

**CAUSES OF DECLINE AND MORTALITY OF
SUBALPINE FIR IN THE BULKLEY AND MORICE
TIMBER SUPPLY AREAS OF THE
PRINCE RUPERT FOREST REGION**

by

J. Schulting and M. Schulting
Pathocon Consulting
4075 Jade Drive
Prince George, British Columbia

British Columbia Ministry of Forests
Victoria, British Columbia
Forest Service Internal Report

PM-PB-74

Submitted February 1987

Not for Publication

March 1991

(The contents of this report may not be cited in whole or part without the written approval of the Director, Protection Branch, Ministry of Forests, 31 Bastion Square, Victoria, British Columbia V8W 3E7)

ACKNOWLEDGEMENTS

This project was conducted with funding supplied by the Forest Resource Development Agreement. We wish to thank Bob Duncan and Duncan Morrison of the Canadian Forestry Service for their assistance in identification of pests. Also, Mike Geisler, Wayne Martin and Tim Ebata of the Protection Branch, Prince Rupert Forest Region for their assistance in organization of the field work.

EXECUTIVE SUMMARY

The objective was to assess the damage from insects, diseases and abiotic factors in subalpine fir stands by means of survey strips and sample plots in order to determine the cause(s) of subalpine fir decline and mortality. This project was implemented due to subalpine fir decline and mortality in the Bulkley and Morice Timber Supply Areas (TSAs). High losses had been recorded in previous surveys of these areas, but knowledge of the causal agent(s) was far from precise.

Twelve stands were surveyed, nine of which had been identified as having a significant pest problem in project PB-3a. Intensive survey strips, 100m long and 10m wide, were placed through areas of high damage incidence. This method, which was non-random, was selected in order to determine all of the causal agents in damaged areas rather than to record pest incidence per se. Along each transect all declining and dead subalpine fir were examined and the associated insects or disease recorded. If necessary, specimens were sent to Forestry Canada for confirmation. Trees were mapped, numbered, and tagged for future remeasurement, and crown and tree class were recorded. In addition, an ecological assessment of each area was performed.

Several pests were found in 85% of the affected trees, while 15% exhibited no known causal agents. Western balsam bark beetle, the most commonly located pest, was found alone or in association with several pathogens, notably *Inonotus tomentosus* and *Armillaria* spp. The beetle was recorded in 55.8% of afflicted trees. Root feeding beetles (*Hylurgops* spp.) were also noted. Root and butt rots accounted for 52.5%, decays 5-8%, needle diseases 1.2%, and abiotic factors 1.7%. A high proportion (31.9%) of western balsam bark beetle attack was associated with other damaging agents. Root disease may be causing decline and mortality alone or in combination with bark beetle attack; however, the exact relationship could not be determined in this survey. Root disease was present on approximately 50% of the sites investigated, and was severe on three of these.

Recommendations from this study included the following. More surveys should be conducted to adequately determine the extent of subalpine fir dieback and mortality outside of bark beetle attacked areas to determine the impact of the other damaging agents identified in this project. The stands examined in this survey should be closely monitored in future.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	ii
EXECUTIVE SUMMARY	iii
1 INTRODUCTION	1
2 METHODS	2
3 RESULTS	3
4 DAMAGING AGENTS	
4.1 <u>Western Balsam Bark Beetle - <i>D. confusus</i></u>	5
4.2 <u>Root Feeding Beetles - <i>Hylurgops</i> spp.</u>	5
4.3 <u><i>Tomentosus</i> Root Rot - <i>Inonotus tomentosus</i></u>	6
4.4 <u><i>Armillaria</i> spp.</u>	7
4.5 <u>Root Dieback</u>	8
4.6 <u><i>Coniophora puteana</i></u>	9
4.7 <u>Decays</u>	10
4.8 <u>Miscellaneous Damaging Agents</u>	10
5 CONCLUSIONS	11
6 REFERENCES	12

APPENDICES

A	Site Ecological Information	13
B	Site Soil Information	14
C	Site Inventory Information	15
D	Site Descriptions	16

TABLES

1	Damaging Agents in Subalpine Fir Stands	37
2	Pest Complexes Encountered	38

FIGURES

1	Location of Sites Studied	39
----------	----------------------------------	-----------

INTRODUCTION

Subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) is an important conifer species in the sub-boreal forests of north central British Columbia. Subalpine fir comprises 12% of the total volume of timber in British Columbia (B.C. MoF 1983). Within the Bulkley TSA of the Prince Rupert Forest Region, subalpine fir makes up 41% of the net operable volume (Stock 1986). Most commonly subalpine fir stands are mixed with lodgepole pine (*Pinus contorta* var. *latifolia* Engel.), and hybrid spruce (*Picea glauca* X *engelmannii* Engel.). Pure subalpine fir stands are generally older, i.e., more than 140 years (age class seven).

Although this conifer species is widely distributed in British Columbia, only one damaging agent, western balsam bark beetle (*Dryocoetes confusus* SW.) has been well documented.

This project was undertaken to determine causes of decline and mortality of mature subalpine fir in the Morice and Bulkley TSAs in the Prince Rupert Forest Region.

The objectives of this study were:

1. to determine whether decline and mortality in subalpine fir of the Morice and Bulkley TSAs were due to factors (insect, disease and abiotic) in addition to western balsam bark beetle; and
2. where possible, identify these causal agents using field characteristics and send representative samples to Pacific Forestry Centre for confirmation.

Although not required in this contract, attempts were made to identify all pests located. Insects were identified by Bob Duncan, Pacific Forestry Centre, and identification of diseases was attempted by Pathocon Consulting and Duncan Morrison at Pacific Forestry Centre, using diagnostic cultural characteristics. Not all of these culture identifications have been completed.

2 METHODS

Twelve stands were surveyed in the Morice and Bulkley TSAs (Figure 1). Nine of these stands were selected from candidate stands whose *D. confusus* incidence levels had been estimated by Stock (1986). The other three stands were selected from forest cover maps. The stands selected had subalpine fir as a major tree species component and showed signs of subalpine fir decline and mortality.

The stands were surveyed using a line transect method. These strips were 10m wide and 50 or 100m in length. The location of the transect was selected to intersect areas of subalpine fir decline and mortality. The length of the transect was dependent on changes in stand composition (especially the proportion of subalpine fir present) and time limitations. Details of each survey are given in the description of each site in Appendix D. The survey design allowed us to lay out a transect that could easily be followed by MoF staff to check our transects.

In the first stand we decided to run a transect at a random location from the road. This, however, was not an efficient method of locating declining trees for examination. As we were trying to determine the causal agents of decline and mortality in subalpine fir and not their incidence, we decided that transects purposely selected to intersect clumps of declining and dead trees would better serve the purpose of this study. Subjective location of transects yielded more declining trees per unit effort and were thus more efficient.

All declining and dead subalpine fir trees within the transect were examined. This consisted of examining the crown, bole, root collar and roots of each tree searching for insects, diseases or abiotic causes. Pests detected were identified in the field where possible, or samples were collected for identification. Each tree examined was numbered for identification and labelled with an aluminum tree tag. The position along the transect was recorded. The crown status of each declining or dead tree (dead, red, thin, etc.) was noted, as was its position within the canopy (main canopy, lower main, etc.). For each site, an Ecological Classification Reconnaissance Form was completed.

3 RESULTS

A number of damaging agents were associated with declining or dead subalpine fir. Fifteen per cent of the dead or declining trees examined had no identifiable causal agents. This was, for the most part, due to masking by saprophytic fungi. Most pests, aside from *D. confusus* affected the root system and lower stem area.

