Multistage sampling technique to assess Root disease impact

on the Clearwater and Nezperce N.F.

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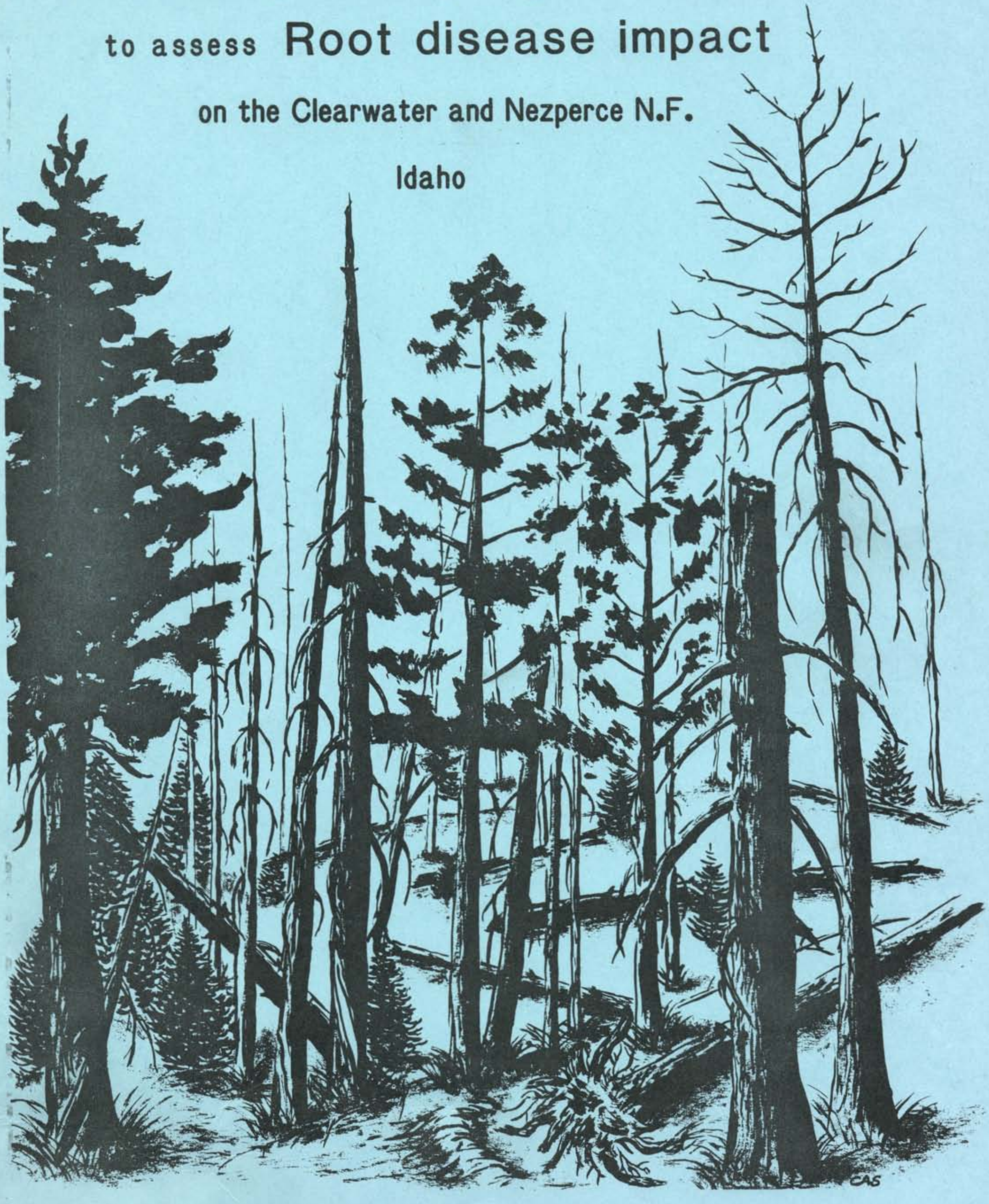

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A MULTI-STAGE SAMPLING TECHNIQUE TO ASSESS ROOT DISEASE IMPACT ON THE CLEARWATER AND NEZPERCE NATIONAL FORESTS, IDAHO

by

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ABSTRACT

A multi-stage sampling technique, having selection based on probability proportional to size, was used to determine root disease losses on the Nezperce and Clearwater National Forests in northern Idaho. This technique used large-scale aerial transparencies of standard timber inventory subcompartments and compared frequency of root disease mortality found on the photographs with that from ground surveys. About 35 percent of tree mortality on both Forests was associated with root diseases. About 2.2 trees/ha and 0.4 trees/ha, respectively, were lost annually due to root diseases on the Nezperce and Clearwater National Forests. Root pathogens frequently found were *Armillaria mellea*, *Phaeolus schweinitzii*, *Phellinus weirii*, and *Fomes annosus*. Many root-diseased trees were also attacked by bark beetles. This technique of root disease survey needs refinement to reduce errors and thereby improve accuracy of loss estimates.

