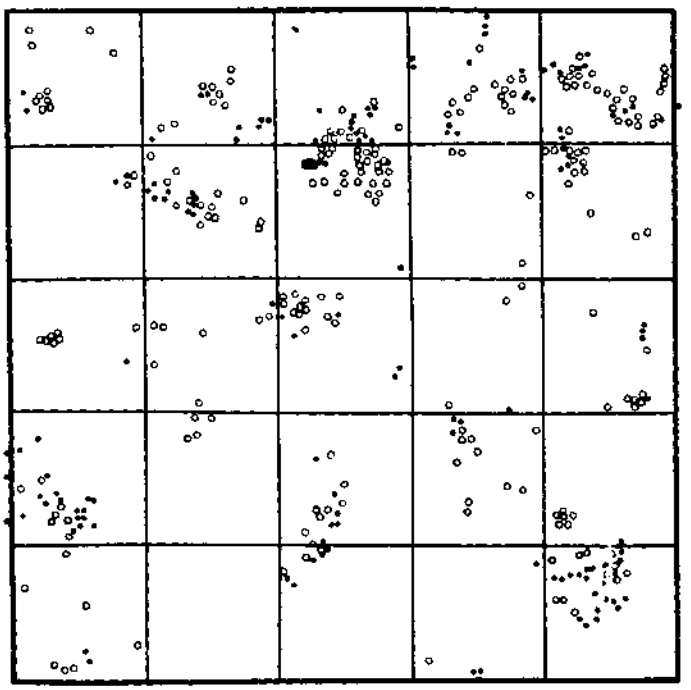

Figure 1.--Mortality from **Phellinus weirii** *on the 10-acre plot on Martha Flat.*

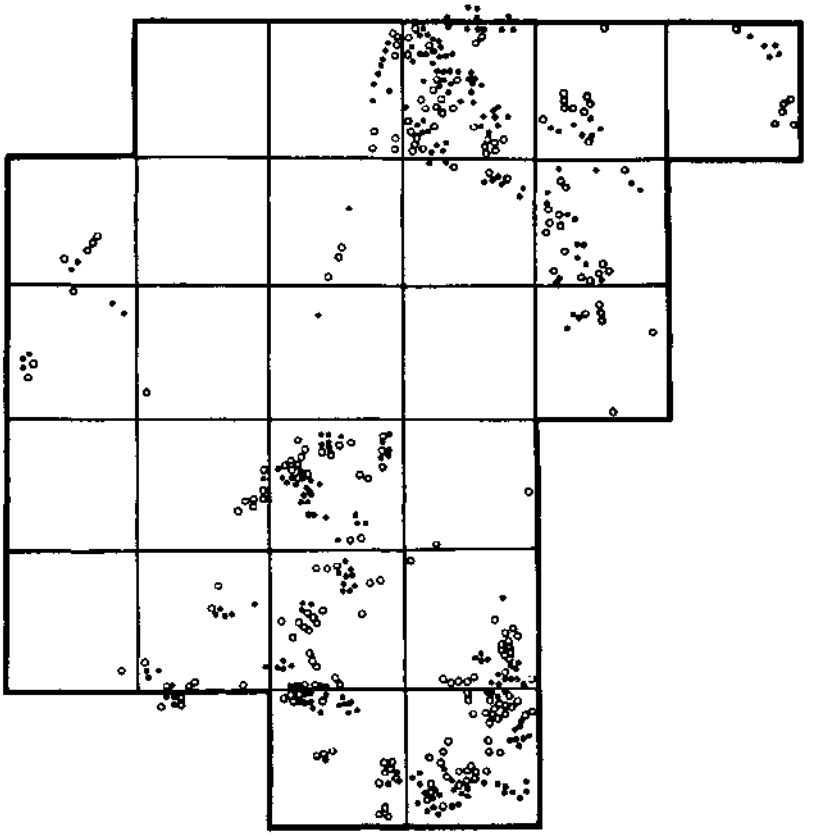

Figure 2.--Mortality from **Phellinus weirii** *on the 10-acre plot on Martha Creek.*

Collected Data

The following data were recorded by 0.4-acre blocks on each 10-acre plot:

1. At time of establishment and after 25 years.
   (a) Diameter at breast height (d.b.h.) by 2-inch classes and species category (Douglas-fir, other conifer, or hardwood) of each living tree greater than 3 inches.
   (b) D.b.h. and estimated year of death of mortality caused by P. *weirii* since previous plot examination.
   (c) Location of P. *weirii* mortality (figs. 1 and 2).
2. At periodic intervals.
   (a) D.b.h. of P. weirii-caused mortality since last examination and estimated year of death.
   (b) Location of P. weirii-caused mortality (figs. 1 and 2).

