

**DEVELOPMENT OF SAMPLING PROCEDURES
FOR TREE ROOT DISEASES IN THE
DRY-INTERIOR, DOUGLAS-FIR
BIOGEOCLIMATIC SUBZONE**

by

Maureen Curran and John Schulting
Pathocon Consulting
4075 Jade Drive
Prince George, British Columbia

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

PM-PB-80

Submitted March 1986

Not for Publication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)

FOREWORD

This report is one of a series of internal reports distributed by Forest Protection Branch, B.C. Ministry of Forests, to record accomplishments and interim or provisional results for the information of staff, colleagues, and others.

In the Canada-British Columbia Forest Resources Development Agreement (FRDA) 1985 to 1990, over 100 pest control projects were directly funded by the province and administered by protection staff. To facilitate application of the results, and development of improved forest health management strategies, the contractors reports have been edited and distributed as internal reports. Accordingly, any opinions and recommendations expressed are those of the contractor, and not necessarily those of the ministry or the FRDA management committee.

For details or more information about the report or project, please contact forest health staff at Protection Branch or at the forest region offices.

J. Muir, RPF
Acting Manager
Forest Health
Forest Protection Branch

The guidelines for internal reports outlined in the Protection Manual were adhered to as closely as possible. All manuscripts were altered to comply with a common format, but entire reports were not rewritten to conform to a standardized outline.

Most Executive Summaries were the work of Graham Hawkins of MoF Inventory Branch (formerly with Pacific Coast Forest Biology). All word processing was accomplished by Catriona Kaufman of Top Kat Services. Will Gordon of R. White Woods inc. prepared all maps and figures.

R. White, editor
R. White Woods inc.

ACKNOWLEDGEMENTS

This project was funded under Backlog Research Program of the Canada-British Columbia Forest Resource Development Agreement, 1985-90. Assistance from H. Merler in the Kamloops regional office and A. Lewinski, J. Cruikshank and D. Harris in the Merritt district was greatly appreciated. Drs. W. Bloomberg, Forestry Canada, Pacific Forestry Centre, and J. Muir, Protection Branch, B.C. Ministry of Forests, were the project leaders.

EXECUTIVE SUMMARY

The objectives of the study were to:

1. Conduct a root disease survey in three cut blocks of 15-20ha each. Map and record all infected trees.
2. Analyze the survey data to develop root disease survey methods toward determining suitable management options for the Vernon-Salmon Arm area.

Three sites with mixed age and species and a history of selective harvesting were selected for trials of survey methods. All three areas contained *Armillaria* root disease and laminated root rot. All infected trees were mapped, and species, size, and infection codes were recorded. Infection class was coded as dead, heavy, medium, and light. Tree species were tallied by infection class and height class.

Two different sampling procedures were developed for each disease. Both clumped and diffuse infection was noted for laminated root rot, while *Armillaria* root disease had a clumped distribution. The transect infection method was not used. Instead, prism (BAF 2-6) and fixed area plots were considered in conjunction to a quick reconnaissance to stratify the area by infection levels. The fixed area plots were 10m x 20m or 20m x 20m in size and yielded good estimates for laminated root rot. Data on *Armillaria* root disease were obtained by running 10m-wide strips at 50m intervals and recording all diseases within these strips. This method was found to be quite accurate for a clumped disease distribution, but was also time consuming. *Armillaria* root disease appeared to be associated with cut stumps, thus leading to the hypothesis that selective cutting is exacerbating the problem.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	ii
EXECUTIVE SUMMARY	iii
1 INTRODUCTION	1
2 METHODS	
2.1 <u>Selection and Description of Study Sites</u>	2
2.2 <u>Survey Methods</u>	3
3 SYMPTOMOLOGY OF THE DISEASES	
3.1 <u>Distribution Patterns</u>	
3.1.1 <i>Phellinus weirii</i>	6
3.1.2 <i>Armillaria ostoyae</i>	6
3.2 <u>Symptomology Classes</u>	7
4 TREE DATA	9
5 DEVELOPMENT OF ROOT DISEASE SAMPLING PROCEDURES	
5.1 <u>Laminated Root Rot</u>	10
5.2 <u><i>Armillaria ostoyae</i> Root Disease</u>	11
6 RESULTS	14
7 REFERENCES	15

APPENDICES (not included)

A	Illustrations of the Symptomology Classes
B	Listing of Individual Tree Data - Kentucky Site 1
C	Listing of Individual Tree Data - Kentucky Site 2
D	Listing of Individual Tree Data - Nicola Site
E	Field Maps - Kentucky Site 1
F	Field Maps - Kentucky Site 2
G	Field Maps - Nicola Site

TABLES

1	Height Estimates for Field Crew	16
2	Tree Data for Kentucky Site 1	17
3	Tree Data for Kentucky Site 2	18
4	Tree Data for Nicola Site	19
5	Age, Height and DBH for Kentucky Site 1	20
6	Age, Height and DBH for Kentucky Site 2	21
7	Age, Height and DBH for Nicola Site	22
8	Simulation 1: Kentucky Site 1 (10m x 20m Plots)	23
9	Simulation 2: Kentucky Site 1 (20m x 20m Plots)	24
10	Simulation 3: Kentucky Site 2 (10m x 20m Plots)	25
11	Simulation 4: Kentucky Site 2 (20m x 20m Plots)	26
12	Simulation 5: Nicola Site (10m x 1 807m Strip)	27
13	Simulation 6: Nicola Site (10m x 2 010m Strip)	28
14	Nicola Site: Percentages of Area in Clumps and in High Risk Areas of Clumps	29

1 INTRODUCTION

Phellinus weirii (Murr) Gilbertson and *Armillaria ostoyae* (Romagn.) Herink cause root diseases of many coniferous tree species in British Columbia. Douglas-fir, true firs, spruces, western hemlock, western larch and pines are susceptible to varying extents. *P. weirii* usually occurs in infection centers which arise from infected stumps from previous stands (Wallis 1976). The fungus spreads from tree to tree by means of contacts between healthy and diseased roots. Spores have not been found to be an important factors in spread within a stand. Root diseases cause a decrease in radial increment growth and height growth due to the loss in root conducting tissue. All infected trees eventually die, depending on the length of time of infection, tree age, size, species, and site factors.

In the field, root diseases are indicated by above-ground symptoms, and identified by below-ground signs or features of the fungi. Above-ground symptoms of root disease include openings in the stand where dead trees have been windthrown or hardwoods have grown in, standing dead trees, trees with a stress crop of cones. *P. weirii* is identified by grayish ectotrophic mycelium on infected roots, red-brown stain and laminar pitted decay in the infected roots or butt of trees.