INTRODUCTION

Root diseases cause long-term management problems within many forests of the Northern Region. Previous estimates of root disease impact (James and Stewart 1981; Williams and Leaphart 1978) were based on amount of commercial forest land occupied by large active root disease centers determined from aerial photographs. However, these estimates failed to include root disease mortality outside large centers. They also did not estimate amount of tree mortality and associated volume losses. Therefore, we designed a comprehensive survey to estimate root disease-associated tree mortality and volume losses as well as total area of disease-infested forests. This survey design was tested on the Clearwater and Nezperce National Forests in northern Idaho during 1981.

MATERIALS AND METHODS

Our survey was based on a three-stage variable probability sampling design using forest timber inventory subcompartments as primary sample units (Barnard 1978). This enabled us to use previously acquired qualitative and quantitative stand information from the subcompartments (Stage and Alley 1972). Within each subcompartment, stands were delineated by photo interpretation classes based on stand height, texture, and stocking; several of these subcompartments were previously inventoried using standard Northern Region procedures. Stands delineated within subcompartments served as secondary sample units for our survey.

Transparent overlay grids (fig. 1) were used to sample approximately 25 percent of the area within each stand. The overlay outlined 0.4 ha (1 acre) cells (tertiary sample units) on the photos.

Large scale (1:4,000) photography was taken of the inventoried subcompartments on both the Clearwater and Nezperce National Forests during August 1980. Kodak Ektachrome infrared aerochrome film (type 2443) was used; areas were photographed with a Fairchild T-12 camera equipped with a 30.5 cm (12 inches) focal length lens. Flight lines were arranged with approximately 30 percent sidelap and 60 percent endlap on each frame interval.

