

Factors Affecting Infection of Precommercial Thinning Stumps by *Heterobasidion annosum* in Coastal British Columbia¹

D. J. Morrison²

Abstract: Stumps of Douglas-fir, western hemlock, Sitka spruce, and amabilis fir were sampled in precommercially thinned stands to determine the percentage of stump surface area colonized by *Heterobasidion annosum*. There were significant differences among species in the percentage of stumps colonized. Seasonal patterns were evident for each species; however, differences were not significant. Both the percent incidence of infection and the percentage of surface area colonized increased with increasing stump diameter. The results indicate that stump treatment to prevent infection is not necessary for Douglas-fir, but it should be considered for the most susceptible species, Sitka spruce and amabilis fir.

Coastal British Columbia (B.C.) includes Vancouver Island, the Queen Charlotte Islands and the mainland west of the Coast Mountains. The region extends from 48° 20' to about 55° N latitude. It is mountainous and contains several major river valleys and numerous fjords which extend the maritime climatic influence into the Coast Mountains.

The forest land classification of the region is based on climate, soil and vegetation (Krajina 1965, Klinka and others 1984). Annual precipitation ranges from 600 mm in the rain shadow of the Vancouver Island mountains to 4500 mm at locations on the outer coast. Commercial forests occur within the coastal Douglas-fir zone (CDF), which is located on southeastern Vancouver Island, and the coastal western hemlock zone (CWH). The commercial coniferous tree species in those zones are Douglas-fir [*Pseudotsuga menziesii* (Mirb.) France], western

hemlock [*Tsuga heterophylla* (Raf.) Sarg.], amabilis fir [*Abies amabilis* Dougl. ex Forbes], Sitka spruce [*Picea sitchensis* (Bong.) Carr.] and western red cedar [*Thuja plicata* Donn]. Second-growth stands are established either by planting, primarily of Douglas-fir, or by natural regeneration; most of these stands require precommercial thinning at between 12 and 20 years of age to achieve optimum stocking.

Heterobasidion annosum (Fr.) Bref. occurs throughout coastal B.C., except in the driest parts of the CDF zone. Sporophores of *H. annosum* are common on diseased old-growth stumps and logging residue, although often they are difficult to locate. Spores of *H. annosum* are present in the air spora throughout the year, although their numbers are lowest during summer and winter and are reduced by precipitation (Reynolds and Wallis 1966). Except for western red cedar, fresh stumps of the commercial species are susceptible to infection by airborne spores of the fungus (Morrison and Johnson 1970, Wallis and Reynolds 1970). The stump and its roots may be colonized by the fungus, which spreads to adjacent residual trees at root contacts (Morrison and Johnson 1978). In most stands, particularly those which are naturally regenerated (unburned and not planted), precommercial thinning creates large numbers of susceptible stumps. If even a small percentage of these stumps are colonized by *H. annosum*, the amount of inoculum on the site increases markedly (Morrison and Johnson 1978).

A study in the Prince Rupert Forest Region (Morrison and others 1986) showed that tree species, stump diameter, and season of thinning influence the number of stumps that are colonized. The purpose of the work described here was to evaluate the effect of these factors on stump infection by *H. annosum* throughout the coastal B.C. region in order to determine hazard from annosus root disease.

¹ Presented at the Symposium on Research and Management of Annosus Root Disease in Western North America, April 18-21, 1989, Monterey, California.

² Forest Pathologist, Forestry Canada, Pacific Forestry Centre, Victoria, B.C. Canada.

