DECAY ASSOCIATED WITH LOGGING INJURY TO SPRUCE AND BALSAM IN THE PRINCE GEORGE REGION OF BRITISH COLUMBIA[1]

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ABSTRACT

In a study of decay associated with logging damage in the Prince George region of British Columbia, 873 spruce and balsam trees with 2938 scars were analyzed. Scars averaged 5, 15, and 31 years of age and were classified according to their position, size, and depth. The relation of scar infection to locality, tree diameter, site, and to scar position, size, depth, and age was studied. The average volume of decay associated with scars of different types and ages was determined, and the fungi most frequently found associated with the decay are reported.

INTRODUCTION

Although selective cutting has been in general practice in parts of British Columbia for a number of years, the significance of damage to residual stands is unknown. The most common type of damage is scarring and, although it is well known that scars provide avenues of entrance for decay-producing fungi, studies have been made of only a few western North American tree species (4, 7). The present study was undertaken in the Prince George region at the request of the British Columbia Forest Service. It was to determine some of the factors influencing the infection of scars by decay-producing fungi, and the relative amount of decay associated with scars of different types and ages on residual spruce (*Picea glauca* (Moench) Voss var. *albertiana* (S. Brown) Sarg.) and balsam (alpine fir) (*Abies lasiocarpa* (Hook.) Nutt.).

METHODS

With the exception of broken tops, all scars were classified according to their position on the tree, size, and depth. Four scar positions were recognized: roots, ground-contact, butt, and upper-bole. Scars occurring entirely below the ground level were classed as root scars, those in contact with the soil, other

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than root scars, were classed as ground-contact scars (Fig. 1); those with their lower edge occurring between ground level and d.b.h. were classed as butt scars (Fig. 2); and those occurring entirely above d.b.h. were classed as upper-bole scars (Figs. 3, 4). Three scar sizes were recognized: those having a surface area up to 36 sq. in. were classed as size 1; those having a surface area between 37 and 144 sq. in. were classed as size 2; and those having a surface area greater than 144 sq. in. were classed as size 3. Two scar depths were recognized: if the sapwood had been gouged the scar was classed as having depth *s* (Fig. 5), and if the bark had been removed without obvious damage to the sapwood the scar was classed as having depth *b* (Fig. 6).

Each scar was examined by sectioning and was classed as healthy or infected[3]. Cubic foot volumes of the associated decay were computed by Smalian's formula. Scars having less than 0.1 cu. ft. of associated decay were classed as infected, but the volume data were not compiled.

All trees examined were felled and dissected into 16-foot logs. The upper surfaces of all lateral roots were uncovered for a distance of 3 ft. from the base of the tree. Height, age, diameter inside bark at the time of examination, and diameter inside bark at the time the stand was partially cut, were recorded. Cubic foot volumes, from a stump height of 1 ft. to the top of the tree, were computed by Smalian's formula for all trees examined in the stands having an average scar age of 15 and 31 years.

Residual stands were selected for sampling on the basis of time since the initial cut, forest site, and stand composition. Sampling was confined to the Devil's Club (*Picea glauca* var. *albertiana, Abies lasiocarpa, Fatsia horrida* Benth. & Hook. ex S. Wats., *Athyrium filix-femina* (L.) Roth), and Sarsaparilla—Oak Fern (*Picea glauca* var. *albertiana, Abies lasiocarpa, Aralia nudicaulis* L., *Dryopteris linnaeana* C. Chr.) associations of the spruce-balsam type (1). Of the six tentatively identified forest associations in the spruce-balsam type, the Devil's Club (D-C) and the Sarsaparilla—Oak fern (A-D) are the two most extensive. The D-C association, or site, ranks second in site quality and mature trees average 129 ft. in height. The A-D site ranks fourth in site quality and mature trees average 117 ft. in height.

The six stands selected for sampling were within a 50-mile radius of Prince George: Summit Lake, 30 miles north; Stone Creek, 25 miles south; Willow River, 20 miles east; Giscome, 25 miles east; Aleza Lake, 40 miles east; and Upper Fraser, 50 miles east. The stands near Summit Lake, Stone Creek, Willow River, and Upper Fraser had scars 5 years of age. The stand near Giscome had scars averaging 15 (14-16) years of age and the stand near Aleza Lake had scars averaging 31 (24-38) years of age.

RESULTS

The Relation of Scar Infection to Locality

Infection levels of the 5-year-old butt and upper-bole scars sampled on spruce in four localities are reported in Table 1. Chi-square tests of independence showed that the differences between infection levels of scars at Summit Lake

[3] In this study the term "infection" refers to incipient or advanced decay. A small amount of blue-stained wood was associated with most scars on spruce and occasionally with scars on balsam, but in the absence of decay scars were classed as healthy.

TABLE 1

THE RELATION OF INFECTION OF BUTT AND UPPER-BOLE SCARS TO LOCALITY (SPRUCE WITH 5-YEAR-OLD SCARS)

Locality	Diam. class (in.)	Ave. age	Site	No. of trees	Scar classes: Butt 2 s Total No.	Butt 2 s Infected %	Upper-bole 1 b Total No.	Upper-bole 1 b Infected %
Summit Lake	12-16	172	A-D	41	50	92	11	36
Stone Creek	12-16	113	A-D	34	37	97	19	21
Willow River	12-16	119	A-D	39	41	68	62	10
Upper Fraser	12-16	152	D-C	33	34	65	11	9

and Stone Creek, and between infection levels at Willow River and Upper Fraser, were not significant ($P > .25$). However infection levels recorded at Summit Lake and Stone Creek were significantly different from those at Willow River and Upper Fraser ($P < .05$).

