A Model for Estimating Current and Future Timber Volume Loss from Stem Decay Caused by *Heterobasidion annosum* and Other Fungi in Stands of True Fir[1]

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Abstract: In 1979, an equation was developed to estimate the percentage of current and future timber volume loss due to stem decay caused by Heterobasidion annosum and other fungi in advance regeneration stands of grand and white fir in eastern Oregon and Washington. Methods for using and testing the equation are presented. Extensive testing in 1988 showed the equation to be valid for estimating volumes of timber loss due to stem decay in grand fir stands in northern Idaho, in white fir stands in southern Oregon and northern California, in red fir stands in northern California, and in western hemlock stands in western Oregon and Washington. Intensive testing of these and other species in western North America and in other geographical areas should be done to verify the utility of the fir decay model.

In western North America, the true firs (Abies spp.) attain maximum economic and ecological importance. Fir timber volumes in Oregon and Washington are 17.2 billion cubic feet (0.5 cubic meters) distributed among several species: noble fir (Abies procera Rehd.), Pacific silver fir (A. amabilis (Dougl.) Forbes), subalpine fir (A. lasiocarpa (Hook.) Nutt.), California red fir (A. magnifica A. Murr.), white fir (A. concolor (Gord. & Glend.) Lindl.:Hildebr.), and grand fir (A. grandis (Dougl.:D. Don) Lindl.). These true fir species are an important timber resource. Stands of fir also protect watershed, hold mountain snowpacks, and provide cover and thermal protection for wildlife. They are also valuable as aesthetic components of recreational landscapes, and for specialty products such as Christmas trees and decorative greenery (Franklin 1981).

Annual stem decay losses in true firs in Oregon and Washington have been estimated at 25 million cubic feet (0.7 million cubic meters) (Childs and Shea 1967). Over 20 percent of the decay in advance grand and white fir regeneration is caused by Heterobasidion annosum (Fr.) Bref. in eastern Oregon and Washington (Aho and others 1987). Other fungi that cause appreciable stem decay in true firs are Echinodontium tinctorium (Ell. & Ev.), Hericium Abietis (Weir:Huber) K. Harrison, Pholiota limonella (Pk.) Sacc., and Stereum sanguinolentum (Alb. & Schw.:Fr.) Fr.

Stem decay losses in noble fir, Pacific silver fir, California red fir, and subalpine fir are less serious than in white fir and grand fir. Consequently, there are few reports of stem decay damage in these species in Oregon and Washington. Although studies (Morrison and others 1986) show stumps of Pacific silver fir to be highly susceptible to infection by H. annosum, the incidence of infection or decay in young trees has not been reported. Stem decay fungi most commonly found in advance regeneration stands of Pacific silver fir and subalpine fir include S. sanguinolentum and E. tinctorium (Smith and Craig 1970, Herring and Etheridge 1976). The fungi most commonly associated with stem decay in young-growth California red fir include H. annosum, P. limonella, and Y. tinctorium (Aho and others 1983). Noble fir is probably the most decay-resistant species among the true firs, but occasionally & tinctorium causes significant losses in mature timber (Filip, G.M., unpublished)[3]. Incidence of stem decay fungi in advance regeneration stands of noble fir has not been reported.

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DEVELOPMENT OF THE FIR DECAY EQUATION

Methods

In the field in 1979, 24 stands of advance regeneration of grand fir and white fir in eight National Forests in eastern Oregon and Washington were sampled to determine the incidence of fungal infection and stem decay (Filip and others 1983). A variety of stand and tree characteristics were recorded to relate these to amounts of stem decay. A total of 464 living stems averaging 5.9 inches (15.0 cm) in diameter at breast height (DBH) and 77 years of age were sampled systematically in all stands (approximately 20 trees per stand). Only potential crop trees were sampled because it was assumed that noncrop trees would be destroyed during stand improvement. Each tree was felled and measured to determine total cubic volume and volume of stem discoloration and decay. Each tree was dissected into 1- to 2-foot (0.3 to 0.6 m) bolts to just above the lowest whorl of live branches, and these bolts were returned to the laboratory.