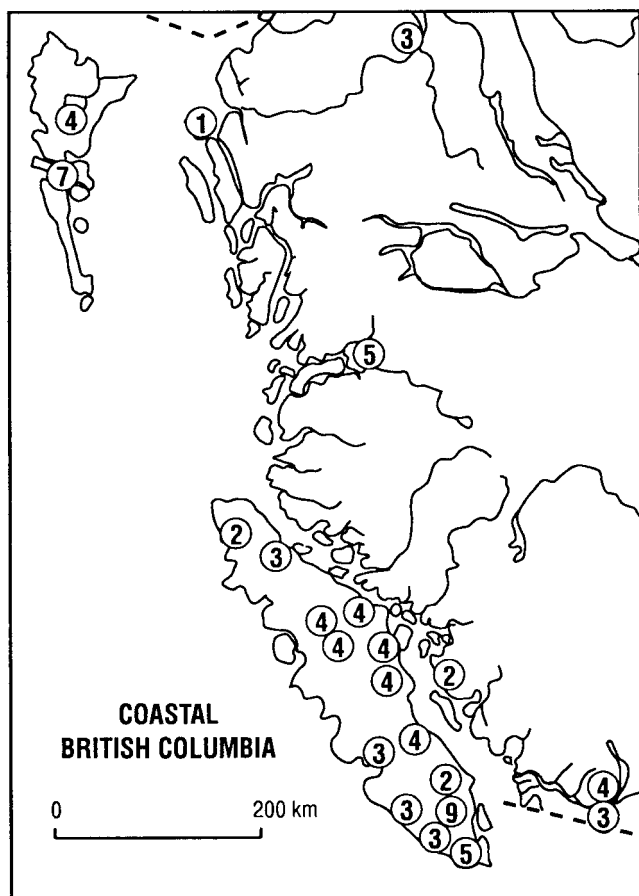


Figure 1--Location of precommercially thinned conifer forest stands in which stumps were sampled for *Heterobasidion annosum* in coastal British Columbia. The number in each circle indicates the number of stands sampled at each location.

METHODS

Stumps were sampled in 83 precommercially thinned stands in the coastal B.C. region (Fig. 1). Other studies show that the proportion of stumps colonized by *H. annosum* declines for a few years after thinning (Dimitri and others 1971, Morrison and Johnson 1978); hence, only stands thinned 3-5 years previously were sampled. For each tree species, 25 stumps in each 5-cm diameter class (2.5-7.4, 7.5-12.4, etc.) were sampled along random transects through each stand. After 5 to 15 cm was trimmed from the top of the stump and discarded, depending on the number of years since thinning, a disk 2-4 cm thick was cut from each stump. These disks were incubated between layers of moist newspaper for about 5 days, then the areas showing the conidial stage of *H. annosum* were marked on each disk. The

areas colonized by *H. annosum* on each disk were traced on transparent plastic and were measured with a planimeter. The diameter-inside-bark of all disks and the heartwood diameter for Douglas-fir disks were measured. The season of thinning was noted from stand management records.

The data were analyzed as follows: plots and regressions of standard deviations against the means were examined, and the dependent variables were transformed to reduce associations between their means and variances. The values for percent infection of the susceptible stump area were arcsine-transformed. Colonized area values were logarithmically transformed by taking the base-10 logarithm of one plus the value. Disease incidence, a binary variable with values 0 (uninfected) or 1 (infected) for each stump, was converted into the infected proportion of the stumps found within each cell (stand by species by diameter-class subgroup), and was then arcsine-transformed.

These transformed variables were subjected to analysis of covariance by the method of least squares, using the General Linear Model procedure of SAS (SAS Institute 1985), to better enable attribution of dependent-variable variation to classification and continuous independent variables in spite of missing cells and unequal numbers of stumps per cell.

Disease incidence, untransformed, was also subjected to categorical analysis by logistic regression, using the CATMOD procedure of SAS (SAS Institute 1985).

RESULTS

Douglas-fir stumps occurred in 38 of the 83 stands sampled, western hemlock stumps in 75, amabilis fir stumps in 25, and Sitka spruce stumps in 11. The only stands that contained a sufficient number of Sitka spruce stumps to make a sample were on the Queen Charlotte Islands. For each species, a majority of the stands sampled had stumps in the 5, 10, and 15 cm diameter classes, about 40 percent of stands contained 20 cm diameter stumps and only two or three stands had 25 cm diameter stumps. The number of stands available for sampling varied for each species, stump diameter class and season of thinning. Consequently, unequal numbers of stands were sampled. For example, the number of stands precommercially thinned in each season varied due to operational constraints

Table 1. Infection of precommercial thinning stumps by Heterobasidion annosum in coniferous forest stands in coastal British Columbia.