On balsam there were no significant differences between infection levels of similar scar classes at the four localities. Infection levels averaged 96 and 54% for butt and upper-bole scars, respectively.

The Relation of Scar Infection to Tree Diameter

Infection levels of the 5-year-old butt and upper-bole scars sampled on spruce and balsam of two diameter classes are reported in Table 2.

TABLE 2

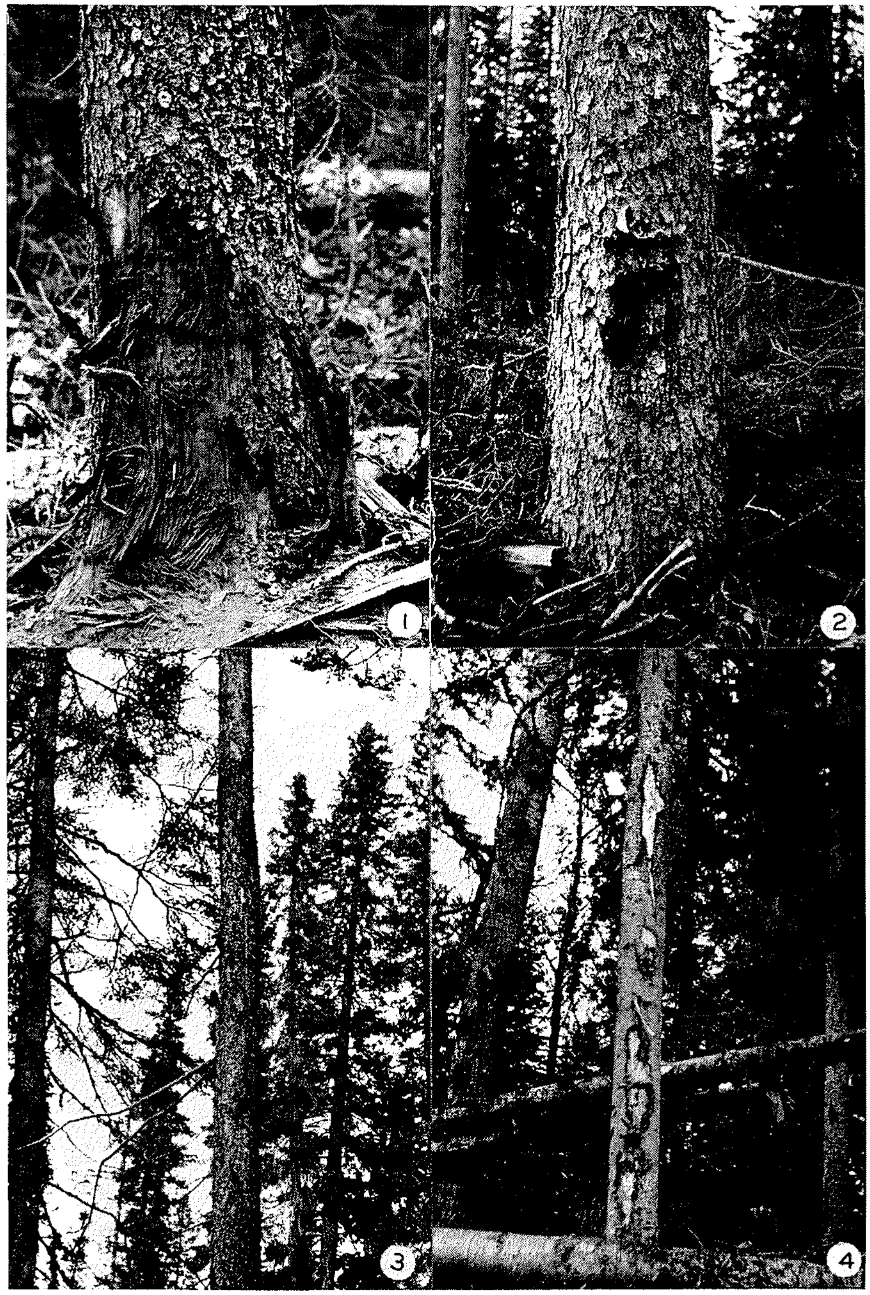
THE RELATION OF SCAR INFECTION TO TREE DIAMETER (SPRUCE AND BALSAM WITH 5-YEAR-OLD SCARS)

Species	Diam. class (in.)	Ave. age	Plot No.[1]	Site	No. of trees	Scar classes: Butt 2 s Total No.	Butt 2 s Infected %	Root and ground-contact Total No.	Root and ground-contact Infected %
Spruce	4-6	100	9	A-D	40	45	76	11	82
	12-16	113	9	A-D	34	37	97	29	93
Balsam	4-6	86	8	A-D	40	46	93	6	100
	12-16	133	8	A-D	40	44	100	9	100

[1] Plot numbers refer to residual stands at Summit Lake (8) and Stone Creek (9).