A. ostoyae induces the host tree to exude large amounts of resin through the bark in this area. Under the bark, characteristic mycelial fans of this fungus are evident. In a tree that has been killed for some time, mycelial fans may still be present on the roots or the imprint of the fans may be present in the wood or hardened resin. Sporophores of this fungus are more common than those of *P. weirii*. They appear as golden colored mushrooms in the autumn and are often referred to as honey mushrooms.

The purpose of this project was to determine the distribution of *P. weirii* and *A. ostoyae* in three all aged, multi-specied, selectively harvested stands in the Dry-Interior Douglas-fir (IDFc) biogeoclimatic subzone of British Columbia, and develop appropriate root-disease survey methods.

2 METHODS

2.1 Selection and Descriptions of Study Sites

The sites used in this project were chosen by the Merritt District MoF staff in conjunction with Hadrian Merler, regional forest pathologist, Kamloops Region, and approved by Dr. Bill Bloomberg, research scientist, Canadian Forest Service at Pacific Forest Centre. The stands were selected using the following criteria:

- a. they were known to be infected by *P. weirii* or *A. ostoyae*;
- b. they were considered typical for the district with regard to species composition, age structure, and previous disturbance due to harvesting;
- c. they were accessible in January and February when the field research was to be conducted.

Three stands were selected: two at the Kentucky-Alleyne Recreation Area, and one near Nicola Lake. The sites were referred to as Kentucky Site 1, Kentucky Site 2, and Nicola Site. Kentucky Site 1 is located approximately six kilometres east off of the Princeton-Merritt Highway along the Kentucky-Alleyne Recreation Area access road. Kentucky Site 2 is located an additional four kilometres along this access road close to Loon Lake. Nicola Site is located approximately 25km north of Merritt on km15 of the Monck Park Road.

Kentucky Site 1 was stocked mainly with Douglas-fir and lodgepole pine with a small amount of yellow pine. The trees ranged in age from zero to 115 years; in height from 0.5 to 35m; and diameter at breast height from 0.5 to 65cm. The distribution of the trees varied across the site depending on the extent of disturbance. In highly disturbed areas, the trees were often sparsely distributed, with dense clumps of trees interspersed. In the less disturbed areas there was a higher average frequency of trees, and clumping was less apparent. The location of the disturbed areas is shown in the final map of Kentucky Site 1. This site was selectively logged in 1976. Stumps remaining from this harvest were evident throughout this stand, but occurred with a higher frequency in sparsely treed areas. Hence, it appeared that the sparser areas were related to the harvesting practices in 1976. There were some veteran Douglas-fir and yellow pine present in the stand, which appeared to be of low vigour.

Kentucky Site 2 was also composed mainly of Douglas-fir and lodgepole pine. The site was more homogenous with regard to tree density than Kentucky Site 1. However, there was a large area of hardwoods and disturbance, which is shown in the final map of Kentucky Site 2. The upper right corner of this map is a ridge-top, where site features (shallow soil, etc.) have caused the sparse distribution of trees. This stand was selectively harvested in 1958-59, and was generally more densely treed than Kentucky

Site 1. The trees were from zero to 110 years old, and ranged from 0.5 to 35m in height.

Nicola Site was composed mainly of Douglas-fir with a lesser component of both lodgepole and yellow pine. The trees in this stand were quite strongly clumped, as is shown on the final map of Nicola Site. Roads were present through the site and were also depicted. This site was selectively harvested from 1966 to 1968. The disturbance caused by this harvest was still readily apparent in the form of skid roads and clearings. The trees were up to 150 years old and ranged in height from 0.5 to 35m.

2.2 Survey Methods

A 10ha plot was chosen at each stand. A baseline was established along the most accessible edge of the plot, and transects were located perpendicular to the baseline at 50m intervals. The baseline was marked with flagging tape at the location of each transect. The location of the baseline and transects for each site is shown.

For each transect, all trees within 25m of the transect were examined. Trees with symptoms of root disease were recorded on a field map. The location, species, symptoms, diameter at breast height and height were recorded for all infected trees. The symptoms distinguished in the survey were described in detail. The following classes of symptom severities were based on observations at the three stands. (Illustrations of the symptom severity are in Appendix A.)

Laminated root rot

Light

Height increment reduced in relation to presumed healthy surrounding trees of the same species of similar height and stocking density. No noticeable crown thinning or chlorosis was present. Identification of this class was difficult as other factors (i.e., site features) could cause height increment reduction, particularly for lodgepole pine. Hence, potential light class trees were recorded at the surveyor's discretion, based on site features, the condition of the surrounding trees, stand density and other root rot evidence (windfalls or dead trees with typical laminated, pitted rot).

Medium

Height increment loss resulted in a rounded crown. Chlorosis, if present, was light and occurred throughout the crown. Crown thinning was present, with 65% of the needles cast.

Heavy

Height increment was strongly reduced, causing a pronounced rounding of the crown. Thin crowns had more than 65% of the needles cast. The needles were often chlorotic, appearing straw colored. Red needles were interspersed throughout the crown. Douglas-fir had fairly homogenous crown thinning, whereas infected pines had more patchy needle loss.

Dead

Tree dead with usually reduced height increment, rounded crown, thinned foliage, a few red or yellow needles present or needles absent snags were included if there were identifiable signs of the fungus.

Armillaria root disease

Light

Height increment was reduced in relation to presumed healthy surrounding trees of the same species of similar height and stocking density. No noticeable crown thinning or chlorosis was present. Identification of this class was difficult because other site features could cause leader reduction, particularly for lodgepole pine. Hence, the surveyor considered the condition of surrounding trees, stand density, and other root rot evidence (i.e., mycelial fans or resinosis in nearby symptomatic or dead trees) when determining this class of severity.

This class was not very frequent, presumably due to the speed in which *A. ostoyae* kills infected trees.

Medium

For older trees, height increment was reduced. Needles were chlorotic, slightly yellow- to brown-tinted. Basal resinosis was often present. Root collar area under the bark often had mycelial fans.

For younger trees, height increment was often reduced, usually over a two- to four-year period. Needles were chlorotic, slightly yellow- to brown-tinted. Basal resinosis was present. Examination of the cambial layer usually revealed mycelial fans typical of the fungus.