In the laboratory, a total of 21,249 isolations were attempted by aseptically splitting each bolt to expose wounds and stem and twig piths (Aho and others 1987). Isolations were attempted from stem and twig piths, heartwood, sapwood, wetwood, ingrown tissue, fir engraver beetle (Scolytus ventralis LeConte) galleries, discolored wood, and decayed wood.

Results

Decay Fungi and Wounding Incidence

Of 655 isolations of decay fungi from 247 of 464 trees, E. tinctorium was recovered most frequently, followed by H. annosum and P. limonella (fig. 1). A total of 141 of 464 trees had discoloration and decay which accounted for 2.2 percent of the total merchantable stand volume. Most (55 percent) of the discoloration and decay was caused by E. tinctorium, H. annosum, and P. limonella (fig. 2). A total of 334 wounds on 248 trees were classified and dissected. At least 45 percent of all trees with wounds had decay fungi present. Decay fungi most frequently isolated from wounded trees were E. tinctorium, P. limonella, and H. annosum (fig. 3). Most of the isolations of H. annosum were from discolored or decayed wood, whereas most of the isolations of E. tinctorium were from clearwood (fig. 4). These data support the hypothesis that fungi such as H. annosum invade wounds and initiate the decay process almost immediately, whereas other fungi such as E. tinctorium enter hosts via minute branchlet stubs, become dormant after branchlet stubs occlude, and are activated by wounds in the vicinity of dormant infections (Aho and others 1987).

Fir Decay Equation

An equation was developed from the above data to estimate the percentage of total crop tree volume affected by both incipient and advanced decay caused by all species of fungi (Filip and others 1983):

$$\text{LogN (DV\%)} = 1.8\ \text{LogN (AG)} + 0.8\ \text{LogN (WD\%)} - 0.4(\text{AS}) - 10.4$$

where DV% = Percentage of total crop tree volume with incipient and advanced decay
AG = Mean crop tree total age (years)
WD% = Percentage of crop trees with one or more wounds

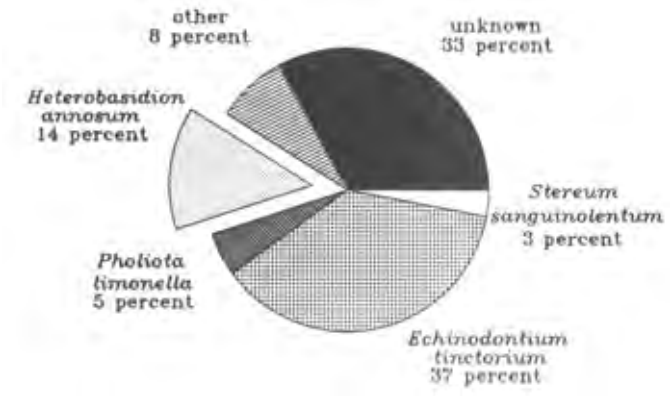

Figure 1--Frequency of isolation of wood decaying fungi from clear, discolored, and decayed wood in 247 of 464 white fir and grand fir trees in eastern Oregon and Washington.

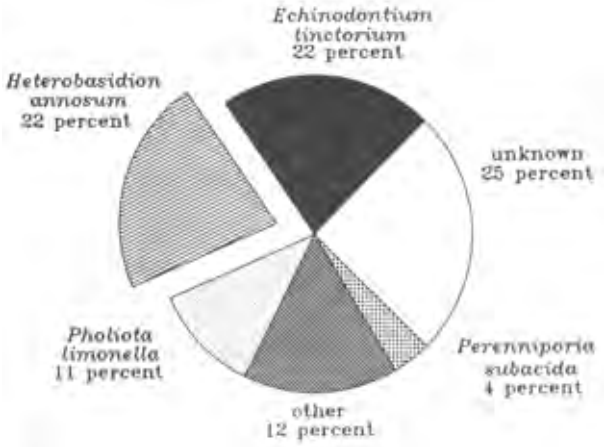

Figure 2--Frequency of isolation of wood decaying fungi from decayed wood in 141 white fir and grand fir trees in eastern Oregon and Washington.