CAPTIONS FOR PAGES 33 AND 34

FIGURE 1. A large and deep ground-contact scar on spruce.
FIGURE 2. A butt scar on spruce with an area of 37 to 144 sq. in. and with the sapwood gouged.
FIGURE 3. Upper-bole scars on spruce.
FIGURE 4. Butt and upper-bole scars on balsam.
FIGURE 5. A butt scar on balsam with obvious damage to the sapwood.
FIGURE 6. An upper-bole scar on spruce without obvious damage to the sapwood.
FIGURE 7. A longitudinal section through a small 5-year-old scar showing incipient decay at the base of the scar.
FIGURE 8. Incipient decay associated with a 5-year-old scar.
FIGURE 9. Decay associated with a large 31-year-old scar.
FIGURE 10. Decay associated with a large 38-year-old scar.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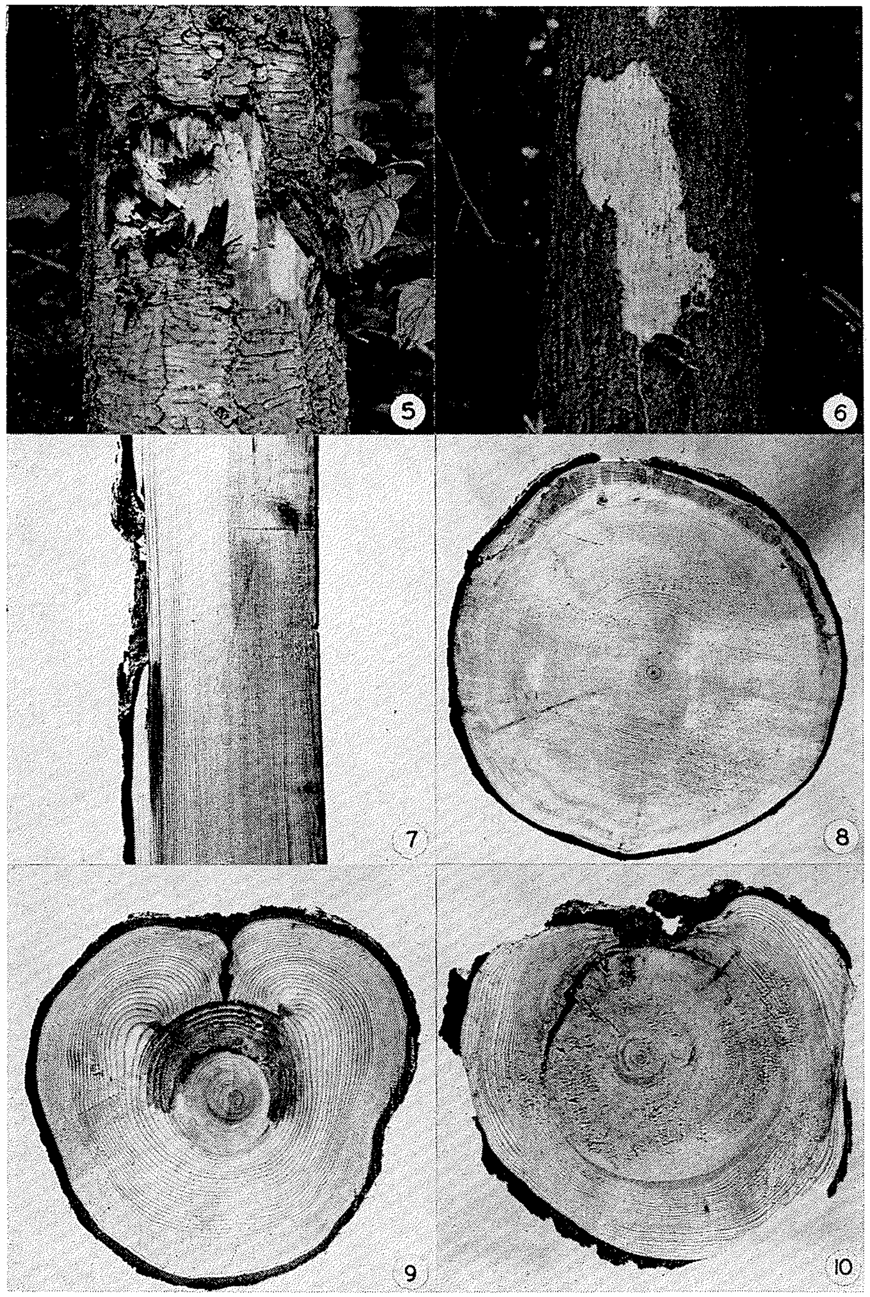
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With the exception of root and ground-contact scars on balsam, scars on 12- to 16-in. trees had higher levels of infection than scars on 4- to 6-in. trees, but significant differences were recorded only for butt scars on spruce ($P < .01$). Infection levels of root and ground-contact scars on selected balsam in the two diameter classes were 100%.

The Relation of Scar Infection to Site

Infection levels of the 5-year-old butt, root, and ground-contact scars sampled on spruce and balsam occurring on two different sites are reported in Table 3. The differences between infection levels of both spruce and balsam scars on the two sites were not significant.

TABLE 3

THE RELATION OF SCAR INFECTION TO SITE (SPRUCE AND BALSAM WITH 5-YEAR-OLD SCARS)

						Scar classes			
						Butt 2 s		Root and ground-contact	
Species	Diam. class (in.)	Ave. age	Plot No.	Site	No. of trees	Total No.	Infected %	Total No.	Infected %
Spruce	12-16	172	8	A-D	41	50	92	24	88
	12-16	166	8	D-C	39	43	88	16	88
Balsam	4-6	86	8	A-D	40	46	93	6	100
	4-6	88	8	D-C	31	31	100	6	100

The Relation of Scar Infection to Scar Position, Size, Depth, and Age

The infection levels obtained for 5- and 15-year-old spruce and balsam scars are presented graphically in Fig. 11. Because of the influence of locality on infection levels, the data presented in this section were obtained only from stands east of Prince George. Although 890 scars on spruce and 859 scars on balsam were examined for the presence of decay, significance could not be tested in all scar classes owing to small sample sizes. Accordingly, interpretations have been drawn from the general trends indicated by most of the data.