The exploration for mycelial fans in medium infected trees was destructive and was used only for confirmation of the disease if no other indicative features such as nearby dead trees with mycelial fans were present.

Heavy

For older trees, height increment was reduced, forming a rounded crown. Needle loss was pronounced (greater than 65%). Remaining needles were slightly chlorotic to straw-yellow in color. Severe basal resinosis was usually present. Root crown was usually 90-100% girdled by mycelial fans. Trees in this category will likely die in the next growing season as girdling has progressed to a fatal or near fatal level. This class was uncommon, presumably due to the speed of death.

For younger trees, height increment may be reduced for up to five years. Needle loss was pronounced (greater than 65%). Severe resinosis usually was present, and the root crown usually was 90-100% girdled by mycelial fans.

Dead

For older trees, dead trees usually showed symptoms, i., rounded crown, needle chlorosis and loss, height increment reduction. Pronounced basal resinosis and mycelial fans were present, and the fans usually completely girdled the root collar. Snags were included in this class if there was evidence of *A. ostoyae*.

For younger trees, dead trees had needles present, usually bright red. These trees showed up to six years of reduced height growth. Basal resinosis and mycelial fans were present.

Tree diameter was measured using a diameter tape. Tree heights were estimated, and were compared to actual heights as measured with a Suunto clinometer. A linear regression was completed for each field crew member, and the actual heights are included in the report (Table 1). Stumps were examined for signs of root diseases. Clearings, skidroads, and other site features were recorded and mapped.

The position of each tree, along with its infection class and corrected height class are included in the final maps. An analysis of the distribution for each disease on the finished maps and development of survey methods were undertaken in conjunction with Dr. Bill Bloomberg and with consultation from Dr. Julien Demaerschalk.

3 SYMPTOMOLOGY OF THE DISEASES

3.1 Distribution Patterns

3.1.1 *Phellinus weirii*

Infection by *P. weirii* was found in three different forms: scattered individual trees, classic root disease infection centers, and diffuse centers. Individual infected trees were only detectable if the disease was advanced enough that pronounced above-ground symptoms were present. These scattered trees were usually found in the more disturbed sparser areas. The identification of these trees was by above-ground symptoms, due to the snow and frozen ground at the time of survey, making verification on the roots or root collar impossible.

Classic infection centers with central clearings or areas of hardwood invasion, windfalls and symptomatic trees extending out from the central mortality area were present. These centers are typical of the type described by Morrison (1981) and Wallis (1976) for the coast. However, they differ in that there were fewer light to medium symptomatic trees than is typical for these types of centers on the coast. This may be due to a slower spread of *P. weirii* and slower development of the symptoms in the interior. Small clearings with old *P. weirii*-infected stumps were found, yet there were often few or no dead or symptomatic trees surrounding these stumps, suggesting that the disease progression is very slow. This may be due to a slow spread rate, less favourable conditions for the disease, or other factors.

A diffuse center differs from a classic center in that there is no clearing or clump of hardwoods in the former. Rather, there is a large number of symptomatic or apparently healthy trees scattered throughout the 'center.' These trees can be of various ages and sizes (including main canopy trees). This type of center is common, and the identification of the disease in it should be confirmed using below-ground symptoms. The presence of ectotrophic mycelium, laminated pitted rot, windfalls or incipient red-brown staining of the xylem indicates the presence of *P. weirii*.

Differences between the expression of symptoms of infected Douglas-fir and lodgepole pine were noted during the survey. Douglas-fir appears to be prone to rotting. Advanced rot was found extending into the butts of trees, which sometimes showed only light to medium above-ground symptoms. Examples of this were found mainly in Kentucky Site 1, and included fairly small (and presumably young) trees (10m).

3.1.2 *A. ostoyae*

The distribution of *Armillaria ostoyae* infection seems to support the idea that thinning or selective harvest increases the nutrient base for the disease, allowing a sudden increase in its ability to attack healthy trees. This increase in attacking ability occurs

after about 10 years of increased nutrient base (van der Kamp 1986). The centers were generally quite small. The progression of the disease in individual trees appeared to be rapid for trees under 15m in height (progressing from light to dead in approximately five years). The spread of the mycelium from tree to tree could therefore be quite rapid as one would expect a positive relationship between the spread of mycelium within and between trees. The centers were often associated with stumps of trees harvested between 1966 and 1968. Many of these stumps showed signs of *A. ostoyae* invasion. The stumps which did not show signs of invasion may have been infected below the root collar, or evidence of infection may have been eradicated by deterioration of the stump. The sizes of the infection centers (most approximately five metres) appear consistent with a center age of about 10 years. This would be expected if they arose due to the selective harvest between 1966 and 1968. Induction of *A. ostoyae* centers, or stimulation of the spread of pre-existing centers would likely be due to a drastic increase in the inoculum potential as the fungus invades the cut stumps. Actual spread of the fungus to form a center would follow a delay period during which it invaded the cut stump (for this site 10 years). If the *A. ostoyae* has been 'released by' the selective harvest, this would indicate a potentially serious problem with selective harvests in areas with *A. ostoyae* infection. The stands which are prone to this type of attack would have to be identified to prevent increased losses due to thinning or selective harvesting.

3.2 Symptomology Classes

Generally the first indication of *P. weirii* and *A. ostoyae* infection in the field is the presence of single or clumped dead or symptomatic trees. Typical root disease symptoms are a decrease in height increment, rounding of the crown, crown thinning, chlorotic foliage, and often a stress crop of cones. Upon location of a tree or trees with any of these listed symptoms, confirmation of the presence and identification of the disease is important. If the tree or nearby trees are dead or windblown, the roots or root collar can be examined. In the case of *P. weirii*, red-brown staining in the root xylem, or laminar pitted rot (with brown mycelium in the pits) in the roots or butt of the tree are indicative of infection. With *A. ostoyae*, basal resinosis and the presence of mycelial fans at the root collar under the bark are positive indicators of the disease. In the case of single trees which look symptomatic but are still alive, the use of above-ground features to identify the presence of the disease is necessary. These features are covered in more detail later in this section.

There are several criteria a tree must fulfill before it can be included as diseased. These are:

- a. tree is not an understory in a very dense stand (tree is not being strongly suppressed);

- b. tree has not experienced extreme physical damage which may produce such symptomology;
- c. tree is not affected by another disease, insect or abiotic factor to the extent that symptoms present could have been caused by such pests.