After blocks having more than 10 percent of basal_area in hardwoods were eliminated, analysis of covariance ($P < 0.05$) of data by block was used to relate: (1) number and basal area of trees killed before plot establishment to number and basal area of those killed in the following 25 years, (2) increase in living basal area in 25 years to number of stems or basal area lost to *P. weirii* for the same period, (3) increase in living basal area in 25 years to number of stems or basal area killed before plot establishment and (4) percent increase in number of steins or basal area over 25 years to number of stems or basal area lost to P. *weirii* for the same period. The regressions from the two plots were compared to determine whether a common regression could represent both plots.

Openings in the crown canopy associated with activity of P. *weirii* were visually projected to the ground, measured with a steel tape, and mapped at 1:396 scale.[3] The area within mapped openings was measured with a digitizer coupled with a computer.

When surviving trees occurred in openings, their diameters at breast height were measured. Within openings, the area occupied by these survivors was assumed to be the same as that occupied by trees of the same basal area in uninfested blocks. (Area+basal area = average ground area occupied per unit basal area.) The area occupied by survivors was subtracted from that of measured openings to arrive at a corrected "area out of conifer production."

In 1961 and 1962, samples of P. weirii-infested wood were collected for isolation of the fungus. These isolates were cross plated on malt agar to determine clonal relationships among infection centers (Childs 1970). As new mortality occurred, additional samples were collected to further define clonal boundaries of the infestation.

Results

For the 25 years after plot establishment, numbers of conifer stems decreased from 5,078 to 2,978 on the Martha Flat plot (table 2), whereas basal area increased from 1,437 to 2,068 square feet; on the Martha Creek plot, stems decreased from 5,475 to 2,647 (table 3), but basal area increased from 1,558 to 1,988 square feet. Average diameter increased from 7.2 to 11.3 inches at Martha Flat and from 7.2 to 11.7 inches at Martha Creek (table 1). Average number of trees and average basal area per acre on the two plots approximate what is normal for site III Douglas-fir stands (McArdle et al. 1949).

Basal area of conifers and numbers of stems varied considerably among 0.4-acre blocks on each plot. Typically, greater basal area is associated with greater numbers of stems, not larger trees. Lowest stocking of conifers when plots were established

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[3] Blocks 1 through 5 on the Martha Flat plot were destroyed before openings could be measured.

Table 2—Stand inventory on the Martha Flat plot at establishment and 25 years later

Block number	Basal area at plot establishment			Basal area 25 years later			Stems at plot establishment			Stems 25 years later		
	Douglas-fir	Other conifers	Hardwoods	Douglas-fir	Other conifers	Hardwoods	Douglas-fir	Other conifers	Hardwoods	Douglas-fir	Other conifers	Hardwoods
	Square feet						Number					
1	79.46	0.37	9.29	92.38	2.70	11.93	262	3	12	132	20	12
2	71.30	.96	2.97	113.25	3.09	5.23	314	8	6	186	23	11
3	73.17	.09	3.80	107.28	1.09	7.90	274	1	4	158	7	7
4	64.34	0	0	97.87	.09	0	277	0	0	179	1	0
5	48.56	0	0	73.42	.28	0	200	0	0	150	2	0
6	51.40	0	.35	77.49	.48	1.46	136	0	1	85	3	6
7	57.58	.09	.70	73.82	.63	2.14	230	1	2	107	6	5
8	66.15	.57	1.96	79.05	1.29	3.80	301	4	3	128	4	4
9	54.83	1.27	0	79.22	3.00	.96	238	7	0	130	4	6
10	54.76	.09	0	66.39	.09	.37	290	1	0	135	1	3
11	49.66	.44	2.77	77.95	.28	6.21	131	2	5	90	2	20
12	57.18	.09	0	86.27	.48	1.72	187	1	0	129	3	5
13	57.58	.09	0	78.88	.37	.09	235	1	0	124	3	1
14	68.83	.48	2.33	96.48	1.33	6.21	274	3	5	131	4	13
15	66.37	0	.70	81.04	.63	.57	267	0	2	123	6	4
16	37.02	.83	0	62.26	.39	.72	91	3	0	83	2	4
17	45.86	.28	0	67.52	.74	.09	116	2	0	81	2	1
18	48.50	.20	.35	74.89	.55	.35	142	1	1	97	1	4
19	66.78	5.02	2.18	93.65	4.12	1.96	212	15	4	112	9	4
20	73.87	.09	.55	85.21	.20	2.27	254	1	1	117	1	6
21	34.41	1.18	0	54.92	2.84	0	83	4	0	62	2	0
22	46.86	0	.55	85.01	.17	.96	113	0	1	85	2	3
23	24.48	.17	0	45.93	.63	3.99	58	2	0	49	3	10
24	70.95	.92	6.63	108.25	3.66	7.81	183	5	13	100	9	15
25	53.12	.92	17.72	75.14	5.65	26.00	141	4	23	71	14	23
Total	1,422.96	14.15	52.85	2,033.57	34.78	92.74	5,009	69	83	2,844	134	167