Spruce

Infection levels decreased markedly with increase in height above ground. After 15 years essentially all root and ground-contact scars were infected while the average level of infection was 70% in butt scars and 38% in upper-bole scars. Apparently conditions near the ground are more suitable for infection of scars than those higher up the tree. Nevertheless, the influence of scar position on infection was evident only for scars with an area less than 144 sq. in., because nearly 100% of the scars, in all positions, with an area greater than 144 sq. in., were infected. Somewhere between a scar area of 144 sq. in. and that of the larger scar areas encountered in this study, the position of scars on a tree no longer had an influence on infection levels.

Scar size had considerable influence on infection of butt and upper-bole scars, but did not appear to affect infection levels of root and ground-contact scars. Thus, after 15 years essentially all root and ground-contact scars were infected, while butt scars of depth *s* in the 1, 2, and 3 size classes were 45, 90, and 100% infected, respectively and upper-bole scars of depth *s* in the 1, 2 and

3 size classes were 19, 59 and 94% infected, respectively. The influence of scar size on infection was not as apparent in 5-year-old scars. However, with few exceptions the trend toward a higher level of infection with increasing scar size was still evident.

Scar depth appeared to influence the infection levels of some 5- and 15-year-old butt and upper-bole scar classes and not others. Of the 7 size classes with an apparently adequate sample of depth *b* and *s* scars, 4 had a higher level of infection of scars of depth *s* than of scars of depth *b*. The choice of definitions for scars of depth *b* and *s* probably influenced the results obtained for scars of

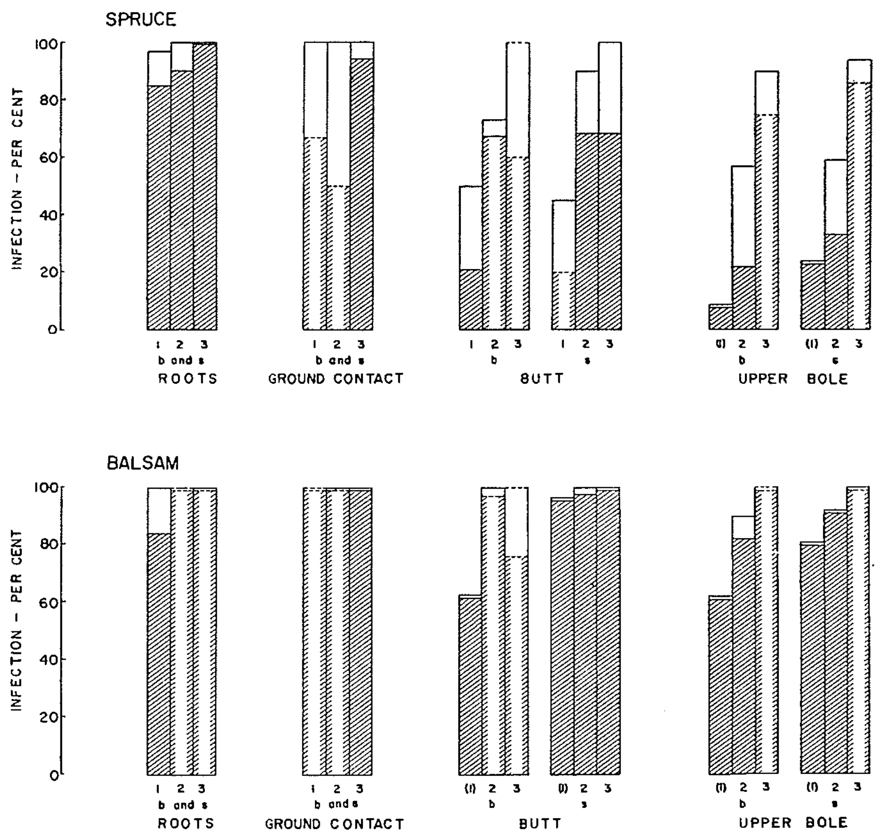

FIGURE 11. Percentage of 5- and 15-year-old scars with infection on spruce and balsam in stands east of Prince George, B.C. Crosshatched areas represent infection of 5-year-old scars and clear areas represent infection of 15-year-old scars. Broken crosshatched areas and broken lines over clear areas represent infection of 5- and 15-year-old scars calculated from samples of less than 9 scars. Brackets indicate that infection level values have been averaged for these scars because higher values were obtained for 5-year-old scars than for 15-year-old scars.

any one size. Scars of depth *s* included those gouged deeply by bulldozer blades as well as those with only slight damage to the exposed sapwood surface. If the scars of depth *s* sampled had only slight damage to the exposed sapwood surface, the infection level obtained would probably be very little different from the infection level obtained for the same size of scars of depth *b*.

A marked influence of scar age on infection levels was evident from the results obtained for 5- and 15-year-old butt and upper-bole scars. All 5-year-old butt and upper-bole scars represented by a sample of 9 or more scars had infection levels considerably less than 15-year-old scars of the same class, with the exception of size 1 upper-bole scars. Most root and ground-contact scars were infected within 5 years.

Balsam

Infection levels decreased with increasing height above ground. After 15 years all root and ground-contact scars were infected while the average level of infection decreased to 92% in butt scars and to 79% in upper-bole scars.

The effect of scar size on infection levels was evident from the results obtained for 5-year-old root and upper-bole scars and for 15-year-old butt and upper-bole scars. Differences in levels of infection were greater between size 1 and 2 scars than between size 2 and 3 scars for most scar classes. For example, 15-year-old upper-bole scars of depth *s* in the 1, 2, and 3 size classes were 74, 91, and 100% infected, respectively. Although scar size did not affect the infection levels of all scar classes, the samples in such cases were probably too small to give reliable results.