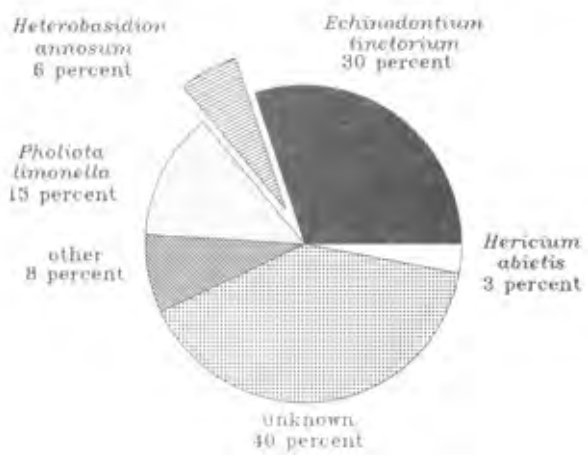

Figure 3--Frequency of isolation of wood decaying fungi from 112 wounded and infected white fir and grand fir trees in eastern Oregon and Washington.

AS = Stand aspect (0 = N, NW, NE, W, flat; 1 = S, SE, SW, E)
LogN = Natural logarithm
(R^2 = 0.70, SE = 0.79)

This equation can be programmed on hand-held calculators or data recorders. It can be used to predict percentage of decay at any preharvest time in the future because "mean crop tree total age" is a variable in the equation. Also, the "percentage of crop trees with one or more wounds" can be increased, especially if future stand entries are planned. Board-foot (Scribner) defect percentages can be calculated for stands •11 inches (30 cm) DBH by multiplying cubic decay percentages by a factor of 2.7 (Aho 1977). Managers of true fir stands in eastern Oregon and Washington routinely use this equation to predict current and future amount of stem decay.

TESTING OF THE FIR DECAY EQUATION

In 1988, data from four different areas were used to test the fir decay equation that was developed in Oregon and Washington. Only the comparisons in southern Oregon stands were done with data that were collected within the geographic range and with the species used to develop the equation. The other three tests were done with data from other species or from areas beyond the range of model development. Methods of stand sampling and data collection for all four areas were similar to those used to originally develop the fir decay equation.

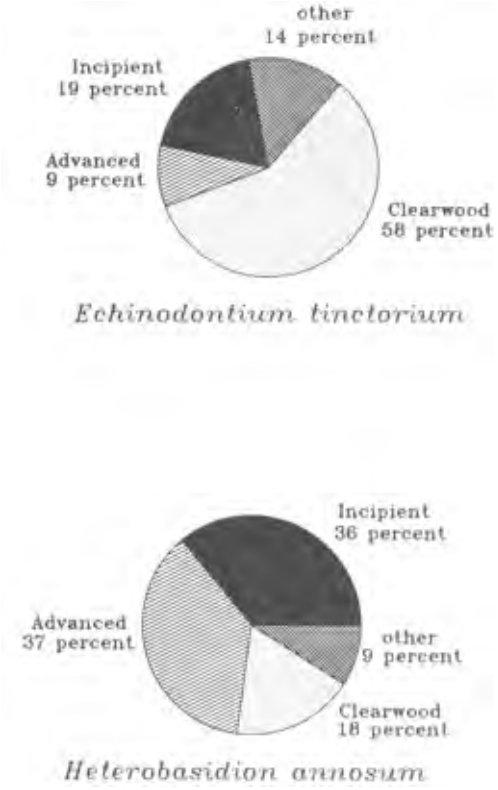

Figure 4--Source of isolations of Heterobasidion annosum and Echinodontium tinctorium from 98 white fir and grand fir trees in eastern Oregon and Washington.