The agents detected were mainly of four types:

- 1 bark beetles;
- 2 root and collar feeding beetles;
- 3 root and butt rots;
- 4 stem decays.

In addition, foliage disease and foliage feeding insects were detected, but they did not appear to cause substantial decline or mortality. A gall was found on the stems and branches of many trees in Site 11, yet no fungal agents were isolated from it (Funk 1987, personal communication). Yellow witches broom rust (*Melampsorella caryophyllacearum*) was also observed in one site, but only on one tree.

Table 1 lists the agents found and the number of trees (out of 242 declining or dead trees examined) affected by each. The proportion of trees infected is also shown. Insects were present in 144 trees, or 59.5% of the afflicted trees examined, root and butt rots in 127 (52.5%), decays in 14 trees (5.8%), needle diseases in three (1.2%), and abiotic factors in four (1.7%). *D. confusus* was the most common insect pest affecting 55.8% of the examined trees. Root dieback was found on 48 trees (19.8%). *Armillaria ostoyae*, not previously reported in this area, and *I. tomentosus*, seldom reported on subalpine fir, were found on several trees on some sites.

Also as indicated in Table 1, several agents occurred as a complex on a single tree. The proportion of these complexes as a proportion of the total occurrences of each agent is listed. A high proportion of the occurrences of *D. confusus* (31.9%) was in combination with a disease. Table 2 lists the complexes identified and the number of times they occurred. Complexes consisting of unidentified root dieback and other root pathogens were not included in these lists as the root dieback in question may in fact have been caused by the root pathogen identified.

Total root excavations were not performed. Only the larger roots (and those around them), within one or two metres of the bole, were examined, as it was felt that root pathogens would likely be affecting these roots if symptoms of decline or if mortality were being induced. Thus, pathogen complexes on roots might have been undetected,

especially where the root pathogen was present in small quantities or located far from the bole on distal roots. Also where the tree had been dead for a number of years, often bark beetle galleries could still be discerned but the roots were too decayed by saprophytes for examination. Thus, the proportion of pest occurrences as members of a complex can be expected to be conservative.

The number of trees with any given agent varied greatly from site to site. The site descriptions in Appendix D list the pests found on each declining or dead subalpine fir tree examined. Most sites had a large component of trees attacked by *D. confusus*. This was expected as the high visibility of the symptoms produced led to bias during the site location towards sampling of beetle infestations. Other agents showed greater variation, being absent on some sites and very common (and damaging) on others. To put our data into a management context, ecological data, soil features and stand inventory information were recorded. This information is presented in Appendices A-C; however, no conclusions characterizing site types and damage to trees could be made since the sampling design was not random.

4 DAMAGING AGENTS

4.1 Western Balsam Bark Beetle - *D. confusus*

D. confusus was present in all of the study transects. It was found alone or in complexes on 135 (55.8%) of the affected trees examined. The severity of attack on each tree varied from a few, apparently unsuccessful, attacks to extensive attacks resulting in large areas of cambium and bark necrosis which girdled and killed the tree. Only trees which were in decline (or dead) or which showed pronounced resinosis and/or possessed numerous beetle galleries within three metres of the ground were recorded. *D. confusus* galleries were identified by their characteristic shape and tunnel diameter, and by the presence of beetles and grubs within them. In those trees which showed no decline, there were often numerous small insect bore holes which exuded a small amount of resin. These holes penetrated through the bark, but usually ended within one or two centimetres thereafter. The diameter of these bores (which ended upon reaching the cambium) and the discovery of dead *D. confusus* specimens in some of these holes suggest that they represented unsuccessful attacks.

The beetle-infested trees in the study expressed a range of symptomology:

- 1 Green - no crown symptoms;
- 2 Green - crown thinned, some dead bark;
- 3 Red - dead, girdled at some point;
- 4 Gray - dead, usually dead too long to diagnose.

Blue stain fungi (*Ceratocystis* spp.) were often associated with *D. confusus* attacks; however, blue staining was not discernable in many of the infested trees examined in this study.

4.2 Root Feeding Beetles - *Hylurgops* spp.

Hylurgops spp. beetles were found attacking living subalpine fir tissue. *H. reticulatus* was found in Site 2 attacking the live roots of Tree 24. *H. rufipennis* (identification tentative due to imperfect beetle sample) was found feeding on the living inner bark tissue on Sites 6 and 12. While their feeding holes were fairly numerous on the trees from which beetles were collected, there were few beetles to be found. Feeding galleries similar to those from which the beetle was collected were quite common on the roots of subalpine fir on Site 12. Also, similar feeding galleries were found on roots on other sites. In these cases, the insects responsible for these galleries were not found. It is quite possible that they were present but not located.

Many of the galleries in Site 12 were occupied by *Armillaria* species; however, whether this avenue of infection ever led to successful *Armillaria* invasion was not determined. Neither of the *Hylurgops* species has previously been described on subalpine fir.

Evidence of root feeding of various types was fairly common on subalpine fir, but the agents responsible were generally absent. Feeding across the grain caused mortality in smaller roots or necrosis of parts therein. As well, wounding was very common in roots even when embedded in mineral soil. The nature of the wounding was unclear, as the wounds were partially or completely callused over. As most of these wounds occurred on roots within mineral soil, few causes other than insect feeding were imaginable. Where callusing of wounds was not completely successful, rotting of the center of the root was common. Incomplete callusing probably resulted where the area of necrotic or removed cambium was large or where infection by a fungus occurred shortly after the wound was produced.

4.3 *Tomentosus* Root Rot - *Inonotus tomentosus*

Inonotus tomentosus was positively identified on subalpine fir in four sites. It occurred alone or in combination with *Armillaria* spp., root dieback or *D. confusus*. *I. tomentosus* was common on spruce and pine on these sites, and in other sites where it did not appear to attack subalpine fir. The appearance of the disease on subalpine fir varied from one tree to the next. In many cases it was not evident except in the form of necrotic root bark and cambium. Such necrosis occurred in patches interspersed with living tissue or occupied all the bark tissue distal to a certain point. Rotting of the xylem occurred, although not necessarily in conjunction with superficial necrosis. The rot produced was pitted and varied in color from light tan to red brown. The mycelium in the pits was cream to yellow in color. Decay was found advancing in the central portions of the root or in an off-centered band within the root. While off-centered decay is less common with *tomentosus* root rot, such a pattern might be expected where transfer of inoculum occurs by root contact or graft to a large diameter root.

I. tomentosus decay was not as common in subalpine fir as in spruce and pine. Instead, roots appeared to have been killed (girdled) by *I. tomentosus* and subsequently rapidly invaded by saprophytic fungi. This resulted in roots being completely rotted away within two metres from the bole without characteristic *tomentosus* rot being present to any extent. This phenomenon would tend to make identification of this disease on subalpine fir in the field very difficult. Trees which were severely affected by *tomentosus* root rot typically expressed classic root rot symptoms, including thinning crowns, height increment reduction, and reduced needle length.

In some sites, such as Site 6, *I. tomentosus* was very common on pine, spruce and subalpine fir. On Site 6, *I. tomentosus* appeared to be causing greater losses than *D.*

confusus. *Tomentosus* root rot centers were not sufficiently developed to show up on air photos. Clumps of subalpine fir mortality visible on air photos would more likely resemble past beetle attack. Scattered gray trees, in the absence of red trees, would indicate *tomentosus* root rot. The behavior of *I. tomentosus* on subalpine fir cannot be concluded from such a limited study. However, if the lack of decayed subalpine fir roots bearing viable (and durable) *I. tomentosus* mycelium found is normal, propagation of the disease into subsequent rotations by decayed wood is not likely to occur unless infected spruce or pine were present in the stand.