4 TREE DATA

The numbers of infected trees for the three study sites tallied by species, size (height class) and infection class, are shown in Tables 2-4. Of a total of 1 759 trees infected on Kentucky Site 1, 37% were lodgepole pine, 63% Douglas-fir and less than one per cent yellow pine. On Kentucky Site 2, out of 738 infected trees, 43% were Douglas-fir, 56% lodgepole pine, and less than one per cent of spruce and yellow pine. At Nicola Site, 1 099 trees were infected, of which 87% were Douglas-fir, 13% lodgepole pine, and less than one per cent were spruce. Individual tree observations are listed in Appendices B to D. Field maps of this data are presented in Appendices E to G.

For Kentucky Site 1, the majority of infected Douglas-fir trees (57%) were in height class 1 (0-5m). Within this class, 53% were dead, and 34% light symptom severity class. Forty-four per cent of the total observed trees were dead, and 36% were light severity class. For lodgepole pine, 32% of the trees were in height class 1, of which 69% were dead. Twenty-five per cent of the lodgepole pine were in height class 2, and 42% of these were dead. Forty-five per cent of the lodgepole pine were dead, and 22% and 19% heavy and medium severity classes, respectively.

For Kentucky Site 2, 70% of the infected Douglas-fir trees were dead. Of these, 38% were in height class 1 and 33% were in height class 2. Thirty-three per cent of the Douglas-fir were in height class 1 and 28% in height class 2. For lodgepole pine, there was a stronger grouping of the data. Seventy-four per cent of the lodgepole pine were dead, and of this 21% were in height class 1, 35% in height class 2, and 21% in height class 3. The distribution of trees in height classes was more balanced with the lodgepole pine: 21%, 40%, 25% and 28% in classes 1, 2, 3 and 4, respectively.

At the Nicola Site, 87% of the Douglas-fir were dead: 68% were in height class 1 and 21% in height class 2. Sixty-four per cent of the Douglas fir were in height class 1 and 21% in height class 2. Similarly, for lodgepole pine, the majority (83%) of the trees were dead. Of these dead trees, 36% were in height class 1.

In Tables 5-7, height, age, and diameter at breast height are tabulated for sample trees from each of the three stands. Because the stands are not homogenous with respect to tree density, it is not unusual that there are variable heights and dbh's for trees of the same age. For example in Kentucky Site 1, a 49-year-old tree had a height of 6.5m and a dbh of 10cm, while a 50-year-old tree had a height of 27m and a dbh of 37cm. This variability was encountered on all three sites.

5 DEVELOPMENT OF ROOT DISEASE SAMPLING PROCEDURES

All of the three stands were all-aged and had been selectively harvested. The young trees were commonly in thickets and were in need of thinning. The presence of root disease in these stands was readily apparent. However, the extent of this infection was not easily assessed. As the distribution of trees varied between the sites and the behavior of the two diseases appeared to differ, a different sampling procedure was developed for each of the two diseases.

5.1 Laminated Root Rot

The two stands (Kentucky Site 1 and Kentucky Site 2) with laminated root rot showed a clumped distribution of infected trees. However, classic infection centers (Wallis 1976) were not always present. There were scattered and diffuse centers that precluded the use of a transect or line intercept survey method as used in coastal forests. Also for these stands the frequency of infection appeared correlated with tree density, i.e., in dense areas infection was more frequent. This might be more related to disturbance.

This variation suggested that a low intensity survey, aimed at stratifying the stand by infection levels might be useful and time saving (Demaerschalk 1986). This survey would be a 'walk through' during which any large-scale variation in infection levels would be noted. If such variation were present, the site would be stratified. Areas with very little root rot would be sampled at a low intensity, and those without or with extremely high infection might not be sampled at all. Stratification of the site requires that only areas large enough to be treated, e.g., thinned, would be delineated.

When planning a preliminary survey, every effort should be made to traverse the whole length and width of a stand. Also, any differences in stocking density and level of disturbance, possibly related to the level of infection, should be considered. Surveys would require personnel experienced in identifying root disease, and estimating the amount of infection levels. Therefore, preliminary stratifications will be limited to very obvious variations until survey personnel have extensive experience with these methods.

For areas with laminated root rot, it was assumed (Bloomberg 1986) that the most useful information from a survey would be the proportion of trees infected for each species and height class. For this information, the use of systematic fixed area or prism plots would be appropriate. Fixed-area plots could be rectangular or circular. However, rectangular plots are easier to lay out. If prism plots were used, a small basal area factor (BAF 2-6) is recommended.

A baseline should be established along an accessible edge of the stand and transects set out perpendicular to the baseline at regular intervals. Plots should be located at equal distances along these transects. Two sets of plots should be used: in the first set

which would occur more frequently, all trees would be recorded. Each tree species, height or dbh class and symptom severity class (healthy is an appropriate infection class) would be noted. In the second set of plots, fewer in number, tree height, dbh, age, species and symptom class would be recorded. The labour intensive nature of these latter plots makes it necessary to reduce sample size for feasibility. From these data, stand age and the volume of infected and non-infected standing timber by species can be determined.

Simulations of the proposed survey methods were carried out on the final maps. However, because only infected trees were recorded in the field, the accuracy of the proposed survey methods was extrapolated from the accuracy of the estimated total number of trees infected, and the proportion of trees in each height and severity class. In practice, healthy trees would be noted, and the proportions of infected trees in each height class estimated. Simulations on the Kentucky Sites were carried out using plots of 10m x 20m (200m) and 20m x 20m (400m) at the frequency of one plot per 0.4ha. One set of simulations was carried out for each of the Kentucky Sites. The results from these simulations are given in Tables 8 to 11.

Using a 10m x 20m plot yielded some good estimates for severity class totals, but they were quite variable in accuracy. For Kentucky Site 1, the Douglas-fir dead estimates were within 10%; however, the estimate for lodgepole pine medium severity class on this site was 50% too low. The height class estimates in this plot size were not very accurate. For Kentucky Site 2, the estimates for height classes 1 and 2 were both out by more than 50%. Due to the variation in these estimates this plot size would probably be inappropriate for this survey.

Using a 20m x 20m plot yielded good estimates for the total tree counts by species with one exception. In Kentucky Site 2, lodgepole pine was underestimated by over 45%. The other three estimates of total species were within five per cent. Using this size of plot, the estimates for both the totals by symptom severity class and the totals by height class were better than the smaller plot size; however, there was some variability in the accuracy of the estimates. For Kentucky Site 1, the total for the heavy severity class were within six per cent, but the estimated total for dead trees was overestimated by 30%. Overall, these estimations obtained from 20m x 20m plots appeared reasonable. This size of plot would probably be adequate for sites similar to the Kentucky Sites with respect to age class composition and distribution.