Scar depth appeared to influence infection of only the smallest butt and upper-bole scars.

An influence of scar age on infection levels was indicated from the results obtained for only size 1 root scars and size 2, depth *b* upper-bole scars. All other 5-year-old scar classes, with an apparently adequate sample, had infection levels equal to or greater than corresponding infection levels obtained for 15-year-old scars.

Thus, the trends in infection levels noted for the position, size, and depth of spruce scars applied to balsam scars, but they were not as pronounced. However, scars on balsam appeared more susceptible to infection than scars on spruce; all infection levels less than 100% in spruce were smaller than infection levels for the corresponding scars on balsam, and unlike the results obtained in spruce, very little increase in infection occurred after 5 years.

Decay Associated with Scars on Spruce and Balsam

The decay associated with 15-year-old scars and certain classes of 31-year-old scars was determined for spruce and balsam in stands east of Prince George. The average volume of decay per scar, expressed as a percentage of the average gross volume of each tree, is presented graphically in Fig. 12. The decay associated with each 5-year-old scar was generally less than 0.1 cu. ft. and was not recorded.

Spruce

A total of 516 fifteen-year-old scars and 85 thirty-one-year-old scars were sampled. The average gross volume of each tree was 22.5 and 28.6 cu. ft. for trees with 15-year-old and 31-year-old scars, respectively. The results reflect infection levels because all scars, infected and non-infected, were used for calculating the loss from decay. Values obtained for 15-year-old scars ranged from a trace of volume lost by the decay associated with small butt and upper-bole scars to an average of 5.8% of the volume of each tree lost by the decay associated with each large ground-contact scar.

Fifteen years after partial cutting more decay was associated with ground-

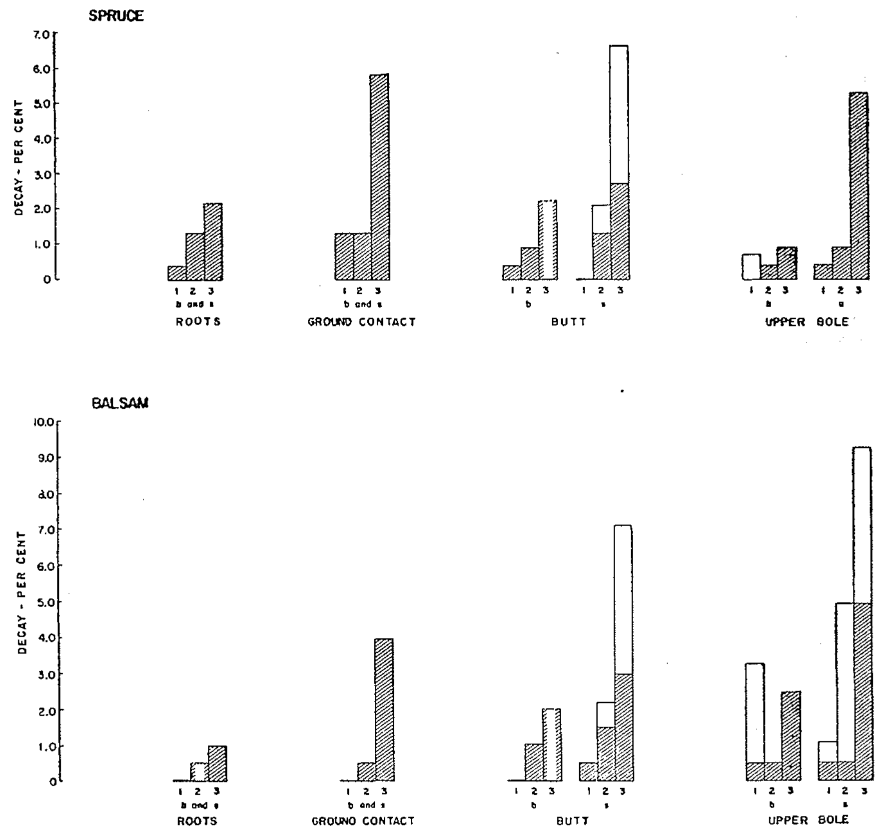

FIGURE 12. Percentage of the average tree volume with decay associated with 15- and 31-year-old scars on spruce and balsam in stands east of Prince George, B.C. Crosshatched areas represent decay in 15-year-old scars and clear areas over crosshatched areas represent decay in 31-year-old scars. Broken crosshatched areas represent decay in 15-year-old scars calculated for samples of less than 9 scars.

contact scars than with scars in the other three positions. Each ground-contact scar resulted in an average of 2.2% and each root, butt, and upper-bole scar in an average of 1.3% of the the tree volume being decayed. The relation of scar size to the amount of associated decay was evident from values obtained for nearly all size classes at each scar position. With the exception of size 1 and 2 ground-contact scars the larger scars in each position had more associated decay than smaller scars. For example, each root scar of size 1, 2, and 3 resulted in a volume loss of 0.4, 1.3, and 2.2%, respectively. The values obtained for upper-bole scars also varied with scar depth. Each upper-bole scar of depth *s* had more associated decay than a scar of depth *b* in the same size class.

The three classes sampled in the case of 31-year-old scars had considerably more associated decay than the same classes of 15-year-old scars. The percentage of the average tree volume lost because of the decay associated with butt scars of depth *s* increased from 1.8% to 2.1% for size 2 scars, and from 2.7% to 6.6% for size 3 scars. Volume loss for size 1, depth *b* upper-bole scars increased from a trace for 15-year-old scars to 0.7% for 31-year-old scars.