4.4 Armillaria species

The fungus previously called *Armillaria mellea* has recently been reclassified into a number of species and intersterility groups, each with its own geographic and host species range (Morrison *et al.* 1985). The two most widespread and common *Armillaria* in British Columbia are *A. ostoyae* and the *Armillaria* intersterility group type 5. *A. ostoyae* is a pathogenic species which attacks and often kills most species of conifers and deciduous species. It is widespread throughout the southern half of the province, but has not yet been officially reported north of 53°N (Morrison *et al.* 1985). *Armillaria* type 5 is a saprophytic fungus found on hardwoods and softwoods throughout most of British Columbia. These two species can be distinguished by the branching form of their rhizomorphs and by the growth pattern of their mycelium. *Armillaria* type 5 rhizomorphs branch monopodially and at right angles. The mycelial fans of this species grow flat between the wood and bark of the tree, showing little penetration into the bark itself. Living tissue is not attacked; hence, no reaction tissue is produced in the tree. *A. ostoyae* rhizomorphs branch in a dichotomous manner. Its mycelial fans often penetrate into the bark, resulting in necrosis of the tissue and deep impressions which can be detected after death. Since *A. ostoyae* attacks living tissue, reaction tissue may be produced in the host. The fans of this species are typically smaller and more branched than those of *Armillaria* type 5. *Armillaria* was identified on 50 trees in the sites studied. Twenty-nine of these were tentatively identified using field characteristics as *A. ostoyae*, two as *Armillaria* type 5, and the remaining 19 were not successfully identified to species.

Confirmation of some of these identifications awaits the results of pairings with haploid testers in culture at the Pacific Forestry Centre. Rhizomorphs which appeared to branch dichotomously were found on the outside of roots with periodic penetration through dead bark tissue. As well, dichotomous rhizomorphs were found growing through decayed wood on the inside of roots. *Armillaria* mycelial fans were found growing in the bark of living roots near or contacting living tissue. *Armillaria* spp. was isolated from the bark and cambium at the interface between living and dead tissue. As well, *Armillaria* spp. was isolated from a yellow mushy rot growing in the xylem of living roots. This ability to attack the xylem and cambium of living roots strongly suggested *A. ostoyae*. Monopodial and right angle branching rhizomorphs

were also quite common. As well, apparent saprophytic mycelial growth was also observed. These symptoms were indicative of *Armillaria* type 5.

A. ostoyae was located in eight sites. In four of these, it occurred on more than three trees. Its highest incidence was in Site 6, in which nine trees were infected. It is likely that *A. ostoyae* occurred more frequently than was confirmed in this study. In many cases, rhizomorph branching form was inconclusive. As well, *A. ostoyae* can grow in a saprophytic manner. Where *Armillaria* was observed but could not be identified to species, it was recorded simply as *Armillaria* spp. It would be logical to assume that some of these incidences were in fact *A. ostoyae*. It is also possible that *A. ostoyae* caused some of the root dieback which was discovered but not identified. Thus, it is possible that the incidence of this disease was somewhat higher than indicated.

Armillaria fans were most often found on roots near the root collar. They seldom extended more than 30cm up the bole. Further from the root collar the (dead) roots were often decayed to an extent which prevented field identification or cultural isolation of *Armillaria*.

Infected trees commonly showed thinning green crowns or were dead; however, where *Armillaria* occurred in pest complexes with *D. confusus*, red trees could also be infected, without discernable thinning of the crown.

4.5 Root Dieback

Root dieback is defined in this project as mortality or decay of subalpine fir roots caused by an unidentifiable agent. Generally, the extent of contamination was advanced to a state which obliterated any indication of the identity of the causal agent. Root dieback was present in all stands and a common occurrence in most of the stands studied. Forty-eight trees or 19.8% of those examined had root dieback. Root dieback was observed in two forms:

Type 1: the cambium dies, and the center of the root decays from the distal to proximal end, resulting in jagged, shortened roots.

Type 2: a root wound is invaded, and the center of the root decays, often while the root is still alive. The decay within the root is olive green in color. This form can eventually kill smaller roots (<5cm).

Both types of dieback had a greenish-colored rot within. This was likely due to a secondary fungus or fungi. Later the root is invaded by a blackish or white mycelial fungus (commonly both) which eventually forms a sheath around the edge.

Parasitic fungi were sometimes isolated from the leading edge of root dieback. In general, these fungi were restricted to the decay in these very small areas which had not yet been invaded by saprophytes. *I. tomentosus* was isolated twice from the interface between sound and decayed wood in advance of root dieback Type 1, and once from the leading edge of decay in a root dieback Type 2. *A. ostoyae* was isolated from the leading edge of central root dieback decay on two samples. *C. puteana* was isolated several times from brown rot within hollowed-out roots with dieback Type 2.

From these data, root dieback appears to be root disease which has been partially or completely replaced by faster growing saprophytes. This would indicate a low competitive ability of these pathogens on this host in certain situations. A vigorous pathogen would not be expected to be replaced so rapidly by saprophytes, especially when advancing in the root's interior. One possible explanation would be the fact that even when disease progressed internally, there was often an opening (in the form of a wound) to the outside through which saprophytes could invade.

The inability to identify the cause of root dieback in many cases has likely resulted in conservative results regarding the number of trees infected with *A. ostoyae*, *I. tomentosus* and *C. puteana*. It is, however, also possible that the root dieback in some cases represented invasion by a pathogen not identified in this report.

In many cases, where decay had not progressed very much, root wounds were evident. Root wounds were callused at the edges, but often they were open in the center. Such wounds appeared to be avenues of infection. Often, the area directly beneath the wound was in the most advanced state of decay, and the decay progressed on either side without reaching any other apparent point of entry. Other wounds which had not led to fungal invasion were common and numerous. Often ten wounds could be counted on one metre of submerged root. The cause of these wounds was not determined. As the roots were covered with humus and mineral soil, trampling or animal damage were not possible causes. It is likely that these wounds were the result of insect attack of some sort. Such insects would have to be subterranean feeders whose attack resulted in deep (at least to the cambium) wounds to the root.

4.6 *Coniophora puteana*

C. puteana was isolated in culture several times from crumbly brown rot in hollowed or centrally rotted subalpine fir roots and butts. Both living and dead roots were affected. It is likely that *C. puteana* is the cause of some of the unidentified root dieback. Often small amounts of brown crumbly rot were present along the edges of the saprophytic growth. The extent of root infection (especially the distance from the butt to which it can extend) was unclear. In many trees, brown butt rot was indicated but not identified. Most of these were likely *C. puteana*. Ten trees were determined to be infected with *C. puteana* and six were classified as brown butt rot.

C. puteana has been reported on subalpine fir throughout North America (Hinds *et al.* 1960; Hepting 1971). As a root and butt rot, *C. puteana* can cause decline and in severe cases, mortality due to windfall.

4.7 Decays

Phellinus pini was present on a total of ten trees in five sites. *P. pini* was fairly common in Site 4, especially on very old (>200 years) trees and suppressed trees. Severely infected trees showed reduced numbers of small branches, and reduced incremental growth of the apical and lateral shoots. This resulted in narrow, broken (uneven) crowns. Often the upper portion of the crown was killed, leaving a "spike" top. In many such trees, no merchantable volume remained. *Echinodontium tinctorium* has been observed on subalpine fir, but, not in any of the sites in this study.