5.2 Armillaria Root Disease

At the Nicola Site, *Armillaria* root disease was also clumped. These clumps coincide with dense clumps of conifers. In the infected stand, there appeared to be a potential of resurgence of *A. ostoyae* after thinning. Hence, both the area currently occupied by *A. ostoyae*, and the proportion of each species infected (by height class) appeared to be important considerations for stand management. The possibility of a resurgence of

A. ostoyae about 10 years after a thinning suggested that a safety zone should be designated around infected trees in medium to dense clumps of trees. This was conservatively set at five metres. Trees within this zone presumably were at higher risk of infection before harvest.

In surveying root disease at the Nicola Site, there was a problem of how to record the infections between the clumps of infected trees. As the frequency of trees is low in these areas, it can be argued that it is important to know if they are infected or not. Yet as the majority of the stand volume is in the clumps of trees, these areas may be considered of little importance to stand management. The spread of *A. ostoyae* in open areas is likely to be slow or non-existent as root contacts are few and far between and the nutrient base is limited. The decision as to whether to include these areas of scattered infected trees will likely be determined by the management objectives for the stand.

We decided that the incidence of root disease could be easily recorded in the open areas but the recording of safety zones, a more time-consuming task, should only be performed in the clumped areas. A strip transect rather than plots on a transect was judged to be the most effective way of measuring the area of the stand present in clumps and the infected areas within the clumps.

For this survey, a baseline should be established along an accessible edge of the stand. Transects should be set out at equal distances along the baseline. The width of the transect strip and the spacing of transects will depend on the area to be sampled and the sampling intensity required. Along the strip transect, species, height or dbh class, and infection class of each tree (including healthy ones) should be recorded. In a series of subplots, tree height, dbh, species, infection class and age should be recorded. From these data the stand age and volume infected and healthy by species can be determined. The area of the stand with clumps of infected trees can be estimated by recording the points along the transect at which it enters and leaves a clump of infected trees. This distance between these points is calculated for each clump and the distances for all the clumps encountered are summed and compared to the total length of all the transect lines. The proportion of the line which falls within clumps represents the proportion of the stand within clumps. Similarly, the area of the clumps infected or at high risk (within five metres of an infection) by *A. ostoyae* can also be determined in this manner.

Recording data for each tree within a 10m-wide transect would be a long, tedious process. A time-saving alternative would be to determine stocking or density (by age and species) within clumps in the subplots used for age and volume measurements. Such data sampling could be combined with data from the pre-stand tending assessment. These stocking data, along with the estimate of the non-infected area within clumps, could be used to extrapolate the total number of trees by species and age class. Healthy trees would not be recorded except where they were located in infection

centers. The proportion of trees infected could be calculated using the estimated healthy tree totals.

Simulations for *Armillaria* root disease surveys at the Nicola Site were carried out on the map using the strip transect method. Ten-metre-wide strips were laid out at intervals of 50m across the baseline. All infected trees were recorded that fell within this strip. As the healthy trees were not recorded on the maps, estimates were based on the number of infected trees and their proportions of species, height classes and symptom classes. The proportion of the transect line that fell within the clumps was used to estimate the proportion of the stand which was clumped. The area infected or within five metres of a visible infection was surveyed and estimated in the same manner. The results from the two simulations are present in Tables 12 to 14. To determine the accuracy of the area estimates, the actual area of the stand in clumps was measured from the maps. The area of the clumps in high risk was also measured from the maps. A boundary of five metres was placed around all infected trees and the area within this was considered high risk.

The estimates from the strip transect simulation (Tables 12 and 13) appeared quite accurate. One estimate of total number of trees was within two per cent. This is not unusual as the simulations covered 18% and 20% of the area. The estimates of proportion of trees by species were also accurate, within three per cent. The estimates for proportions in infection classes and height classes were generally good, within 10% for the major groupings for Douglas-fir. As the population size of lodgepole pine is smaller, it is not surprising that the estimates are less accurate.

The estimates of percentage of area in clumps and in high risk in clumps were good, within 16% for the two simulations. The estimates of the area in high risk in clumps were also good, within 14% for the two simulations. This indicates a good correlation between proportion of transect distance and proportion of clumped area. If the clumps were of an irregular size, such as long and narrow, this method would likely be less accurate.

6 RESULTS

The survey methods proposed appear suitable but further simulations are recommended in order to appraise their theoretical accuracy and precision. Also these methods must be tested in the field in order to appraise their feasibility, practicality and the amount of training required. Should these methods be adopted, decisions will have to be made regarding the use of the information obtained. The level of infection at which stand tending is no longer feasible and the effects of lower levels of infection on stand tending operations are two questions which are likely to arise. To further complicate matters, the answers are likely to be different depending on which of the two root diseases is present. Of concern is the apparent association of *A. ostoyae* infection centers with cut stumps in the Nicola Site. It is quite possible that selective harvesting or thinning will exacerbate or even create root rot problems in stands with *A. ostoyae*. It may be that identification of such areas, rather than estimating the amount of *A. ostoyae* present is the more appropriate approach.

7 REFERENCES

- Bloomberg, W. 1986. Personal communication.
- Demaerschalk, J. 1986. Personal communication.
- Morrison, D.J. (1981. *Armillaria* root disease. A guide to disease, diagnosis, development and management in British Columbia. Canadian Forestry Service, Pacific Forest Research Centre, Victoria, B.C., BC-X-203.
- van der Kamp, B.J. 1986. Personal communication.
- Wallis, G.W. 1976. *Phellinus (Poria) weirii* root rot. Detection and management proposals in Douglas-fir stands. Canadian Forestry Service, Forest Technical Report 12, 16pp.