Southern Oregon Comparisons

Heterobasidion annosum is responsible for stem decay (Aho and others 1987) and mortality (Schmitt and others 1984) in southern Oregon white fir stands. In 1984, an evaluation was conducted to determine the incidence of decay in four stands of white fir that had been underburned between 1962 and 1982 on the Fremont National Forest in southern Oregon (Goheen and others 1985). The fir decay equation (from above) was tested by determining if the decay values observed in the four southern Oregon stands were within their associated 95 percent prediction intervals. Prediction intervals were calculated using the SAS/STAT Package Version 6 (SAS Institute 1987). Observed decay values for all four stands were within their associated prediction intervals (fig. 5). It appears that the fir decay equation can be used to reliably estimate stem decay in similar white fir stands in southern Oregon.

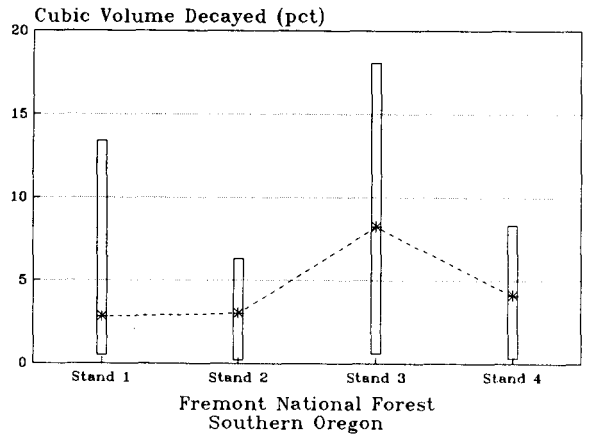

Figure 5--Levels of decay (bars) predicted by the fir decay equation for four underburned stands of white fir in southern Oregon. Stars within the bars represent actual decay volumes measured for each stand.

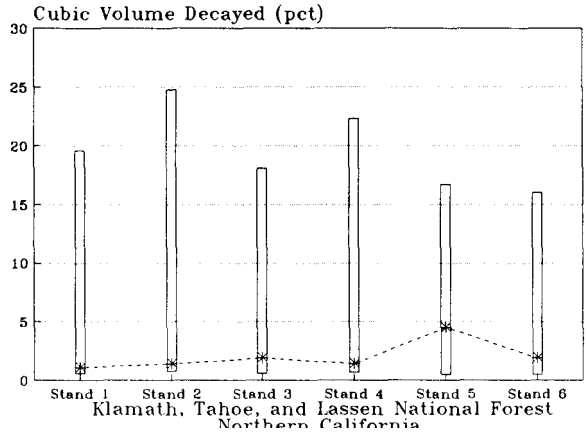

Figure 6--Levels of decay (bars) predicted by the fir decay equation for three stands of white fir (odd-numbered stands) and three stands of red fir (even-numbered stands) in northern California. Stars within the bars represent actual decay volumes measured for each stand.

This is not surprising: the equation was developed from data gathered in southern Oregon.

Northern California Comparisons

In 1981, a study was conducted to determine the incidence of decay in three stands of white fir and three stands of red fir on the Klamath, Lassen, and Tahoe National Forests in northern California (Aho and others 1983, 1989). Over 3 percent of the cubic volume of decay was caused by H. annosum. Data collected in 1981 were used in 1988 to test the fir decay equation. The observed decay values for the six stands in northern California were on the low end but still within the associated 95 percent prediction intervals (fig. 6). These comparisons suggest that the fir decay equation developed in Oregon and Washington can be used in northern California for white fir and for a previously untested species, red fir.