Amylostereum chailletii was also isolated from decayed subalpine fir in Site 6. Although *A. chailletii* has been found to be a common decay causing fungus of subalpine fir in B.C. (Parker & Johnson 1960), it was not common in trees in this study. Because this study focused on dead and declining trees, only severely decayed trees or those bearing conks were investigated. Slightly decayed trees or decays which produce few fruiting bodies were not examined. Nevertheless, *A. chailletii* appeared to be less common than the other two wood decay fungi identified.

4.8 Miscellaneous Damaging Agents

Fir-willow rust, *Melampsora abietis-capraearum*, was found on one tree in each of two sites. It resulted in chlorosis in affected branches but little else. Yellow witches broom rust, *Melampsorella caryophyllacearum*, was found on one tree in Site 4. This tree was dead and no other cause for mortality could be found; however, it is unlikely that the broom rust could have caused the death. In Site 11 trees had galls on many of the branches and stems. These galls were examined by Alvin Funk at the Pacific Forestry Centre and no fungal cause for the galls was discovered. Each gall appeared to start from one small point in the wood. This may be where an insect had fed when the tree was younger or where a virus or bacteria was introduced; however, no positive cause was determined.

5 CONCLUSIONS

The results of this study showed that mature subalpine fir in the Morice and Bulkley TSAs is affected not only by western balsam bark beetle, but also by *I. tomentosus*, *A. ostoyae*, *Hylurgops* spp., and *C. puteana*. *A. ostoyae* has not previously been reported as being of significant impact on subalpine fir in this area. *I. tomentosus* has been reported on subalpine fir in British Columbia, but has been considered of little importance. Both of these species were clearly of significant impact on subalpine fir in this study. *Hylurgops rugipennis* and *H. reticulatus* have not previously been reported attacking subalpine fir. The importance of these beetle species is unclear. Further study may demonstrate that these are significant pests.

Complexes were commonly observed, involving combinations of diseases and insects. The frequency of complexes of a root pathogen and *D. confusus* complexes (31.9%) on *D. confusus*-infested trees suggested that predisposition by root pathogens may play a part in localized *D. confusus* outbreaks. Such predisposition could be allowing *D. confusus* to establish and subsequently spread to other surrounding trees.

The importance of this predisposition factor cannot be assessed without further study. Possibly a study should include a proportion of randomly selected, new beetle attacks which involve root pathogens. Further study is also required to obtain quantitative information on the incidence levels and associated impact of *I. tomentosus*, *A. ostoyae*, *C. puteana*, galls and *Hylurgops* spp., to evaluate the importance of these pests. As well, further study is required regarding the impact of these pests (and possibly others) on younger, or immature stands. Because subalpine fir has recently been suggested as an alternative species for planting in stands with *I. tomentosus* root rot areas, further investigation of the susceptibility of subalpine fir to this disease is desirable.

6 REFERENCES

- B.C. Ministry of Forests, 1983. Annual Report, B.C. Ministry of Forests, 1982. Victoria, B.C.
- Funk, A. 1987. Personal communication.
- Hepting, G.H. 1971. Diseases of forest and shade trees of the United States. U.S.D.A. For. Serv., Agricultural Handbook No. 386, 658pp.
- Hinds, T.E., F.G. Hawksworth and R. Davidson. 1960. Decay of Subalpine fir in Colorado. Section Paper No. 51. Rocky Mtn. Forest and Range Exp. Stn., Ft. Collins, Colo.
- Morrison, D., D. Chu and A.L.S. Johnson. 1985. Species of *Armillaria* in British Columbia. Can. J. Plant Path. 7:242-246.
- Parker, A.K. and A.L.S. Johnson. 1960. Decay associated with logging injury to Spruce and Balsam in the Prince George Region of British Columbia. For. Chron. 30-46.
- Stock, A.J. 1986. Assessment of pest damage to Subalpine fir stands in the Bulkley Timber Supply Area. B.C. Ministry of Forests Internal Report PM-PB-54. March 1991.

APPENDIX A SITE ECOLOGICAL INFORMATION

Site No.	Biogeoclimatic Subassociation	Elevation (M)	Slope (%)	Aspect Degrees	Moist. Regime	Nutri. Regime
1	ICHg2/04	700	40-60	225	5	C-D
2	ESSFk/07	1 200	45	40	5	C-D
3	SBSel/01.2	1 000	0	n/a	4	C-D
4	SBSel/01.1	900	20	25	4	C
5	SBSel	900	0	n/a	5	B-(C)
6	SBSel/07	1 000	70	320	5	C-D
7	SBSel/07	1 000	28	220	5	C-D
8	ESSFk/01	1 200	0	n/a	4-5	C
9	ICHg3/01.2(a)	1 000	27	220	4	C
10	SBSel/07	900	0	n/a	5	C-D
11	SBSel/01.1	1 000	0	n/a	4	C
12	SBSel/08	1 000	0	n/a	5	D-E

APPENDIX B SITE SOIL INFORMATION

Site No.	Soil Type	Soil Tex.	Soil pH	Humus Type	Humus pH	Rooting Depth	Drainage
1	Gray Luvisol	SiL	5.0	Hemimor	4.0	Shallow	Good
2	O. Dystric Brunisol	SiCL	4.0	Hemimor	4.0	20cm	Mod.-Good
3	O. Dystric Brunisol	L	4.0	Hemimor	5.0	>25cm	Mod.-Well
4	O. Dystric Brunisol	L	4.0	Hemimor	4.0	>30cm	Well
5	Eluviated Dystric Brunisol	SL	4.0	Hemimor	4.0	20cm	Imperfect
6	Eluviated Dystric Brunisol	L	4.0	Hemimor	4.0	>30cm	Well
7	Brunisolic Gray Luvisol	CL	6.0	Hemimor	4.0	30cm	Imperfect
8	Brunisolic Gray Luvisol	CL	4.0	Hemimor	4.0	20cm	Imperfect
9	Dystric Brunisol	SL	4.0	Hemimor	4.0	>40cm	Well
10	O. Dystric Brunisol (hummocks) and Gray Luvisol (depressions)	L CL	4.0 6.0	Humimor	5.0	25cm	Mod. to Imperfect
11	Humoferric Podzol	SL	4.5	Hemimor	4.0	>25cm	Well
12	Gray Luvisol	C	7.0	Mormoder	6.0	25cm	Imperfect

APPENDIX C SITE INVENTORY INFORMATION

Site No.	Species	Age Class	Height Class	DBH (cm)	Stems Per Ha
1	Hw, Bl, (Sxw)	-	-	-	-
2	Bl, (Sxw)	6-7	2	24	3 000
3	Bl, (Sxw)	8	3	35	1 300
4	Bl, (Sxw)	7-8	3	37	1 000
5	Bl, Pl	7	3	32	600
6	Sxw, Bl, (Pl)	5-6	3	35	1 400
7	Sxw, BL, (Pl)	7-8	4	40	500-1 400
8	Bl, (Sxw, Pl)	8	3	50	1 000
9	Bl, Sxw, Pl, Hw	5-7	5	50	800
10	Bl, Sxw, Pl	7	4	49	640
11	Bl, (Sxw)	7-8	3	35	900
12	Sxw, Bl	8	3	48	850

APPENDIX D DESCRIPTIONS OF SITES

Ecological features, soil data and stand inventory information for the twelve sites are summarized in Appendices A, B and C.