TABLE 1 HEIGHT ESTIMATES FOR FIELD CREW**John Schulting**

$$\text{actual height} = 0.38335 + 0.85726 (\text{height estimate})$$

Actual Height Class (m)	Modified Height Class (m)
0 - 5	0 - 6.3
5 - 10	6.3 - 12.1
10 - 15	12.1 - 18.0
15 - 20	18.0 - 23.8
20 - 25	23.8 - 29.6
25 - 30	29.6 - 35.4
30 - 35	35.4 - 41.3

Tim Bekhuys

$$\text{actual height} = 0.69196 + 0.86342 (\text{height estimate})$$

Actual Height Class (m)	Modified Height Class (m)
0 - 5	0 - 5.0
5 - 10	5.0 - 10.8
10 - 15	10.8 - 16.6
15 - 20	16.6 - 22.4
20 - 25	22.4 - 28.2
25 - 30	28.2 - 33.9
30 - 35	33.9 - 39.7

TABLE 2 TREE DATA FOR KENTUCKY SITE 1**Douglas-fir**

	Height Class (5m classes)							
Infection Class	1	2	3	4	5	6	7	Totals for Infection Classes
• Dead	333	87	21	24	15	10	-	490
• Heavy	34	23	10	17	11	12	-	107
• Medium	52	15	15	12	5	4	-	103
• Light	212	58	51	26	31	19	-	397
• Healthy	-	1	-	-	4	-	-	5
Total for Height Classes	631	183	98	79	66	45	-	Total Trees 1 102

Lodgepole Pine

	Height Class							
Infection Class	1	2	3	4	5	6	7	Totals for Infection Classes
• Dead	145	70	33	32	11	4	-	295
• Heavy	37	49	25	21	10	4	-	146
• Medium	18	28	34	29	12	2	-	123
• Light	9	12	24	28	9	3	-	85
• Healthy	-	-	2	1	1	-	-	4
Total for Height Classes	209	165	118	111	43	13	-	Total Trees 653

Yellow Pine and Spruce

Yellow Pine: dead 1; medium 2; 2 light 6:

TABLE 3 TREE DATA FOR KENTUCKY SITE 2**Douglas-fir**

	Height Class (5m classes)							
Infection Class	1	2	3	4	5	6	7	Totals for Infection Classes
• Dead	112	96	41	18	16	10	2	295
• Heavy	1	2	10	1	9	3	3	29
• Medium	10	10	6	2	8	3	6	45
• Light	4	11	12	4	4	3	4	42
• Healthy	13	-	-	-	-	-	-	13
Total for Height Classes	140	119	69	25	37	19	15	Total Trees 424

Lodgepole Pine

	Height Class							
Infection Class	1	2	3	4	5	6	7	Totals for Infection Classes
• Dead	50	84	52	40	5	10	1	242
• Heavy	1	7	3	10	6	2	-	29
• Medium	1	4	4	14	10	5	2	40
• Light	-	1	2	3	2	2	1	11
• Healthy	-	-	-	1	2	-	-	3
Total for Height Classes	52	96	61	68	25	19	4	Total Trees 325

Yellow Pine and Spruce

Yellow Pine: 1 dead 6; 1 dead 7; 1 heavy 5

Spruce: 1 dead 1; 1 dead 4

4 *Armillaria ostoyae*-infected trees

TABLE 4 TREE DATA FOR NICOLA SITE**Douglas-fir**

	Height Class (5m classes)							
Infection Class	1	2	3	4	5	6	7	Totals for Infection Classes
• Dead	570	175	50	24	14	3	1	837
• Heavy	5	8	2	1	1	-	-	17
• Medium	21	7	3	5	-	-	-	36
• Light	23	13	14	8	8	-	1	67
• Healthy	-	-	1	1	1	-	-	3
Total for Height Classes	619	203	70	39	24	3	2	Total Trees 960

Lodgepole Pine

	Height Class							
Infection Class	1	2	3	4	5	6	7	Totals for Infection Classes
• Dead	44	21	17	18	14	-	-	114
• Heavy	1	1	2	2	-	-	-	6
• Medium	3	-	1	3	1	-	-	8
• Light	2	-	3	1	3	-	-	9
• Healthy	-	-	-	-	1	-	-	1
Total for Height Classes	50	22	23	24	19	-	-	Total Trees 138

Yellow Pine and Spruce

Spruce: 4 dead 1; 1 dead 4

TABLE 5 AGE, HEIGHT AND DBH FOR KENTUCKY SITE 1

Douglas-fir			Lodgepole Pine		
Age	Height (m)	DBH (cm)	Age	Height (m)	DBH (cm)
18	4.1	6.0	18	7.3	10.0
19	4.1	4.0	29	6.5	12.5
20	5.0	6.0	30	4.7	8.5
23	3.0	5.0	34	9.3	10.0
23	5.0	6.0	36	7.6	11.0
24	5.0	7.0	36	9.9	9.5
25	4.3	8.0	37	15.9	17.5
27	5.8	7.0	38	15.9	14.5
28	4.7	6.5	39	16.7	13.0
31	5.0	7.0	41	11.0	18.0
32	6.7	8.0	42	8.6	10.0
33	6.7	8.0	49	9.3	15.0
34	9.5	14.0	54	12.5	11.5
42	15.9	15.0	75	7.6	13.0
43	13.0	16.5	106	14.2	16.0
49	6.5	10.0			
50	27.0	37.0			
51	15.9	15.0			
63	14.6	23.0			
71	17.0	28.0			
74	15.3	13.0			
75	15.3	14.0			
77	13.7	14.0			
85	21.3	29.0			
107	27.9	48.0			
111	27.9	40.0			
111	27.9	38.0			

TABLE 6 AGE, HEIGHT AND DBH FOR KENTUCKY SITE 2

Douglas-fir			Lodgepole Pine		
Age	Height (m)	DBH (cm)	Age	Height (m)	DBH (cm)
16	5.9	5.0	16	6.7	10.0
16	5.0	8.0	19	6.5	4.5
31	5.9	6.0	27	8.2	9.0
34	5.9	6.0	31	14.6	8.0
34	8.2	4.5	36	10.7	10.0
34	6.0	5.0	40	16.7	11.5
35	9.9	9.0	41	12.0	7.5
37	6.9	9.0	42	15.9	9.0
37	12.5	19.0	42	9.0	8.5
40	11.9	16.0	44	16.7	14.5
44	17.1	23.0	54	12.8	10.0
44	16.7	13.0	60	19.7	17.0
53	9.5	10.0	67	21.9	22.0
57	16.7	21.0	71	17.6	19.0
61	21.0	34.0	84	16.2	17.0
71	27.9	44.0	86	14.5	16.0
79	15.4	22.0	86	18.8	23.0
86	14.5	16.0	88	17.1	24.0
120	32.0	58.0	98	24.9	30.0
			109	31.0	51.0