Table 3—Stand inventory on the Martha Creek plot at establishment and 25 years later

Block number	Basal area at plot establishment			Rasal area 25 years later			Stems at plot establishment			Stems 25 years later		
	Douglas-fir	Other conifers	Hardwoods	Douglas-Fir	Other conifers	Hardwoods	Douglas-fir	Other conifers	Hardwoods	Douglas-fir	Other conifers	Hardwoods
	Square feet						Number					
1	23.58	2.62	29.06	40.00	6.37	40.94	57	9	47	27	12	59
2	30.61	2.40	12.46	53.17	3.03	24.56	70	9	16	38	9	36
3	53.08	0	1.59	65.37	.78	6.30	155	0	4	76	6	19
4	88.84	0	0	99.45	.26	.28	303	0	0	128	3	2
5	84.78	0	0	90.51	.17	.20	308	0	0	124	2	1
6	56.33	1.37	7.03	91.71	3.60	12.67	159	5	14	82	15	27
7	57.82	.17	5.45	91.67	.37	6.54	131	2	9	75	3	14
8	77.91	1.68	.87	105.65	2.92	3.86	192	7	2	107	5	10
9	71.17	0	8.77	90. 82	0	13.00	212	0	9	95	0	15
10	67.70	0	0	86.39	0	.37	218	0	0	104	0	3
11	55.85	.35	0	82.02	1.59	1.44	221	4	0	117	9	4
12	57.99	.17	1.57	79.76	.39	3.86	192	2	2	92	2	3
13	78.17	1.75	.55	90.72	3.60	.63	323	9	1	128	13	2
14	70.95	1.92	.70	79.14	3.44	3.36	302	11	2	119	14	9
15	71.91	0	.78	90.10	0	1.70	2B0	0	2	154	0	4
16	68.18	0	1.88	86.32	.17	3.38	245	0	3	105	2	5
17	57.23	.09	0	71.84	.57	.92	179	1	0	82	4	4
18	64.60	.17	0	80.13	2.29	.26	209	2	0	110	7	3
19	59.06	3.49	0	60.75	6.23	2.03	277	17	0	113	20	5
20	56.96	0	0	71.95	.09	0	233	0	0	105	1	0
21	63.38	0	0	69.01	.09	0	277	0	0	102	1	0
22	71.12	.63	0	75.87	2.22	.20	202	6	0	125	12	1
23	53.21	0	.35	67.23	.40	5.06	1R5	0	1	104	3	14
24	57.99	0	0	79.40	1.04	.57	230	0	0	111	12	4
25	42.08	.28	.55	46.56	1.92	5.63	149	2	1	63	6	8
Total	1,540.50	17.09	71.55	1,946.34	41.62	137.76	5.3R9	86	113	2,486	161	252

was 150 trees per acre (block 13, Martha Flat) and after 25 years, 98 trees per acre (block 1, Martha Creek). Low stocking of conifers was due in part to competition from hardwoods.

Although hardwoods sometimes invade openings caused by root rot, hardwoods were usually found in areas where root rot was not evident. Stocking was as high as 830 trees per acre (block 13, Martha Creek) at time of plot establishment and 522 trees per acre after 25 years (block 2, Martha Flat).