Species	Stands	Stumps Colonized	Stumps > 10% Area Colonized	Area Colonized All Stumps	Area Colonized Inf. Stumps
	No.	Pct	Pct	Pct	Pct
Douglas-fir	38	5.9a+	2.7	1.6	16.0a+
Hemlock	75	9.8b	7.0	4.3	27.7b
Sitka spruce	11	16.8c	12.7	11.4	32.3b
Amabilis fir	25	21.3d	15.8	8.6	32.7b

+ Means within the column followed by a different letter are significantly different ($P < 0.01$) according to Duncan's multiple range test.

such as snow depth in the winter and spring (particularly in high elevation western hemlock-amabilis fir stands) and fire hazard during the summer.

The entire surface of stumps of western hemlock, amabilis fir and Sitka spruce was susceptible to infection by airborne spores, whereas only the sapwood of Douglas-fir stumps, which comprised about 69 percent of the surface area, could be infected by airborne spores. Heterobasidion annosum was not found in any stumps from nine of the 83 stands sampled; two stands contained only Douglas-fir stumps and seven stands contained Douglas-fir and western hemlock stumps. Four of the nine stands were thinned in the spring, one in the summer, three in the autumn and one in the winter.

Species Susceptibility

Species susceptibility as indicated by percent stumps infected and percent surface area colonized on infected stumps was (in increasing order) Douglas-fir, western hemlock, Sitka spruce, and amabilis fir (Table 1). Disease incidence values for the species differed significantly ($P < 0.01$) from each other, and values for percent stump surface area colonized for hemlock, Sitka spruce, and amabilis fir differed significantly ($P < 0.01$) from that for Douglas-fir. Species susceptibility differences also are apparent from the distribution of mean disease incidence and mean percent surface area colonized for stands containing each species (Figs. 2 and 3). Most notably, the percentage of stands lacking or with low incidence of diseased stumps and low stump surface area colonized is high for Douglas-fir and low for amabilis fir and Sitka spruce.

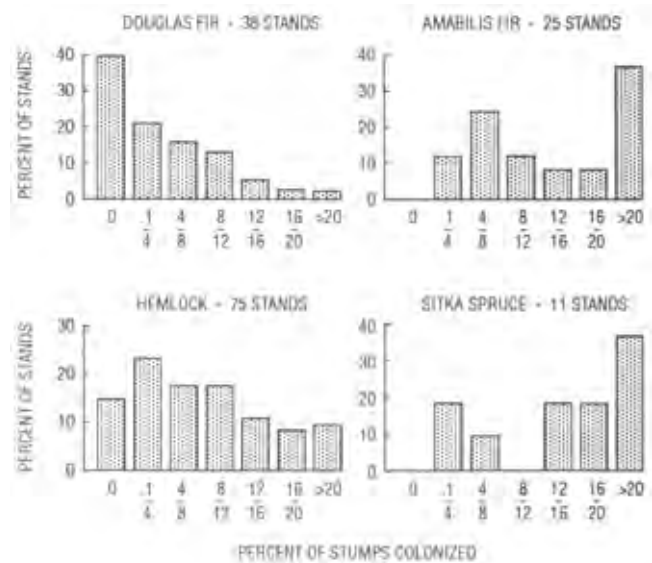


Figure 2--Percentage of conifer forest stands containing Douglas-fir, western hemlock, Sitka spruce, and amabilis fir within categories of percent stumps colonized by Heterobasidion annosum in coastal British Columbia.

Stump Diameter

For stumps in the 5-20 cm diameter classes of each species, the percentage colonized by H. annosum increased with increasing stump diameter. Percent stumps colonized plotted against stump susceptible area is essentially linear (Fig.4). Percent surface area colonized also increased with increasing diameter for 5-20 cm stumps (Fig.5). Except for Sitka spruce, surface area colonized was lower for 25 cm diameter stumps than for 20 cm diameter stumps.