SITE 1

Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
11	Dead	Lower Main	Root dieback
12	Dead	Lower Main	Brown butt rot
13	Green	Main	Brown butt rot
21	Dead	Lower Main	Root dieback
22	Dead	Understory	Root dieback
23	Dead	Main	<i>D. confusus</i>
24	Dead	Main	<i>D. confusus</i>
25	Dead	Understory	Root dieback

Site 1 is located north of Moriceton, B.C. To reach the site, turn left on Highway 97 just before Seaton. Travel approximately five kilometres down the road; the transect is flagged on the left of the road. Site 1 was located from the information collected by Stock (1986). Although the stand was indicated as being afflicted by *D. confusus*, no beetle kill trees were in evidence from the road. Few trees were found to be declining in the 20m wide, 50m long strip surveyed. A small amount of butt rot was present, but no significant decline occurred. The healthy state of this stand yielded little information on the causes of decline in subalpine fir. Root dieback (possibly *C. puteana*) was the only agent noted in this site.

SITE 2
Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
11	Green	Main	<i>D. confusus</i>
12	Red	Main	<i>D. confusus</i>
13	Red	Main	<i>D. confusus</i>
14	Green/Thin	Lower Main	Root dieback
15	Red/Thin	Main	<i>D. confusus</i>
16	Red	Main	<i>D. confusus</i>
17	Green/Thin	Main	Root dieback, <i>C. puteana</i>
18	Green	Lower Main	Root dieback
19	Dead	Lower Main	<i>Armillaria</i> spp.
110	Dead	Understory	<i>A. ostoyae</i>
111	Green	Lower Main	Root dieback
112	Dead	Understory	Root dieback, <i>D. confusus</i> , Heart rot
21	Red	Main	<i>D. confusus</i>
22	Dead	Lower Main	<i>D. confusus</i>
23	Dead	Lower Main	Root dieback, <i>A. ostoyae</i>
24	Green	Main	<i>D. confusus</i> , <i>H. reticulatus</i>
25	Red	Understory	<i>Armillaria</i> spp., <i>D. confusus</i>

Site 2 is located off the Babine Lake Road. To reach the site, turn left up the fire look-out road past Little Joe Creek. The site is located approximately six kilometres up this road on the left where the first transect tree is flagged. *D. confusus* predominated in this transect, in most cases without evidence of other pathogens. Some root dieback and *Armillaria* spp. were also present. Pest complexes involving *D. confusus* and root dieback and *Armillaria* spp. were discovered in two trees. *Armillaria* appeared to be growing saprophytically and all the infected trees were dead. However, dichotomous rhizomorphs were found in association with the *Armillaria* on Trees 110 and 23. These trees were, therefore, classified as *A. ostoyae*. The root dieback involved hollowed roots, the majority of which contained some evidence of past infection with a white pitted rot. *Hylurgops reticulatus*, a beetle species normally found on pine, was found feeding on the bole of a living subalpine fir (Tree 24).

SITE 3
Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
11	Red	Understory	<i>D. confusus</i>
12	Dead	Main	D.T.L.T.D.*
13	Dead	Main	D.T.L.T.D.
14	Dead	Understory	D.T.L.T.D.
15	Red/Gray	Main	<i>D. confusus</i>
16	Red	Main	<i>D. confusus</i>
17	Red	Main	<i>D. confusus</i>
17.b	Red	Understory	<i>D. confusus</i>
18	Red	Main	<i>D. confusus</i>
19	Red	Main	<i>D. confusus</i>
110	Red	Lower Main	<i>D. confusus</i>
111	Dead	Lower Main	<i>D. confusus</i>
112	Dead	Lower Main	D.T.L.T.D.
113	Dead	Vet	D.T.L.T.D.
114	Dead	Main	D.T.L.T.D.
115	Red	Main	<i>D. confusus</i>
116	Red/Gray	Main	<i>D. confusus</i>
117	Green/Thin	Main	<i>D. confusus</i>
118	Dead	Main	<i>D. confusus</i>
119	Green/Thin	Vet	<i>I. tomentosus</i>
120	Green	Vet	<i>I. tomentosus</i>
21	Red	Main	<i>D. confusus</i>
22	Dead	Main	<i>D. confusus</i>
23	Dead	Main	<i>D. confusus</i> , Root dieback
24	Dead	Main	D.T.L.T.D.
25	Dead	Main	D.T.L.T.D.
26	Dead	Main	<i>D. confusus</i>

Tree No.	Crown Status	Canopy Position	Damaging Agents
27	Dead	Understory	Root dieback, <i>C. puteana</i>
28	Dead	Understory	<i>D. confusus</i>
29	Dead	Understory	<i>D. confusus</i>
210	Dead	Understory	Root dieback
211	Dead	Main	Root dieback, <i>C. puteana</i>
213	Green/Thin	Main	Defoliator
214	Green/Thin	Main	<i>A. ostoyae</i>
215	Dead	Main	D.T.L.T.D.

* D.T.L.T.D. = Dead too long to diagnose.

Site 3 is located on Babine Lake Road, on map sheet 93L15F. To reach the site, travel approximately 28km down Babine Lake Road; the site is on the left, opposite Hill Road. It is marked with two pink flags. The first 50m of this transect passed through densely stocked subalpine fir which was predominantly afflicted by *D. confusus*. At 50m, an area of windfall was found which appeared to have been caused by a very high water table. The ground became progressively more swampy towards the end of the transect. *I. tomentosus* was identified in spruce and adjacent subalpine firs (Trees 119 and 120). Root dieback and butt rot was also present; the latter was believed to be *C. puteana*. *Armillaria* was observed in Tree 214. Living tissue was apparently being attacked and digestion resulted in a sticky mass in which were embedded hardened resin drops. Both this tree and Tree 119 (with *I. tomentosus*) showed root disease crown symptoms.

SITE 4

Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
11	Red	Vet	<i>D. confusus</i> , Heart rot
12	Top Red	Understory	<i>D. confusus</i>
13	Green	Understory	<i>P. pini</i>
14	Dead	Main	<i>D. confusus</i>
15	Dead	Lower Main	<i>D. confusus</i>
16	Red	Main	<i>D. confusus</i>
17	Green	Main	<i>D. confusus</i>
18	Dead	Lower Main	D.T.L.T.D.*
19	Dead	Main	<i>D. confusus</i>
110	Green	Main	<i>D. confusus</i>
121	Top Dead	Vet	<i>P. pini</i>
21	Dead	Understory	<i>D. confusus</i>
22	Dead	Understory	<i>D. confusus</i>
23	Dead	Vet	Root dieback
24	Dead	Main	<i>M. caryophyllacearum</i>

* D.T.L.T.D. = Dead too long to diagnose.

Site 4 is located near Dennis Lake, B.C. on map sheet 93L073. To reach the site, travel down McDonnell Lake Road and turn left just past Dennis Lake; follow this road behind the lake and the site is located on the right, marked with flagging tape at approximately 2.5km. This site consisted primarily of overmature subalpine fir and western hemlock. *P. pini* and *E. tinctorium* were present in the overstory and suppressed understory trees. Although only two trees are indicated as being decayed, only a small number of trees were sampled with an increment borer for decay. Decay in an advanced state produced overstory trees with narrow, broken crowns and often with spike tops. Root dieback was present, but not common or pronounced.