Balsam

A total of 451 fifteen-year-old scars and 134 thirty-one-year-old scars were sampled. The average gross volume of each tree was 19.8 and 18.0 cu. ft. for trees with 15-year-old and 31-year-old scars, respectively.

The percentage of the average tree volume lost because of the decay associated with 15-year-old scars ranged from less than 0.1% in small root, ground-contact, and butt scars to an average of 5.1% in large upper-bole scars.

Fifteen years after partial cutting each ground-contact, butt, and upper-bole scar resulted in an average loss of 1.5% of the tree volume, while the value for each root scar was 0.5%. Calculated volume losses varied with the size and depth of scars in a similar manner to the losses obtained in spruce. With the exception of size 1 and 2 upper-bole scars the larger scars in each position had more associated decay than smaller scars. Each butt scar of depth *s* had more associated decay than a scar of depth *b* in the same size class.

Four of the 6 classes of 31-year-old scars had more than double the amount of decay associated with corresponding classes of 15-year-old scars. The percentage of the average tree volume lost by decay entering butt scars of depth *s* increased from 1.5% to 2.2% for size 2 scars, and from 3.0% to 7.2% for size 3 scars. Volume loss for size 1, depth *b* upper-bole scars increased from 0.5% to 3.3%. Volume loss for upper-bole scars of depth *s* increased from 0.5% to 1.1% for size 1 scars, from 0.5% to 5.0% for size 2 scars, and from 5.1% to 9.4% for size 3 scars.

In both spruce and balsam the percentage of a tree affected by decay associated with a root or ground-contact scar was smaller than indicated by infection levels, because the decay had to reach stump height before being measured and recorded in this study. The same general trend in infection levels of butt and upper-bole scars with scar size and depth was noted in the percentages of volume affected by decay. With the exception of size 1 and 2 ground-contact scars on spruce and size 1 and 2 upper-bole scars on balsam, the smaller a scar the less the volume of associated decay. With the exception of size 1 butt scars on spruce the more superficial a scar the less the volume of associated decay. The effect of scar size on the volume of decay associated with 15-year-old root and ground-contact scars was noted, whereas an effect of scar size on infection levels for the same scars was not discernible, indicating that the larger areas of exposed sapwood allow decay to proceed at a faster rate than smaller areas. The percentage of tree volume affected by decay associated with 15-year-old root or ground-contact scars was generally less in balsam than in spruce. In butt and upper-bole scars, however, the losses were approximately the same despite a higher level of infection in balsam. The rate of development of decay in spruce was apparently greater than that in balsam. The variation in rates may have resulted from the different fungi responsible for decay in the two hosts, as well as from differences in the hosts themselves.

Infection and Decay of Broken Tops

Broken tops occurred frequently in the partially cut stands examined during this study. Based on samples of 11 spruce and 28 balsam, infection levels in 5 years were 54% and 89% for spruce and balsam, respectively. The average volume of decay associated with each broken top was less than 0.1 cu. ft. A sample of 29 spruce and 31 balsam with broken tops demonstrated that all were infected after 15 years, and that volumetric losses amounted to 1.8% and 1.5% of the total tree volumes, respectively. Expressed as a percentage of the average gross volume of the top 16 ft. of each tree, volumetric losses were 53% for spruce and 46% for balsam.

Radial Penetration of Decay in Infected Butt Scars on Spruce and Balsam

The average maximum radial penetration of decay associated with infected butt scars in the three size classes was recorded for a number of 5-, 15-, and 31-year-old scars on spruce and balsam (Fig. 13). These scars were on trees in the stands near Willow River, Giscome, and Aleza Lake. All scars sampled were on spruce in the 12- to 14-in. diameter class and on balsam in the 10- to 12-in. diameter class. In 5-year-old butt scars on spruce the average depth of penetration of decay was 1.5 in. with less than 0.5 in. variation in penetration between scar sizes (Figs. 7, 8). In 15 years the average pentration was 3, 5, and 7 in., and in 31 years 4, 6, and 9 in., for scars of size 1, 2, and 3 respectively (Figs. 9, 10). On balsam with 5-year-old butt scars the average depth of pentration of decay was 1.3 in. with less than 0.5 in. variation in penetration between scar sizes. In 15 years the average penetration was 2, 4, and 5 in., and in 31 years 4, 5, and 7 in., for scars of size 1, 2, and 3 respectively.

Occurrence of Fungi Isolated from Decays Associated with Scars on Spruce and Balsam

Decay-producing Basidiomycetes were successfully isolated in culture from 419 scars on spruce and from 466 scars on balsam in the six stands studied (Table 4). *Stereum sanguinolentum* (Alb. & Schw. ex Fr.) Fr. was isolated from 81% of the scars yielding decay fungi on spruce. The next four most frequently occurring fungi were isolated from only 2% to 5% of the scars. *Stereum sanguinolentum* was isolated over three times more often than any other fungus from all scar classes. *Peniophora septentrionalis* Laurila was the second most common invader of broken tops and *Coniophora puteana* (Schum. ex Fr.) Karst. was the second most frequent invader of root scars.