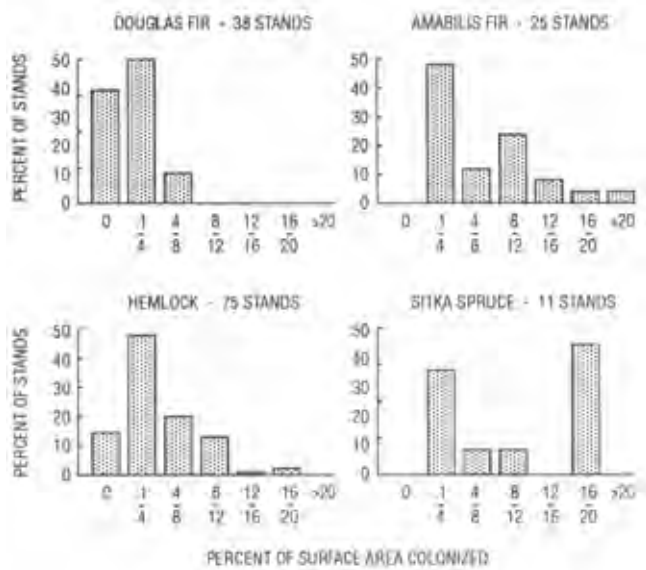


Figure 3--Percentage of conifer forest stands containing Douglas-fir, western hemlock, Sitka spruce, and amabilis fir within categories of percent surface area colonized by *Heterobasidion annosum* in coastal British Columbia.

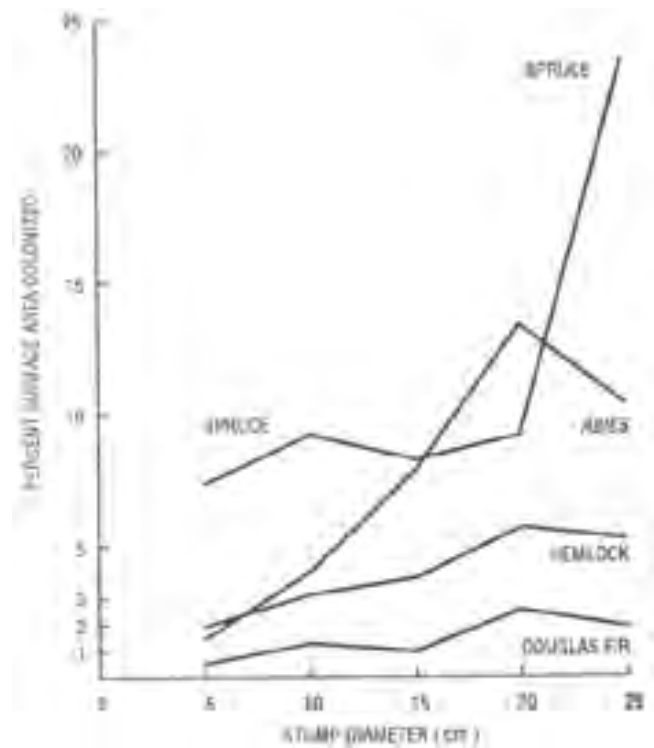


Figure 5--Percentage of stump surface area colonized by *Heterobasidion annosum* for stumps 5-25 cm in diameter from coniferous forest stands in coastal British Columbia.

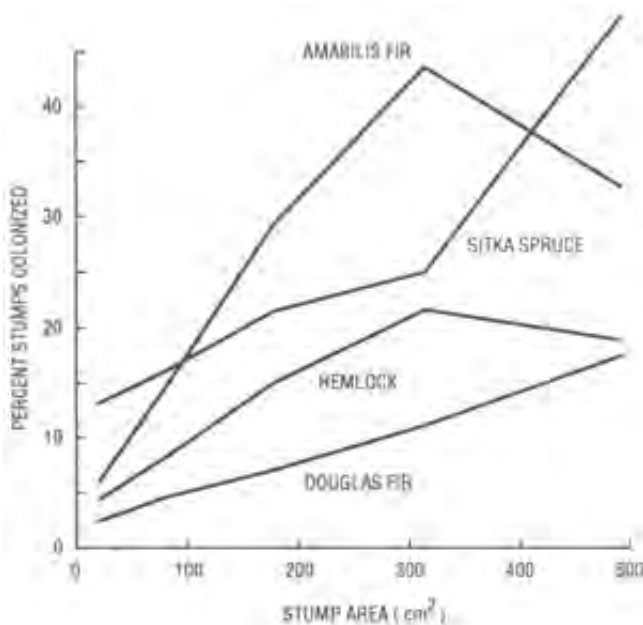


Figure 4--Percentage of stumps colonized by *Heterobasidion annosum* plotted against area of 5-25 cm diameter stumps from coniferous forest stands in coastal British Columbia.