Mortality from P. *weirii* over 25 years (tables 4 and 5) represents only 4.57 percent of stems and 6.33 percent of basal area of conifers at age 40 at Martha Flat and only 4.04 percent of stems and 6.16 percent of basal area at Martha Creek. If stand age 65 is the base, losses to P. weirii are 7.79 percent of stems and 4.40 percent of basal area at Martha Flat and 8.35 percent of stems and 4.83 percent of basal area at Martha Creek. Average diameter o trees killed by P. *weirii* was near the average diameter of living Douglas-fir when the mortality occurred. Mortality from suppression and other causes, although not measured directly, was considerably greater than the one tree per acre per year from P. *weirii.*

Regressions from the two plots did not differ significantly. When data on growth and mortality from root rot were combined and compared by block, using analysis of covariance, significant relationships emerged:

1. Number of trees killed by P. *weirii* over 25 years was related ($r = 0.764$) to number killed by P. *weirii* before plot establishment.
2. Basal area of trees killed by P. *weirii* over 25 years was related ($r = 0.776$) to basal area killed by P. *weirii* before plot establishment.
3. Number of trees killed by P. *weirii* over 25 years was negatively related ($r = 0.317$) to increase in basal area over the same period.
4. Basal area of trees killed by P. *weirii* over 25 years was negatively related ($r = 0.344$) to the increase in basal area for the same period.

Number of trees or basal area killed before plot establishment did not have a significant negative relationship with increase in basal area over 25 years nor did number of trees or basal area killed over 25 years have a significant negative relationship with percent increase in basal area for the same period.

Cross-plating of cultures from dead trees indicated new mortality was caused by the same clone of the pathogen as was previous mortality in the contemporary and preceding stands.

Table 4—Periodic mortality from ~~Phellmus~~ ~~weirii~~. Martha Flat plot

Block number	Before 1951[1]		1951-55		1956-60		1961-65		1966-70		1971-75		1951-75 (total)	
	Stems	Basal area	Stems	Basal area	Stems	Basal area	Stems	Basal area	Stems	Basal area	Stems	Basal area	Stems	Basal area
	Number	Square feet	Number	Square feet	Number	Square feet	Number	Square feet	Number	Square feet	Number	Square feet	Number	Square feet
1	2	1.61	1	0.09	2	0.89	2	0.70	4	2.11	1	0.44	10	4.23
2	6	.89	1	.20	1	.55	0	0	7	1.16	0	0	9	1.91
3	7	1.35	3	.74	0	0	3	.89	3	.74	0	0	9	2.37
4	9	1.75	3	.72	1	.09	5	1.81	5	.62	0	0	14	3.24
5	10	1.20	6	1.16	1	.35	9	2.33	6	2.37	4	4.86	26	11.07
6	2	.09	1	.20	0	0	1	.20	0	0	0	0	2	.40
7	9	1.59	2	.55	2	.89	0	0	6	4.58	4	2.94	14	8.96
8	6	1.37	6	1.11	5	1.96	2	1.09	8	2.55	11	4.62	32	11.33
9	0	0	0	0	0	0	2	.39	1	.20	1	.20	4	.79
10	3	.59	1	.20	4	.63	5	.81	1	.35	2	.44	13	2.43
11	1	.20	2	.63	0	0	2	.74	1	.09	2	1.85	7	3.31
12	2	.89	0	0	0	0	0	0	3	.48	4	1.90	7	2.38
13	5	.76	4	1.02	0	0	3	.98	2	.55	4	1.40	13	3.95
14	1	.09	0	0	0	0	1	.20	1	.09	1	.09	3	.38
15	3	.37	4	.72	0	0	0	0	0	0	4	1.72	8	2.44
16	17	5.54	0	0	1	.09	3	.37	1	1.07	2	.98	7	2.51
17	0	0	1	.35	0	0	0	0	2	.87	1	.09	4	1.31
18	5	1.35	1	.20	2	.55	4	1.88	1	.35	4	2.44	12	5.42
19	3	.63	0	0	0	0	4	1.48	3	1.61	3	.74	10	3.83
20	1	.09	2	.55	0	0	3	1.68	0	0	1	1.77	6	4.00
21	1	.20	2	2.14	0	0	1	2.18	1	.20	3	2.97	7	7.49
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	5	1.03	1	.09	0	0	1	.20	0	0	1	.55	3	.84
24	3	.48	0	0	0	0	0	0	1	.20	0	0	1	.20
25	21	3.75	2	1.33	1	.09	3	.48	4	2.99	1	1.40	11	6.29
Total	122	25.82	43	12.00	20	6.09	54	18.41	61	23.18	54	31.40	232	91.08

[1]Year plot was established.