TABLE 7 AGE, HEIGHT AND DBH FOR NICOLA SITE

Douglas-fir			Lodgepole Pine		
Age	Height (m)	DBH (cm)	Age	Height (m)	DBH (cm)
12	3.5	4.5	10	6.5	9.0
17	12.5	16.5	19	11.6	15.0
18	5.0	5.0	43	11.9	18.0
21	6.7	9.0	49	14.5	20.0
22	5.9	8.0	50	11.9	11.0
22	11.6	11.5	53	12.8	11.0
23	6.0	8.5	71	21.0	18.5
32	11.1	10.0	88	16.7	17.0
34	6.7	12.0			
40	9.3	14.0			
41	10.7	17.0			
41	6.5	10.0	Spruce		
43	5.6	8.0			
43	6.7	7.0	61	9.0	13.5
44	5.6	8.0			
44	12.8	15.0			
45	10.2	9.0			
58	26.0	52.0			
60	11.9	21.0			
73	14.2	21.0			
76	11.6	12.5			
82	12.8	23.0			
87	9.3	12.0			
92	20.2	32.0			
122	25.3	44.0			
148	19.3	35.0			

TABLE 8 SIMULATION 1: KENTUCKY SITE 1
(10m x 20m Plots; 1 Plot per 0.4ha)

Douglas-fir

	Height Class (5m classes)															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	269	(333)	62	(87)	103	(21)	62	(24)	-	(15)	41	(10)	-	-	537	(490)
• Heavy	-	(34)	-	(23)	41	(10)	21	(17)	-	(11)	21	(12)	-	-	83	(107)
• Medium	-	(52)	21	(15)	-	(15)	-	(12)	-	(5)	-	(4)	-	-	21	(103)
• Light	207	(212)	41	(58)	41	(51)	41	(26)	62	(31)	41	(19)	-	-	433	(397)
• Healthy	-	-	-	(1)	-	-	-	-	21	(4)	-	-	-	-	21	(5)
Total for Height Classes															Total Trees	
	476	(631)	124	(183)	185	(98)	124	(79)	83	(66)	103	(45)	-	-	1 095	(1 102)

Lodgepole Pine

	Height Class															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	165	(145)	103	(70)	41	(33)	21	(32)	-	(11)	21	(4)	-	-	351	(295)
• Heavy	-	(37)	41	(49)	41	(25)	62	(21)	-	(10)	-	(4)	-	-	144	(146)
• Medium	-	(18)	41	(28)	-	(34)	21	(29)	-	(12)	-	(2)	-	-	62	(123)
• Light	21	(9)	62	(12)	41	(24)	21	(28)	-	(9)	-	(3)	-	-	145	(85)
• Healthy	-	-	-	-	-	(2)	-	(1)	21	(1)	-	-	-	-	21	(4)
Total for Height Classes															Total Trees	
	186	(209)	247	(165)	123	(118)	125	(111)	21	(43)	21	(13)	-	-	723	(653)

Yellow Pine and Spruce

Numbers given are estimates from simulation.
 Actual numbers of trees in brackets.

TABLE 9 SIMULATION 2: KENTUCKY SITE 1
(20m x 20m Plots; 1 Plot per 0.4ha)

Douglas-fir

	Height Class (5m classes)															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	269	(333)	72	(87)	52	(21)	72	(24)	-	(15)	52	(10)	-	-	517	(490)
• Heavy	10	(34)	31	(23)	21	(10)	10	(17)	-	(11)	10	(12)	-	-	82	(107)
• Medium	41	(52)	21	(15)	-	(15)	-	(12)	-	(5)	-	(4)	-	-	62	(103)
• Light	217	(212)	62	(58)	31	(51)	21	(26)	31	(31)	31	(19)	-	-	393	(397)
• Healthy	-	-	-	(1)	-	-	-	-	21	(4)	-	-	-	-	21	(5)
Total for Height Classes															Total Trees	
	537	(631)	186	(183)	104	(98)	103	(79)	52	(66)	93	(45)	-	-	1 075	(1 102)

Lodgepole Pine

	Height Class															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	165	(145)	145	(70)	21	(33)	31	(32)	10	(11)	10	(4)	-	-	382	(295)
• Heavy	21	(37)	41	(49)	41	(25)	31	(21)	-	(10)	-	(4)	-	-	134	(146)
• Medium	-	(18)	21	(28)	10	(34)	10	(29)	-	(12)	-	(2)	-	-	41	(123)
• Light	10	(9)	31	(12)	31	(24)	21	(28)	-	(9)	-	(3)	-	-	93	(85)
• Healthy	-	-	-	-	21	(2)	-	(1)	10	(1)	-	-	-	-	31	(4)
Total for Height Classes	196	(209)	238	(159)	124	(118)	93	(111)	20	(43)	10	(13)	-	-	Total Trees	
															681	(653)

Yellow Pine and Spruce

Numbers given are estimates from simulation.
 Actual numbers of trees in brackets.

TABLE 10 SIMULATION 3: KENTUCKY SITE 2
(10m x 20m Plots; 1 Plot per 0.4ha)

Douglas-fir

	Height Class (5m classes)															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	60	(112)	120	(96)	40	(41)	-	(18)	-	(16)	20	(10)	-	(2)	240	(295)
• Heavy	-	(1)	-	(2)	-	(10)	-	(1)	20	(9)	-	(3)	-	(3)	20	(29)
• Medium	-	(10)	80	(10)	-	(6)	-	(2)	-	(8)	-	(3)	-	(6)	80	(45)
• Light	-	(4)	60	(11)	-	(12)	-	(4)	-	(4)	-	(3)	-	(4)	60	(42)
• Healthy	-	(13)	-	-	-	-	-	-	-	-	-	-	-	-	-	(13)
Total for Height Classes	60	(140)	260	(119)	40	(69)	-	(25)	20	(37)	20	(19)	-	(15)	Total Trees	
															400	(424)

Lodgepole Pine

	Height Class															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	20	(50)	60	(84)	20	(52)	-	(40)	-	(5)	-	(10)	-	(1)	100	(242)
• Heavy	-	(1)	-	(7)	-	(3)	60	(10)	20	(6)	-	(2)	-	-	80	(29)
• Medium	-	(1)	-	(4)	-	(4)	-	(14)	-	(10)	-	(5)	-	(2)	-	(40)
• Light	-	-	-	(1)	-	(2)	-	(3)	-	(2)	-	(2)	-	(1)	-	(11)
• Healthy	-	-	-	-	-	-	-	(1)	-	(2)	-	-	-	-	-	(3)
Total for Height Classes	20	(52)	60	(96)	20	(61)	60	(68)	20	(25)	-	(19)	-	(4)	Total Trees	
															180	(325)

Yellow Pine and Spruce

Numbers given are estimates from simulation.
 Actual numbers of trees in brackets.