Season of Thinning

Data for stumps of each species show a season-of-thinning pattern for percent stumps colonized and percent stump surface area colonized (Table 2). For each species, the pattern was identical for both parameters. Variation due to season of thinning when compared to the residual variation among stands was non significant. The maximum value of each of those parameters occurred in the summer for Douglas-fir, western hemlock, and Sitka spruce and in the autumn for amabilis fir. The minimum values for each of those parameters occurred in the spring for Douglas-fir and amabilis fir, in the winter for Sitka spruce, and in the autumn and winter for western hemlock. There was little difference among values for two or three seasons for Douglas-fir, western hemlock, and Sitka spruce. Amabilis fir showed the most seasonal variation and Douglas-fir the least.

Table 2. Effect of season-of-thinning on the percentage of thinning stumps colonized and the percentage of susceptible area colonized by Heterobasidion annosum in coniferous forest stands in coastal British Columbia.

Season	<u>Douglas-Fir</u>		<u>Hemlock</u>		<u>Amabilis Fir</u>		<u>Sitka Spruce</u>	
	Colon. Pct	Area Pct	Colon. Pct	Area Pct	Colon. Pct	Area Pct	Colon. Pct	Area Pct
Mar-May	3.0	0.6	10.8	4.2	4.0	1.1	18.0	9.1
Jun-Aug	7.8	3.1	13.1	5.6	12.9	3.6	24.3	14.7
Sep-Nov	6.4	1.4	8.1	3.4	30.4	12.4	18.8	13.0
Dec-Feb	5.8	1.4	9.1	3.4	16.2	10.1	15.1	5.4

DISCUSSION

The amount of airborne inoculum of H. annosum at the time of stand thinning is the most important factor determining the incidence of infection and percentage of stump surface area colonized (Rishbeth 1957, Meredith 1959, Yde-Andersen 1962). A retrospective, quantitative measure of inoculum in each stand was not possible; however, the occurrence of stumps colonized by H. Annosum in 74 of 83 stands confirms previous reports (Reynolds and Wallis 1966, Morrison and Johnson 1970) of the geographical and temporal distribution of the fungus. The nine Douglas-fir or Douglas-fir-hemlock stands in which H. annosum-colonized stumps were not found lacked a common characteristic. The absence of colonized stumps may be related to species composition of the previous stand, in that stands lacking a hemlock component in the old growth are less likely to contain H. annosum inoculum.

The increasing order of susceptibility of the four species was identical to that reported for the Prince Rupert Forest Region (Morrison and others 1986). In the 1986 study, the percentage of Douglas-fir stumps colonized was about one-half that in this study, and for the other species it was 20-30 percent lower in this study. These differences may be attributed to a larger number of stands representing a wider range of geographical location, stump diameter and season of thinning. The average percentages of stumps infected for uninoculated hemlock and Sitka spruce in southeastern Alaska (Shaw 1981) were 3 percent and 12 percent, respectively, which are somewhat lower than for those species on the Queen Charlotte Islands. The difference in incidence between those locations is difficult to explain. The tree species and climate are identical;

however, sporophores are common on old-growth hemlock stumps on the Queen Charlotte Islands whereas they appear to be rare in southeastern Alaska (Shaw 1981). The incidence of H. annosum in stumps of both species 6-15 months after inoculation with conidia and mycelial fragments of H. annosum (Shaw 1981) was similar to the natural incidence observed in this study, suggesting that lower spore populations in Alaska may account for the difference in natural incidence of colonized stumps.

Predictably, target size (stump diameter) is an important determinant of disease incidence, particularly when inoculum levels are low. With abundant inoculum, the lines in Figure 3 could be expected to be parallel to the x-axis. In addition, if inoculum is limiting, the percent surface area colonized would be directly related to stump diameter. In each stand sampled, the age when cut of stumps of all diameters were within 2-3 years of the mean for the stand. If inoculum is not limiting, the increase in percentage of surface area colonized with increasing stump diameter suggests that larger diameter stumps with wider growth rings are more readily colonized than are smaller diameter stumps.