SITE 5
Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
11	Red	Main	<i>D. confusus</i>
12	Red	Main	<i>D. confusus</i> , Root dieback, <i>A. ostoyae</i>
13	Red	Main	<i>D. confusus</i> , <i>A. ostoyae</i>
14	Red/Gray	Main	<i>D. confusus</i> , <i>Armillaria</i> spp.
15	Dead	Lower Main	<i>D. confusus</i> , <i>Armillaria</i> spp.
16	Dead	Main	<i>D. confusus</i>
17	Red/Green	Main	<i>D. rufipennis</i>
18	Dead	Main	<i>D. rufipennis</i>
19	Green/Thin	Main	<i>Hylurgops</i> spp., <i>A. ostoyae</i>
110	Green/Thin	Main	<i>Hylurgops</i> spp.
111	Dead	Main	<i>D. confusus</i>
112	Dead	Vet	<i>P. pini</i>
113	Dead	Lower Main	D.T.L.T.D.*
114	Dead	Lower Main	<i>D. confusus</i>
21	Green	Main	<i>C. puteana</i>
22	Dead	Main	<i>D. confusus</i>
23	Green/Thin	Main	Root dieback, <i>C. puteana</i>
24	Dead	Main	<i>D. confusus</i>
25	Dead	Main	D.T.L.T.D.
26	Dead	Lower Main	<i>D. confusus</i>
27	Dead	Main	<i>D. confusus</i>
28	Green/Thin	Lower Main	<i>D. confusus</i>

* D.T.L.T.D. = Dead too long to diagnose.

Site 5 is located on map sheet 93L083, along the Copper River Ranch Road. It is marked with one long pink flag on a small lodgepole pine on the right side of the road just past the 27km mark. *D. confusus* was present in about half of the afflicted trees along this transect. *A. ostoyae* was also found; it was tentatively identified as such by the fact that mycelium was found on living roots immediately adjacent to living tissue. Root feeders were in evidence in the form of feeding galleries. These galleries were often colonized by *Armillaria*. They may serve as avenues of infection for *A. ostoyae*. The fungus could become established in the small area of necrotic tissue associated with the gallery and spread radially from there. Spruce bark beetles were located on two trees. In fact, it is most likely a combined attack with *D. confusus* which had occurred in these two trees.

SITE 6
Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
1	Red	Main	<i>D. confusus</i>
2	Red	Main	<i>D. confusus</i> , <i>A. ostoyae</i>
3	Red	Main	<i>A. ostoyae</i> , <i>A. chailletii</i>
4	Green/Thin	Lower Main	<i>D. confusus</i> , <i>A. ostoyae</i> , Root dieback, White rot in bole
5	Green/Thin	Main	Cause undetermined
6	Green/Thin	Lower Main	<i>A. ostoyae</i> , <i>I. tomentosus</i> , Root dieback
7	Green/Thin	Understory	Root dieback
8	Green/Thin	Lower Main	<i>H. rugipennis</i> , <i>D. confusus</i> , <i>A. ostoyae</i>
9	Green/Thin	Lower Main	Root dieback, <i>A. ostoyae</i>
10	Green/Thin	Main	Root dieback, <i>A. ostoyae</i>
11	Green	Main	Root dieback, <i>C. puteana</i>
12	Red/Green	Main	<i>D. confusus</i>
13	Dead	Understory	Root dieback, <i>C. puteana</i>
14	Green	Understory	<i>A. ostoyae</i> , <i>I. tomentosus</i>
15	Green	Understory	<i>A. ostoyae</i> , <i>I. tomentosus</i>
16	Green	Understory	<i>I. tomentosus</i>
17	Green/Thin	Main	Cause undetermined
18	Green/Thin	Lower Main	Root dieback, <i>I. tomentosus</i> , <i>A. ostoyae</i> , Brown butt rot
19	Green/Thin	Main	<i>I. tomentosus</i> , Brown butt rot
20	Green/Thin	Main	Root dieback
21	Green/Thin	Main	Root dieback, <i>I. tomentosus</i>
22	Green/Thin	Main	Root dieback

Site 6 is located near Coffin Lake, B.C. on map sheet 93L10D. The site is located at the top of the hillside. Site 6 is best described as a root disease site. *D. confusus* were detected on the outskirts of the stand and determined the position of the plot. A 25m x 40m plot was used in this case, since the slope became too steep to safely traverse beyond the 40m point. All conifer species on the site (spruce, pine and sub-alpine fir) were found to be infected with *I. tomentosus*. *I. tomentosus* was isolated from five balsam trees, alone or in combination with *A. ostoyae* or a butt rot (possibly *C. puteana*). All of these trees were in close proximity to infected spruce and pine. Spruce and pine were attacked at a higher frequency than subalpine fir and the decay which resulted in pine and spruce was more severe. *A. ostoyae* was identified in eight trees and was thus the most common pest identified on the site. *C. puteana* and *Amylostereum chailletii* were also present, the latter causing severe decay of the bole. Pathogen complexes were very common. The root dieback on this site appeared to be due, in some cases, to *I. tomentosus*. *I. tomentosus* was isolated from the leading edge of one hollowed-out root previously classified as root dieback. Three root dieback trees: 11, 20 and 22 were found to have a brown type rot in their root dieback. *C. puteana* was isolated from Tree 22 and was suspected in the other two.

SITE 7

Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
1	Dead	Main	<i>D. confusus</i> , <i>Armillaria</i> spp., Root dieback
2	Red/Gray	Main	<i>D. confusus</i>
3	Red	Lower Main	<i>D. confusus</i>
4	Green/Thin	Main	<i>D. confusus</i>
5	Red	Main	<i>D. confusus</i>
6	Dead	Main	<i>D. confusus</i> , <i>A. ostoyae</i>
7	Dead	Main	Root dieback
8	Green/Thin	Main	Root dieback, <i>A. ostoyae</i> , <i>C. puteana</i>
9	Green/Thin	Main	Root dieback, <i>C. puteana</i>
10	Green/Thin	Main	<i>D. confusus</i> , Root dieback
11	Red	Main	<i>D. confusus</i> , <i>P. pini</i>
12	Green/Thin	Main	<i>D. confusus</i> , Root dieback
13	Red	Main	<i>D. confusus</i> , <i>Armillaria</i> spp., Root dieback
14	Red	Lower Main	<i>D. confusus</i>
15	Red	Main	<i>D. confusus</i>
16	Red	Main	<i>D. confusus</i> , <i>I. tomentosus</i> , <i>A. ostoyae</i>
17	Red	Main	<i>D. confusus</i> , <i>I. tomentosus</i> , Root dieback
18	Red	Main	<i>D. confusus</i> , <i>I. tomentosus</i>
19	Red	Main	<i>D. confusus</i>
20	Green	Lower Main	Root dieback, <i>F. annosa</i>
21	Green	Main	<i>A. ostoyae</i>
22	Green	Main	<i>D. confusus</i> , <i>P. pini</i>
23	Green	Main	<i>D. confusus</i>

Site 7 is located near Jonas Creek, B.C. on map sheet 93L063. To reach the site, follow the Telkwa River Road and turn right just past Jonas Creek. Keep to the left along this road, past the hydro lines, left at the loop, then keep to the right (past two left offshoots); the site is down this road on the left, marked with flagging tape. Follow the flagging tape through the windfall area to the site. No site layout map is included for this site as Wayne Martin, Prince Rupert forest pathologist, was present during the sampling.