Table 5—Periodic mortality from *Phellinus weirii*, Martha Creek plot

Block number	Before 1952[1]		1952-56		1957-61		1962-66		1967-71		1972-76		1952-76 (total)	
	Stems	Basal area	Stems	Basal area	Stems	Basal area	Stems	Basal area	Stems	Basal area	Stems	Basal area	Stems	Basal area
	Number	Square feet	Number	Square feet	Number	Square feet	Number	Square feet	Number	Square feet	Number	Square feet	Number	Square feet
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	10	4.70	2	0.17	2	1.48	1	.35	0	0	3	3.19	8	5.19
3	64	18.24	8	2.77	5	2.79	8	6.39	5	3.29	3	1.94	29	17.18
4	8	2.95	3	.59	0	0	2	.39	3	.83	2	1.27	10	3.08
5	5	1.04	0	0	1	.35	2	.28	1	.09	2	1.09	6	1.81
6	2	.28	0	0	0	0	1	.20	0	0	3	.59	4	.79
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	3	.89	0	0	0	0	3	.89
9	7	1.75	0	0	2	.55	1	.55	0	0	0	0	3	1.10
10	13	2.90	0	0	5	1.72	5	.87	2	.70	3	1.61	15	4.90
11	5	• 54	0	0	1	.35	1	.09	1	.79	0	0	3	1.23
12	0	0	0	0	0	0	0	0	0	0	1	.35	1	.35
13	1	• 09	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	3	.37	0	0	1	.55	2	.63	2	.39	1	.55	6	2.12
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1	.09	2	.55	1	1.40	1	.20	2	1.61	1	.35	7	4.11
18	31	7.77	6	2.42	2	1.94	8	2.42	3	2.14	1	.35	20	9.27
19	0	0	0	0	0	0	1	.79	0	0	1	.35	2	1.14
20	0	0	0	0	0	0	0	0	1	.09	1	.35	2	.44
21	10	1.35	1	.09	2	.44	0	0	2	.39	2	1.94	7	2.86
22	21	4.32	3	1.48	7	1.44	8	3.34	1	.79	3	2.92	22	9.97
23	14	2.77	2	.28	8	3.07	2	1.27	2	.74	5	3.60	19	8.96
24	19	3.20	8	1.55	4	2.27	3	1.53	2	.55	0	0	17	5.90
25	40	9.72	7	2.59	8	2.46	10	4.10	4	1.18	8	4.38	37	14.71
Total	254	62.08	42	12.49	49	20.81	59	24.29	31	13.58	40	24.83	221	96.00

[1]Year plot was established.

Area out of production at stand age 65 totalled 11.24 percent of the Martha Creek plot (table 6) and 7.34 percent of the 20 blocks measured at Martha Flat (table 7).

Table 6—Area lost for production of conifers because of *Pheltinus weirii*, Martha Creek plot

Block number	Gross area lost	Conifer survivors[1]	Hardwood survivors[1]	Net area lost	
	----------	Acres	----------		Percent
1	0	0	0	0	--
2	.0140	0	0	0.0140	3.50
3	.0723	0	0	.0723	18.08
4	.0413	0	0	.0413	10.33
5	.0312	0	0	.0312	7.80
6	0	0	0	0	--
7	0	0	0	0	—
8	.0125	0	0	.0125	3.13
9	.0094	0	0	.0094	2.35
10	.0265	0	0	.0265	6.63
11	.0203	0	0	.0203	5.08
12	0	0	0	0	—
13	.0016	0	0	.0016	.40
14	0	0	0	0	—
15	0	0	0	0	—
16	.0218	0	0	.0218	5.45
17	.0796	0	0	.0796	19.90
18	.0764	0.0049	0	.0715	17.88
19	.0439	0	0	.0439	10.98
20	.0125	0	0	.0125	3.13
21	.1264	.0049	0	.1215	30.38
22	.1534	.0064	0	.1471	36.78
23	.0811	.0061	.0157	.0750	18.75
24	.1046	0	0	.1046	26.15
25	.2621	.0449	.0011	.2172	54.30
Total	1.1909	.0672	.0168	1.1237	11.24

[1] Based on area occupied by conifers of equal basal area on uninfested blocks.