The marked seasonal variation in the incidence of stump colonization by H. annosum observed in Norway spruce by Yde-Andersen (1962) and in pines by Rishbeth (1957) and Meredith (1959) was attributed to weather and fungal competitors. The clear seasonal patterns evident for uninoculated hemlock and Douglas-fir stumps 0.5 year after thinning were much less pronounced and somewhat altered 5 yr after thinning (Morrison and Johnson 1978). In this study, competition from other primary colonizers did not appear to limit the incidence of H. annosum. In most stands,

a number of the stumps sampled were free from Basidiomycete colonizers, except for Armillaria sinapina Bérubé & Dessureault which spread from the roots and invaded the sapwood. Redfern (1989) showed that high moisture content resulting from high rainfall is likely to reduce stump infection by H. annosum in Sitka spruce. His results undoubtedly apply to other tree species and may explain the lower incidence of H. annosum in stumps cut from late autumn to early spring in coastal B.C.

At the beginning of this study, the questions were: Can species, stump diameter, and season of thinning be hazard-rated for stump colonization by H. annosum, and if so, is the hazard low enough in any category to make stump treatment unnecessary and conversely, where should stump treatment be recommended. The proportion of stands (0.4) in which no Douglas-fir stumps were colonized, and the low incidence and low percentage of surface area colonized in most of the other stands indicate that the hazard for Douglas-fir is low. In contrast, the high values of these parameters for amabilis fir and Sitka spruce suggest that the hazard for these species is high, and that treatment of stumps of these species should be considered.

ACKNOWLEDGMENTS

I thank Alan Johnson for technical assistance and Clarence Simmons for statistical analyses.

REFERENCES

- Dimitri, L.; Zycha, H.; Kliefoth, R. 1971. Untersuchungen über die Bedeutung der Stubbeninfektion durch Fomes annosus für die Ausbreitung der rotfäule der Fichte. Forstwissenschaftliches Centralblatt 90:104-117.
- Klinka, K.; Green, R.N.; Courtin, P.J.; Nuszdorfer, F.C. 1984. Site diagnosis, tree species selection, and slash burning guidelines for the Vancouver Forest Region. Land Management Report 25, British Columbia Ministry of Forests, Victoria.
- Krajina, V.J. 1965. Biogeoclimatic zones and classification of British Columbia. In: V.J. Krajina, ed. Ecology of Western North America 1:1-17. Botany Department, University of British Columbia

- Meredith, D.S. 1959. Infection of pine stumps by Fomes annosus and other fungi. Annals of Botany, New Series 23:455-476.
- Morrison, D.J.; Johnson, A.L.S. 1970. Seasonal variation of stump infection by Fomes annosus in coastal British Columbia. Forestry Chronicle 46:200-202.
- Morrison, D.J.; Johnson, A.L.S. 1978. Stump colonization and spread of Fomes annosus 5 years after thinning. Canadian Journal of Forest Research 8:177-180.
- Morrison, D.J.; Larock, M.D.; Waters, A.J. 1986. Stump infection by Fomes annosus in spaced stands in the Prince Rupert Forest Region of British Columbia. Report BC-X-285. Canadian Forestry Service, Pacific Forestry Centre, Victoria B.C.; 12 pp.
- SAS Institute Inc. 1985. User's Guide: Statistics, Version 5 Edition. Cary, NC: SAS Institute Inc.; 956pp.
- Redfern, D.B. 1989. Factors affecting infection of Sitka spruce stumps by Heterobasidion annosum and the implications for disease development. pages 297-307 In: D.J. Morrison, ed. Proceedings of the Seventh International Conference on Root and Butt Rots. Forestry Canada, Pacific Forestry Centre, Victoria, B.C.; 680 pp.
- Reynolds, G.; Wallis, G.W. 1966. Seasonal variation in spore deposition of Fomes annosus, in coastal forests of British Columbia. Canadian Forestry Service Bi-monthly Research Notes 22:6-7.
- Rishbeth, J. 1957. Some further observations on Fomes annosus Fr. Forestry 30:69-89.
- Shaw, C.G. III. 1981. Infection of western hemlock and Sitka spruce thinning stumps by Fomes annosus and Armillaria mellea in southeast Alaska. Plant Disease 65:967-971.
- Wallis, G.W.; Reynolds, G. 1970. Fomes annosus root and butt rot: A threat in coastal British Columbia. Forestry Chronicle 46:221-224.
- Yde-Andersen, A. 1962. Seasonal incidence of stump infection in Norway spruce by air-borne Fomes annosus spores. Forest Science 8:98-103.