D. confusus was very common, as was *A. ostoyae*. *I. tomentosus* was limited to direct root contacts with infected pine and spruce. Pine and spruce were extensively infected with *I. tomentosus*, and windfall was common. Windfall occurred in all three tree species. However, subalpine fir windfall did not show characteristic pitted *tomentosus* rot in the exposed roots.

SITE 8
Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
1	Dead	Main	<i>D. confusus</i>
2	Red/Gray	Main	<i>D. confusus</i>
3	Red/Gray	Main	<i>D. confusus</i>
4	Green	Understory	<i>D. confusus</i>
5	Green	Understory	Root dieback
6	Green	Lower Main	Near <i>I. tomentosus</i> -infected spruce, but no inoculum transfer
7	Green/Thin	Lower Main	Cause undetermined
8	Dead	Main	<i>D. confusus</i>
9	Green	Understory	<i>D. confusus</i>
10	Red	Understory	<i>D. confusus</i>
11	Red	Understory	<i>D. confusus</i> , Root dieback
12	Red	Lower Main	<i>I. tomentosus</i> , <i>D. confusus</i>
13	Red/Gray	Lower Main	<i>D. confusus</i>
14	Green/Thin	Understory	Cause undetermined
15	Green	Understory	<i>D. confusus</i>
16	Red/Gray	Lower Main	Cause undetermined
17	Red	Main	<i>D. confusus</i> , <i>P. pini</i>
18	Dead	Main	<i>D. confusus</i>
19	Green	Main	<i>D. confusus</i>
20	Green	Main	<i>D. confusus</i>
21	Green	Main	<i>P. pini</i>
22	Dead	Main	<i>D. confusus</i> , <i>F. annosa</i>
23	Green	Main	<i>P. pini</i>
24	Green/Thin	Main	Root dieback, <i>C. puteana</i>
25	Dead	Main	<i>D. confusus</i>
26	Green	Main	<i>D. confusus</i>

Tree No.	Crown Status	Canopy Position	Damaging Agents
27	Green/Thin	Main	Scar
28	Green	Main	<i>P. pini</i>
29	Dead	Main	<i>D. confusus</i>
30	Chlorotic	Understory	<i>M. abieti-capraearum</i>

Site 8 is located off Blunt Lake Forest Road on map sheet 93M3B. To reach the site, follow the Blunt Lake Forest Road, keeping to the left at the fork at approximately 6.5km. Turn right past the 10km marker and travel approximately 7km, where a blue flat is marking a left turn. Take this road and the site is flagged with blue tape on the left.

Site 8 is high elevation and shows signs of having undergone lightning and wind damage. Many trees bear fractures the length of the bole. Large trees, whose boles were decayed were broken off at two metres from the ground. *D. confusus* was the predominate cause of mortality and decline. *I. tomentosus* was common on spruce, but was only located once on subalpine fir (Tree 12). The disease was well developed in Tree 12, occupying the roots, butt and two metres up the bole. The decay produced was characteristic of *tomentosus* in appearance. Namely, red and brown stained wood with cream to tan colored pits. *P. pini* was common on this site and was identified by the presence of conks on four tree. *Melampsora abieti-capraearum* occurred on one small understory tree (Tree 30), but was not causing noticeable decline.

SITE 9

Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
1	Green/Thin	Main	<i>A. ostoyae</i> , Root dieback
2	Green/Thin	Main	<i>A. ostoyae</i>
3	Green/Thin	Main	<i>D. confusus</i> , <i>A. ostoyae</i> , Brown butt rot
4	Green/Thin	Main	<i>A. ostoyae</i> , Root dieback
5	Green/Thin	Main	<i>A. ostoyae</i> , Root dieback
6	Dead	Main	<i>D. confusus</i>
7	Dead	Main	<i>D. confusus</i>
8	Red	Understory	Cause undetermined
9	Dead	Main	D.T.L.T.D.*
10	Red	Main	Root dieback
11	Dead	Main	<i>D. confusus</i> , <i>Armillaria</i> spp.
12	Dead	Main	D.T.L.T.D.
13	Dead	Main	D.T.L.T.D.
14	Dead	Main	<i>D. confusus</i>
15	Dead	Main	<i>D. confusus</i> , <i>P. pini</i>
16	Dead	Main	D.T.L.T.D.
17	Dead	Main	D.T.L.T.D.
18	Dead	Main	<i>D. confusus</i>
19	Green	Main	<i>D. confusus</i>
20	Red	Main	<i>D. confusus</i>
21	Dead	Main	<i>D. confusus</i>
22	Dead	Main	<i>D. confusus</i>
23	Dead	Main	<i>D. confusus</i>

* D.T.L.T.D. = Dead too long to diagnose.

Site 9 is located near Kitseguecla Lake. To reach the site, travel down the Kitseguecla Road off Highway 97. Turn right at the Talzen Lake Recreation Site towards Kitseguecla Lake. Approximately three kilometres from the Kitseguecla Lake Recreation Area sign, subalpine fir tree is flagged with blue flagging tape. The site is across the cutblock; to reach it, walk across the cutblock at 68° from this flagged tree and the start of the transect is well flagged.

This site (like Site 6) is located at the edge of a cutblock; the trees near the beginning of the transect were infected by *A. ostoyae* and displayed classic root rot crown thinning symptoms. Further up slope, along the transect, *D. confusus* was virtually the only pest agent detected. The mature spruce and pine trees on the site showed infection by *I. tomentosus*, and *P. pini*, respectively, but neither species was found to be common on subalpine fir. Root dieback was generally found with *A. ostoyae* (on the same tree), and may have been due to *Armillaria* itself.

SITE 10

Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
1	Red	Main	<i>D. confusus</i>
2	Red	Main	<i>D. confusus</i> , <i>Armillaria</i> spp., <i>Hylurgops</i> spp.
3	Dead	Main	<i>D. confusus</i> , <i>Armillaria</i> spp.
4	Red/Gray	Main	<i>D. confusus</i> , <i>Armillaria</i> spp.
5	Dead	Main	<i>Armillaria</i> Type 5, Frost crack
6	Red	Main	<i>D. confusus</i> , <i>A. ostoyae</i>
7	Red	Main	<i>D. confusus</i> , <i>Armillaria</i> spp.
8	Green	Main	Frost crack
9	Dead	Main	<i>Armillaria</i> spp.
10	Red	Main	<i>D. confusus</i> , <i>Armillaria</i> spp.
11	Red	Main	<i>D. confusus</i>
12	Green/Thin	Lower Main	<i>C. puteana</i>
13	Dead	Main	<i>D. confusus</i> , <i>Armillaria</i> spp.
14	Green/Thin	Main	Cause undetermined
15	Dead	Main	D.T.L.T.D.*
16	Dead	Main	<i>D. confusus</i>
17	Green/Thin	Main	Root dieback
18	Dead	Main	<i>Armillaria</i> spp.
19	Dead	Main	<i>Armillaria</i> spp.
20	Green/Thin	Main	Cause undetermined
21	Dead	Main	<i>D. confusus</i>
22	Dead	Main	D.T.L.T.D.
23	Red/Gray	Main	<i>D. confusus</i> , <i>A. ostoyae</i> , Brown butt rot

* D.T.L.T.D. = Dead too long to diagnose.

Site 10 is located down the Morice River Forest Road. To reach the site, turn left off the Morice Forest Road just past the 41km signpost. At 9.5km down this road, keep to the right fork, travel past a landing and the site is on the left marked with pink and blue flagging tape.