Northern Idaho Comparisons

In 1988, a study was conducted to determine incidence of stem decay in twelve 40- to 90-year-old grand fir stands in the Clearwater region in northern Idaho (Filip and others, in press). Although attempts were not made in this study to identify decay fungi, H. annosum has been shown to cause decay in grand fir throughout northern Idaho (Hudson 1972, Chacko and Partridge 1976). Observed decay values for all 12 stands were on the low end but still within the associated 95 percent prediction intervals (fig. 7). The fir equation appears valid for grand fir stands in northern Idaho, and the geographic range of the equation may be extended.

Western Oregon Comparisons

In 1978, a study was conducted to determine the incidence of stem decay in eight thinned and eight unthinned stands of 40- to 120-year-old western hemlock (Tsuga heterophylla (Raf.) Sarg.) in western Oregon and Washington (Goheen and others 1980). Nearly 50 percent of the cubic volume of stem decay was caused by H. annosum. The observed decay values for all 16 stands of hemlock were within their associated 95 percent prediction intervals (fig. 8). This is the first time that the fir decay equation was used to predict decay percentages in a genus other than Abies.

FUTURE TESTING OF THE FIR DECAY EQUATION

The fir decay equation has not been adequately tested in grand and white fir in the interior West nor has it been tested at all for other true fir species such as noble, Pacific silver, or subalpine firs. It is interesting that the fir decay equation may be valid for other species besides true firs such

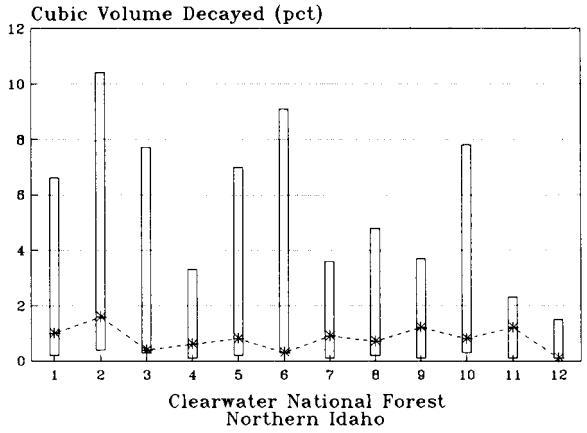

Figure 7--Levels of decay (bars) predicted by the fir decay equation for 12 stands of grand fir in northern Idaho. Stars within the bars represent actual decay volumes measured for each stand.

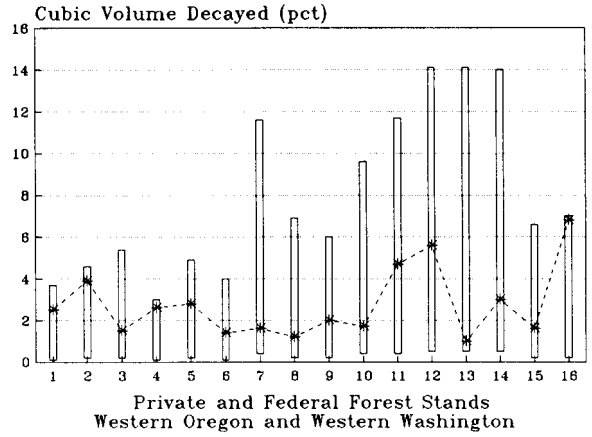

Figure 8--Levels of decay (bars) predicted by the fir decay equation for eight thinned stands (odd-numbered stands) and eight unthinned stands (even-numbered stands) of western hemlock in western Oregon and Washington. Stars within the bars represent actual decay volumes measured for each stand.

as western hemlock. Further testing on other species and in new areas is warranted. Dissection studies are relatively easy to perform: the northern Idaho study was completed in about three weeks with a crew of four. If necessary, the species and incidence of decay fungi associated with studied stands could be determined. However, procedures for collection, isolation, and identification of decay fungi require special expertise and are expensive and time consuming.

The testing of the fir decay equation on other conifer species and in other geographical areas might provide a useful tool for forest managers if the fir decay equation is proven valid. Also, the linking of the fir decay equation to growth and yield models can extend the usefulness and improve the accuracy of both models.

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