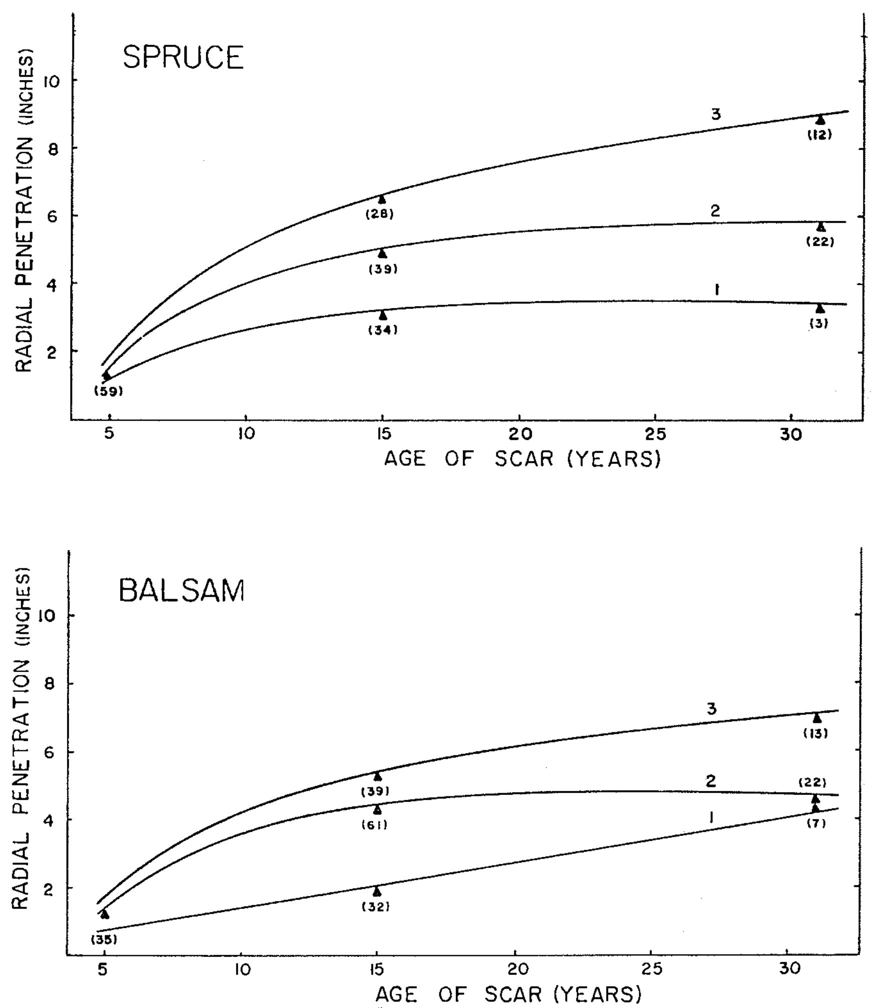

FIGURE 13. Rate of radial penetration by decay-producing fungi in infected butt scars on spruce and balsam. Curves numbered 1, 2, and 3 represent the rates for butt scars having surface areas of 1 to 36, 37 to 144, and over 144 sq. in., respectively. The numbers of scars sampled are enclosed in brackets.

TABLE 4

FREQUENCY OF OCCURRENCE OF FUNGI ISOLATED FROM DECAYS ASSOCIATED WITH SCARS ON SPRUCE AND BALSAM

	Type of Scar					
	Root	Ground-contact	Butt	Upper-bole	Broken top	All scars
Spruce						
Scars yielding decay fungi when cultured (no.)	65	40	229	69	16	419
Decay fungi (percentage of number isolated)[1]						
Stereum sanguinolentum (Alb. & Schw. ex Fr.) Fr.	57	75	88	87	69	81
Peniophora septentrionalis Laurila	3	8	3	10	19	5
Coniophora puteana (Schum. ex Fr.) Karst.	12	5	(1)[2]	—	—	3
Fomes pinicola (Sw. ex Fr.) Cooke	3	8	2	—	6	2
Corticium galactinum (Fr.) Burt	6	5	1	—	—	2
Balsam						
Scars yielding decay fungi when cultured (no.)	11	20	249	165	21	466
Decay fungi (percentage of number isolated)[1]						
Stereum chailletii Pers.	9	60	56	45	19	50
Stereum sanguinolentum (Alb. & Schw. ex Fr.) Fr.	45	25	30	44	62	37
Corticium laeve Pers.	—	—	5	1	—	3
Armillaria mellea (Vahl ex Fr.) Quél.	45	5	(1)[2]	—	—	2
Corticium galactinum (Fr.) Burt	—	5	1	1	—	1

[1] Includes only the 5 most frequently isolated decay fungi.
[2] Less than 0.5%.

Stereum chailletii Pers. was isolated from 50% and *S. sanguinolentum* from 37% of the scars yielding decay-producing fungi on balsam. The next three most frequently occurring fungi were isloated from 1% to 3% of the scars. *S. chailletii* was the most common fungus in ground-contact and butt scars. *S. sanguinolentum* was the most prevalent fungus in broken tops and it was isolated as often from upper-bole scars as *S. chailletii,* and as frequently from root scars as *Armillaria mellea* (Vahl ex Fr.) Quél.

DISCUSSION

A number of factors influencing the infection of scars by decay fungi and the relative amount of decay associated with scars of different types and ages have been examined for spruce and balsam. Since study areas were selected on the basis of particular sampling requirements, individual values obtained for the scar classes in any one area should not necessarily be considered representative of other stands in the same area. The trends shown by the data, however, indicate the important factors to be considered in appraising logging damage in other residual stands of spruce and balsam.

The higher level of infection in butt and upper-bole scars on spruce in stands north and south of Prince George than in stands east of this centre illustrates the danger involved in the application of specific values obtained from one stand to another within the same region. Although differences in the level of infection between stands may decrease with time, the stand with a higher level of infection soon after logging will most likely have a greater volume of decay at the time of the next cutting cycle. Reasons for the differences in infection levels of scars on spruce between stands of the same general region are not clear, but they may be connected with the ecology of *Stereum sanguinolentum*, the principal fungus invading scars on this host. Infection levels in balsam, however, remained essentially the same in all stands. Any variation that might have occurred in infection of balsam scars by *S. sanguinolentum* could not be determined because of the high level of infection by *S. chailletii*. Unfortunately, it was not possible to obtain precise data on the relative abundance of the two fungi in each of the six stands studied because only 42% of the culture samples taken from infected balsam scars yielded any decay-producing fungus when cultured. The relatively low number of scars yielding decay-producing fungi in culture was most likely due to desiccation of culture samples en route to the laboratory and to limitations in the technique used for isolating the fungi.