TABLE 11 SIMULATION 4: KENTUCKY SITE 2
(20m x 20m Plots; 1 Plot per 0.4ha)

Douglas-fir

	Height Class (5m classes)															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	120	(112)	110	(96)	40	(41)	10	(18)	-	(16)	10	(10)	-	(2)	290	(295)
• Heavy	-	(1)	-	(2)	-	(10)	-	(1)	10	(9)	10	(3)	-	(3)	20	(29)
• Medium	-	(10)	40	(10)	-	(6)	-	(2)	-	(8)	-	(3)	-	(6)	40	(45)
• Light	20	(4)	30	(11)	20	(12)	10	(4)	-	(4)	-	(3)	-	(4)	80	(42)
• Healthy	-	(13)	-	-	-	-	-	-	-	-	-	-	-	-	-	(13)
Total for Height Classes															Total Trees	
	140	(140)	180	(119)	60	(69)	20	(25)	10	(37)	20	(19)	-	(15)	430	(424)

Lodgepole Pine

	Height Class															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	50	(50)	30	(84)	10	(52)	10	(40)	-	(5)	-	(10)	-	(1)	100	(242)
• Heavy	-	(1)	-	(7)	-	(3)	60	(10)	10	(6)	-	(2)	-	-	70	(29)
• Medium	-	(1)	-	(4)	-	(4)	-	(14)	-	(10)	-	(5)	-	(2)	-	(40)
• Light	-	-	-	(1)	-	(2)	-	(3)	-	(2)	-	(2)	-	(1)	-	(11)
• Healthy	-	-	-	-	-	-	-	(1)	-	(2)	-	-	-	-	-	(3)
Total for Height Classes	50	(52)	30	(96)	10	(61)	70	(68)	10	(25)	-	(19)	-	(4)	Total Trees	
															170	(325)

Yellow Pine and Spruce

Numbers given are estimates from simulation.
 Actual numbers of trees in brackets.

TABLE 12 SIMULATION 5: NICOLA SITE
(10m x 1 807m Strip)

Douglas-fir

	Height Class (5m classes)															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	686	(570)	194	(175)	17	(50)	28	(24)	-	(14)	-	(3)	-	(1)	925	(837)
• Heavy	-	(5)	-	(8)	-	(2)	-	(1)	-	(1)	-	-	-	-	-	(17)
• Medium	11	(21)	6	(7)	-	(3)	-	(5)	-	-	-	-	-	-	17	(36)
• Light	11	(23)	-	(13)	11	(14)	-	(8)	11	(8)	-	-	-	(1)	33	(67)
• Healthy	-	-	-	-	-	(1)	-	(1)	-	(1)	-	-	-	-	-	(3)
Total for Height Classes															Total Trees	
	708	(619)	200	(203)	28	(70)	28	(39)	11	(24)	-	(3)	-	(2)	975	(960)

Lodgepole Pine

	Height Class															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	11	(44)	33	(21)	11	(17)	22	(18)	17	(14)	-	-	-	-	94	(114)
• Heavy	-	(1)	-	(1)	6	(2)	6	(2)	-	-	-	-	-	-	12	(6)
• Medium	-	(3)	-	-	-	(1)	-	(3)	-	(1)	-	-	-	-	-	(8)
• Light	-	(2)	-	-	-	(3)	6	(1)	-	(3)	-	-	-	-	6	(9)
• Healthy	-	-	-	-	-	-	-	-	-	(1)	-	-	-	-	-	(1)
Total for Height Classes	11	(50)	33	(22)	17	(23)	34	(24)	17	(19)	-	-	-	-	Total Trees	
															112	(138)

Yellow Pine and Spruce

Numbers given are estimates from simulation.
 Actual numbers of trees in brackets.

TABLE 13 SIMULATION 6: NICOLA SITE
(10m x 2 010m Strip)

Douglas-fir

	Height Class (5m classes)															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	512	(570)	199	(175)	55	(50)	20	(24)	40	(14)	10	(3)	-	(1)	836	(837)
• Heavy	15	(5)	-	(8)	5	(2)	-	(1)	15	(1)	-	-	-	-	35	(17)
• Medium	10	(21)	-	(7)	-	(3)	5	(5)	-	-	-	-	-	-	15	(36)
• Light	35	(23)	10	(13)	10	(14)	10	(8)	10	(8)	-	-	5	(1)	80	(65)
• Healthy	-	-	-	-	-	(1)	-	(1)	10	(1)	-	-	-	-	10	(3)
Total for Height Classes	572	(619)	209	(203)	70	(70)	35	(39)	75	(24)	10	(3)	5	(2)	Total Trees	
															976	(958)

Lodgepole Pine

	Height Class															
Infection Class	1		2		3		4		5		6		7		Totals for Infection Classes	
• Dead	35	(44)	5	(21)	10	(17)	30	(18)	20	(14)	-	-	-	-	100	(114)
• Heavy	5	(1)	5	(1)	-	(2)	10	(2)	-	-	-	-	-	-	20	(6)
• Medium	5	(3)	-	-	-	(1)	-	(3)	-	(1)	-	-	-	-	5	(8)
• Light	-	(2)	-	-	5	(3)	-	(1)	-	(3)	-	-	-	-	10	(9)
• Healthy	-	-	-	-	-	-	-	-	5	(1)	-	-	-	-	5	(1)
Total for Height Classes	45	(50)	10	(22)	15	(23)	40	(24)	30	(19)	-	-	-	-	Total Trees	
															140	(138)

Yellow Pine and Spruce

Numbers given are estimates from simulation.
 Actual numbers of trees in brackets.

**TABLE 14 NICOLA SITE: PERCENTAGES OF AREA IN CLUMPS
AND IN HIGH RISK AREAS OF CLUMPS**

Area in clumps	= 29.9% (2.99ha)
Area of clumps in high risk	= 66.0% (1.97ha)

Simulation 7: Nicola Site (Line Intercept Estimation)

Estimate of area in clumps	= 25.0% (2.5ha)
Estimate of area of clumps in high risk	= 68.0% (1.7ha)

Simulation 8: Nicola Site (Line Intercept Estimation)

Estimate of area in clumps	= 34.0% (3.4ha)
Estimate of area of clumps in high risk	= 65.4% (2.2ha)