Both *D. confusus* and *Armillaria* spp. were very common on this site. However, the *Armillaria* appeared, for the most part, to be acting saprophytically and may, therefore, have been *Armillaria* Type 5. Where *Armillaria* spp. was present on trees which were dead and no other causal agent was found, often the trees were dead too long to properly diagnose, but *Armillaria* spp. was present saprophytically. There were signs of *Hylurgops* spp. feeding and a small amount of root dieback, but most trees were beetle killed or had been dead for some time and, therefore, their causal agents could not be determined.

SITE 11

Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
1	Green/Thin	Main	Root dieback, <i>Hylurgops</i> spp. signs
2	Green	Main	Root dieback
3	Dead	Main	<i>D. confusus</i>
4	Dead	Main	D.T.L.T.D.*
5	Chlorotic	Understory	Gall
6	Red	Understory	Gall
7	Dead	Main	<i>D. confusus</i> , Root dieback
8	Dead	Main	D.T.L.T.D.
9	Dead	Main	<i>D. confusus</i>
10	Dead	Main	Gall, D.T.L.T.D.
12	Dead	Main	D.T.L.T.D.
13	Green/Thin	Understory	Gall
14	Dead	Understory	D.T.L.T.D.
15	Chlorotic	Understory	<i>M. abieti-capraearum</i>
16	Dead	Main	Gall, <i>D. confusus</i>
17	Green	Main	Gall
18	Dead	Main	Gall, <i>D. confusus</i> , Frost crack
19	Green/Thin	Main	Cause undetermined
20	Green	Main	Scar
21	Green	Main	Gall

* D.T.L.T.D. = Dead too long to diagnose.

Site 11 is located off the Morice River Forest Road. To reach the site, turn left off the Morice River Forest Road just past the 50km sign post, travel approximately 3.5km down this road and the site is flagged on the left side.

This site was located in a stand which had no recent beetle attacks. Some larger dead trees were present and many smaller ones showed signs of decline (crown thinning). The dead larger trees had been dead a long time, as if perhaps this was previously a beetle kill area. Four trees showed signs of beetle attack, others may have been killed by *D. confusus*, but too long ago to identify it. Four trees showed root dieback and no causal fungal pathogen was identified. *Melampsora abieti-capraearum* was identified on one tree and a frost crack and scar were each found on single trees.

SITE 12

Tree Data

Tree No.	Crown Status	Canopy Position	Damaging Agents
1	Green	Main	<i>D. confusus</i> , <i>A. ostoyae</i> , <i>C. puteana</i>
2	Dead	Main	<i>Armillaria</i> spp., Root dieback
3	Green/Thin	Main	Root dieback, <i>A. ostoyae</i> , <i>C. puteana</i>
4	Green/Thin	Main	<i>A. ostoyae</i> , <i>H. rugipennis</i>
5	Red	Main	<i>D. confusus</i> , <i>Armillaria</i> Type 5
6	Red	Main	<i>D. confusus</i>
7	Dead	Main	<i>D. confusus</i>
8	Green	Main	<i>D. confusus</i>
9	Dead	Main	<i>D. confusus</i>
10	Dead	Main	<i>D. confusus</i>
11	Dead	Main	<i>D. confusus</i>
12	Dead	Main	<i>D. confusus</i> , <i>Armillaria</i> spp.
13	Dead	Main	<i>D. confusus</i> , Root dieback, <i>Armillaria</i> Type 5, <i>C. puteana</i>
14	Dead	Main	<i>D. confusus</i>
15	Dead	Main	<i>D. confusus</i>

Site 12 was also located off the Morice River Forest Road. To reach the site, turn left off the Morice River Forest Road at the road past the 50km mark, travel approximately 1.5km down this road; the site is flagged on the right.

D. confusus was the predominant pest in Site 12. Twelve of the 15 tress were afflicted with it. Of these, *Armillaria* Type 5 was found in a complex with *D. confusus* and *A. ostoyae* twice and with *D. confusus* once. Cubical butt rot, probably *C. puteana*, was found in association with *D. confusus* twice and once with each of *A. ostoyae* and *Armillaria* Type 5.

TABLE 1 DAMAGING AGENTS IN SUBALPINE FIR STANDS

Pest	Frequency (max = 242)	Prop.	Proportion in Complexes
<u>Insects</u>	144	59.5%	31.9%
<i>Dryocoetes confusus</i>	135	55.8%	32.6%
<i>Dendroctonus rufipennis</i>	2	0.8%	0.0%
<i>Hylurgops</i> spp.	7	2.9%	71.4%
<u>Root and Butt Rots</u>	127	52.5%	53.0%
<i>Armillaria ostoyae</i>	29	11.9%	44.8%
<i>Armillaria</i> spp.	19	7.9%	68.4%
<i>Armillaria</i> Type 5	2	0.8%	50.0%
Brown butt rot	6	2.5%	16.7%
<i>Coniophora puteana</i>	10	4.1%	30.0%
<i>Heterobasidion annosum</i>	2	0.8%	100.0%
<i>Inonotus tomentosus</i>	11	4.5%	77.8%
Root dieback	48	19.8%	29.2%
<u>Decays</u>	14	5.8%	50.0%
<i>Phellinus pini</i>	10	4.1%	40.0%
Others	4	1.6%	75.0%
<u>Needle Diseases</u>	3	1.2%	0.0%
<i>Melampsora abieticapræarum</i>	2	0.8%	0.0%
<i>Melampsorella caryophyllacearum</i>	1	0.4%	0.0%
<u>Abiotic Factors</u>	4	1.7%	
Frost cracks	2	0.8%	
Scars	2	0.8%	

TABLE 2 PEST COMPLEXES ENCOUNTERED

Pests	Insect x Insect	Frequency
<i>Dryocoetes confusus</i> x <i>Hylurgops reticulatus</i>		1
	Insect x Disease	
<i>D. confusus</i> x <i>Armillaria ostoyae</i>		5
<i>D. confusus</i> x <i>Armillaria</i> spp.		12
<i>D. confusus</i> x <i>Armillaria</i> Type 5		1
<i>D. confusus</i> x <i>Fomitopsis annosa</i>		1
<i>D. confusus</i> x Heart rot		1
<i>D. confusus</i> x <i>Inonotus tomentosus</i>		2
<i>D. confusus</i> x <i>Phellinus pini</i>		4
<i>D. confusus</i> x Root dieback		11
<i>D. confusus</i> x <i>A. ostoyae</i> x <i>C. puteana</i>		2
<i>D. confusus</i> x <i>A. ostoyae</i> x Heart rot		1
<i>D. confusus</i> x <i>A. ostoyae</i> x <i>Hylurgops</i> spp.		1
<i>D. confusus</i> x <i>A. ostoyae</i> x <i>I. tomentosus</i>		1
<i>D. confusus</i> x <i>Armillaria</i> spp. x <i>Hylurgops</i> spp.		1
<i>Hylurgops</i> spp. x <i>A. ostoyae</i>		1
<i>Hylurgops</i> spp. x Root dieback		1
	Disease x Disease	
<i>Amylostereum chailletii</i> x <i>A. ostoyae</i>		1
<i>A. ostoyae</i> x <i>C. puteana</i>		1
<i>A. ostoyae</i> x <i>I. tomentosus</i>		2
<i>A. ostoyae</i> x <i>I. tomentosus</i> x Brown butt rot		1
<i>I. tomentosus</i> x Brown butt rot		1
Root dieback x Gall		1
Root dieback x <i>F. annosa</i>		1

FIGURE 1 LOCATION OF SITES STUDIED