The lower level of infection of size 2, depth *s* butt scars on spruce in the 4- to 6-in. diameter class than on spruce in the 12- to 16-in. diameter class is difficult to explain on the basis of present knowledge. Since the trees sampled in the two diameter classes were of approximately the same age, perhaps slower-growing trees are more resistant to invasion by fungi than faster-growing trees. The factors responsible for the differences, however, were not of sufficient magnitude to cause differences in the infection levels of either root and ground-contact scars on spruce and balsam, or in size 2, depth *s* butt scars on balsam.

While scar size evidently influenced the infection levels of butt and upper-bole scars on spruce, this factor had little influence on the infection levels of root and ground-contact scars. Since large butt and upper-bole scars present a greater area of exposure to spores of decay-producing fungi than small scars, they are more likely to have favorable infection courts. Root and ground-contact scars are not dependent on airborne spores of fungi for infection, and soil in contact with scars appears to create favorable infection courts for a large number of fungi.

The infection level of size 1 upper-bole scars 5 years after logging was greater than that of the same scar class in the stand partially cut 15 years previously. Conditions may have been more favorable for development of, and infection by, decay-producing fungi during the years following logging of the stands with 5-year-old scars than during the period immediately following logging of the stand with 15-year-old scars. Since healing of most small scars in the upper bole occurred in less than 15 years the chances for decay-producing fungi to enter the 15-year-old scars during the last 10 years were considerably reduced.

Loss through decay in most 15-year-old scars was a rather small percentage of the total volume of a tree. However, trees selected on the basis of having one scar were found to have, on the average, two more. Considering the amount of decay associated with the different scars likely to be present on the same tree, and the increase in decay with time, the loss adds up to a much higher percentage of the total volume of a tree than indicated by the reported percentage of decay associated with a single scar.

Another way of evaluating losses is to consider the volume loss associated with the part of the tree affected. As approximately one-half of the total volume of a spruce or balsam is contained in the lower 16 feet of the tree the values reported herein for percentage of decay associated with root, ground-contact, and butt scars should be approximately doubled to obtain an estimate of loss in the basal log. Again, although volume losses resulting from the presence of decay in broken tops were less than 2% of the total volume of a tree they amounted to approximately 50% of the volume of the average top 16-ft. log.

Other factors requiring consideration by forest managers are the loss from windthrow of trees with scarred roots weakened by decay; the loss of vigorous growth and often considerable volume through tops being broken in the logging operation; the increase with time in the danger of breakage at the site of larger scars because of deep radial penetration of decay; and the intensity of the initial cut. Wright and Isaac (7) have shown that the intensity of the initial cut influences the number of logging scars occurring in a stand. In their studies lightly-cut stands had a higher percentage of basal scars and a lower percentage of upper-bole scars than heavily-cut stands.

The high frequency of isolation of *S. sanguinolentum* from spruce scars and of *S. chailletii and S. sanguinolentum* from balsam scars in relation to other decay-producing fungi leaves little doubt that these fungi are the most important invaders of all scar types in the Prince George region. The most important root and butt rots encountered during earlier decay studies of spruce in Alberta and British Columbia (2, 3, 5) and of balsam in British Columbia (6), were rarely found associated with scars during this investigation. *Stereum sanguinolentum* was the trunk rot most frequently isolated during previous decay studies of spruce and balsam, but *S. chailletii* was isolated only rarely. The type of infection court created on different parts of a tree appears to determine to a considerable extent the decay-producing fungi attacking the tree, and should be considered when comparing the results of a decay study in one region with the results obtained in other regions.

Summary

1. In a study of decay associated with logging damage in the Prince George region of British Columbia, 873 spruce and balsam trees with 2938 scars were analyzed. Scars averaged 5, 15, and 31 years of age and were classified according to their position, size, and depth.

2. Scars on spruce in one stand north and another stand south of Prince George were found to have a higher level of infection than scars in two stands

east of Prince George. There were no significant differences between the infection levels of scars on balsam in the four localities.

3. Five-year-old butt scars on spruce in the 12- to 16-in. diameter class had a significantly higher level of infection than butt scars on trees in the 4- to 6-in. diameter class. There was no significant difference between the infection levels of butt scars on balsam in the two diameter classes.

4. There were no significant differences between the levels of infection of butt, root, and ground-contact scars on spruce and balsam located on two different forest sites.

5. The level of infection of 5- and 15-year-old scars on spruce and balsam varied with the position, size, and the depth of scars. Differences were more apparent in spruce than in balsam. In scars up to 144 sq. in. total area the higher up the tree scars occurred, the lower the level of infection. In 15-year-old scars over 144 sq. in. in size the position of scars had little influence on infection levels. The effect of size and depth of scars on infection was most apparent in butt and upper-bole scars.

6. The same general trend noted for the infection levels of butt and upper-bole scars was noted for percentages of volume decayed. For the first 15 years after scarring the rate of decay in balsam scars was less than the rate in spruce scars.

7. The most frequent and important invader of all scar types on spruce was *Stereum sanguinolentum*. *Stereum chailletii* and *S. sanguinolentum* were the most important invaders of all scar types on balsam.

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