Table 7—Area lost for production oif conifers because of Phellinus weirii, Marrtha Flat plot

Block number[1]	Gross area lost	Conifer survivors[2]	Hardwood survivors[2]	Net area lost	
		Acres			Percent
6	0.0265	0	0	0.0265	6.63
7	.0484	.0290	0	.0194	4.85
8	.0422	0	0	.0422	10.55
9	0	0	0	0	--
10	.0318	0	0	.0318	7.95
11	.0410	0	0	.0410	10.25
12	.0361	.0008	0	.0353	8.83
13	.0372	0	0	.0372	9.30
14	0	0	0	0	—
15	.0409	0	0	.0409	10.23
16	.0551	.0306	0	.0245	6.13
17	.0331	0	0	.0331	8.28
18	.0655	.0069	0	.0586	14.65
19	.0175	0	0	.0175	4.38
20	.0109	0	0	.0109	2.73
21	.0687	.0130	0	.0557	13.93
22	0	0	0	0	—
23	.0210	0	.0066	.0210	5.25
24	0	0	0	0	—
25	.0946	.0030	.0333	.0916	22.90
Total	.6705	.0833	.0399	.5872	7.34

[1] Blocks 1-5 were destroyed before data were taken.

[2] Based on area occupied by conifers of equal basal area on uninfested blocks.

Discussion

The Martha Flat and Martha Creek sites were selected because damage to the stand by P. *weirri* was apparent. The stand has not been subjected to thinning, fertilization, control of competing vegetation, or other management practices. Because presence of root rot was a criterion for selection, one might expect more damage at this site than would be typical of young, unmanaged Douglas-fir stands.

Losses to P. *weirii* over 25 years (about 4.6 percent of basal area at stand age 65) cannot be considered catastrophic, but at this age with average stand diameter less than 12 inches, continued damage must be expected before commercial maturity.

Although mortality from other causes (primarily suppression) was far greater than from P. *weirii,* most of these trees would not have become crop trees. Many of the trees killed by *P. weirii* would otherwise have become crop trees. Their basal area, had they not been lost, could have increased considerably by age 65. Thus, the estimates for loss of basal area are conservative.

In addition, the nature of the disease (causing persistent openings in stands) increases its relative importance among all causes of mortality. Forested areas opened by the disease (over 11 percent of Martha Creek and over 7 percent of Martha Flat plots) cannot be expected to yield timber in the present forest generation. Not only will these openings increase in size in coming years, but they will carry over into future forest generations unless specific control measures are applied (Hadfield and Johnson 1977). Further indirect losses can be expected because the stand, which is over-stocked in most areas, cannot be thinned without increasing losses from windthrow of root-rotted residual trees (Hadfield and Johnson 1977).

Incidence of the disease for the 25 years after plots were established was related to its incidence before establishment; that is, in areas where substantial mortality was recorded when plots were established, mortality (measured either as number of trees or as basal area) was likely to continue to be substantial in the next 25 years. This supports the contention that spread of the disease depends primarily on distribution and amount of vegetative inoculum (Childs 1970). Clonal analysis of fungus cultures from trees killed by P. *weirii* also supports this, since all new infections appeared to result from contact with vegetative inoculum associated with root systems of current or past generations.

The diameter of trees killed by P. *weirii* was not unlike the average diameter of Douglas-fir alive at the time mortality occurred. Even though losses from root rot are a relatively small part of total mortality (numbers or basal area), the disease itself did significantly affect stand productivity, since both number and basal area of trees lost over 25 years were negatively related to increase in basal area over the same period. Although loss was not related to percent increase in basal area on the two plots combined, the relationship was significant on the Martha Flat plot alone. By one rule of thumb, damage doubles about every 15 years (Childs 1960). This appears to be the case for Martha Flat. Martha Creek, however, has a near constant rate of damage.

Perhaps the most inclusive measure of damage in unmanaged stands is area out of production. Estimates of area out of production can be converted to estimates of timber loss by comparing them with cruises of similar, uninfested stands or with yields from appropriate volume tables; but losses from reduced growth of live, infected trees is not accounted for, and unsalvaged mortality within delineated openings is ignored. In some cases, scattered mortality from root rot not associated with definite stand openings can be added to the volume not realized from areas out of production to further refine estimates of damage.

At the time these two plots were established, *P. weirii* was a relatively unknown consideration in forest management. Twenty-five years of data have indicated that the disease can be destructive in unmanaged stands but that under the conditions of infection encountered in this stand at age 40, severe damage is not likely to occur in one rotation. Unless control measures are implemented after this stand is harvested or unless future stands on the site are established and managed to reduce P. *weirii* losses, greater damage is likely to occur in future rotations of Douglas-fir.

This is a case study of two plots in one root-rot-infested stand. The disease might affect other stands on other sites similarly, or perhaps differently enough to change these conclusions.

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Metric Equivalents

1 acre = 0.404 7 hectare
1 foot = 0.304 8 meter
1 chain = 20.116 8 meters
1 mile = 1.609 34 kilometers