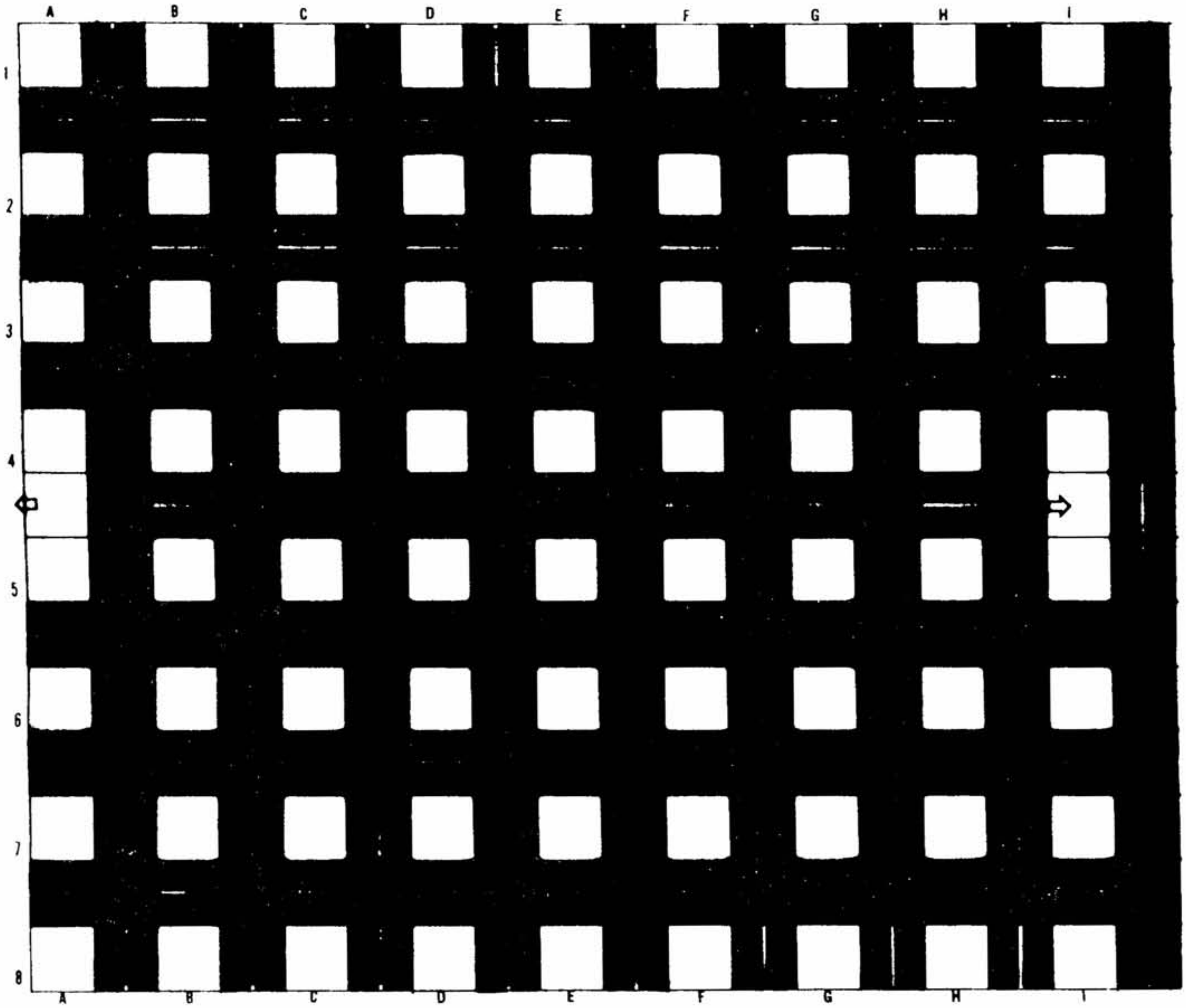

Figure 1.--Grid with 0.4 ha (1 acre) cells that served as tertiary sample units.

Twenty-four subcompartments on the Nezperce National Forest and 30 subcompartments on the Clearwater National Forest were surveyed for root diseases (figs. 2 and 3). Inventory subcompartments not included were either within a designated wilderness, contained poorly stocked, non-commercial stands, or had inadequate photo coverage. Subcompartments ranged in size from 93.1 ha (230 acres) to 228.7 ha (565 acres) with an average of 173.7 ha (429 acres).

Surveyed subcompartments and stands within them were delineated on the transparencies and interpreted for tree mortality. A Bausch and Lomb stereo interpretation system 95 was used for photo interpretation (fig. 4).

Dead trees within cells were placed into one of four categories: (1) current root disease-caused mortality, (2) current mortality not associated with root diseases, (3) past root disease-caused mortality, and (4) past mortality not associated with root disease. Current mortality included recently fading trees with bright yellow foliage. Snags and faders, pale or red in color, were classified as past mortality. Root-diseased trees were distinguished by their sparse foliage, chlorotic crowns, and proximity to suspected disease centers. Counts of dead trees found in the 0.4 ha cells were expanded to give estimates for stands and subcompartments for each mortality class. These expanded mortality counts were used for ground check plot selection.

Subcompartments to be ground checked were selected by probability proportional to size (PPS) sampling (Cochran 1963). In PPS sampling, selection of sample units is based on frequency or size of units. In this case, old root disease mortality, extrapolated from the 0.4 ha cells, was used as the selection criterion. Nine subcompartments were selected for ground checking on the Nezperce National Forest and seven subcompartments on the Clearwater National Forest (figs. 2 and 3). Within each subcompartment, two stands were selected by PPS; within each selected stand, two cells were similarly chosen for on-the-ground survey. Selected cells were then identified on the transparency and their boundaries scribed on the emulsion side of the film (fig. 5). All sampled subcompartments were also photo interpreted for possible root disease mortality not directly associated with probable disease centers. Areas with consistent scattered tree mortality (at least three trees per ha)were delineated on transparencies and expanded using previously described techniques (James and Stewart 1981; Williams and Leaphart 1978) to obtain forest-wide estimates of root disease-infested area.

Cells were located on the ground using small-scale resource photography and our color infrared transparencies with the aid of a field stereo viewer and an Abrams CB-1 stereoscope (fig. 6). Approximate cell corners were marked with flagging and boundaries were delineated with string. All dying and standing dead trees (not broken off) within cell boundaries were tallied by species and marked with logging crayon to prevent double counting. Each tallied tree was measured (diameter at breast height)

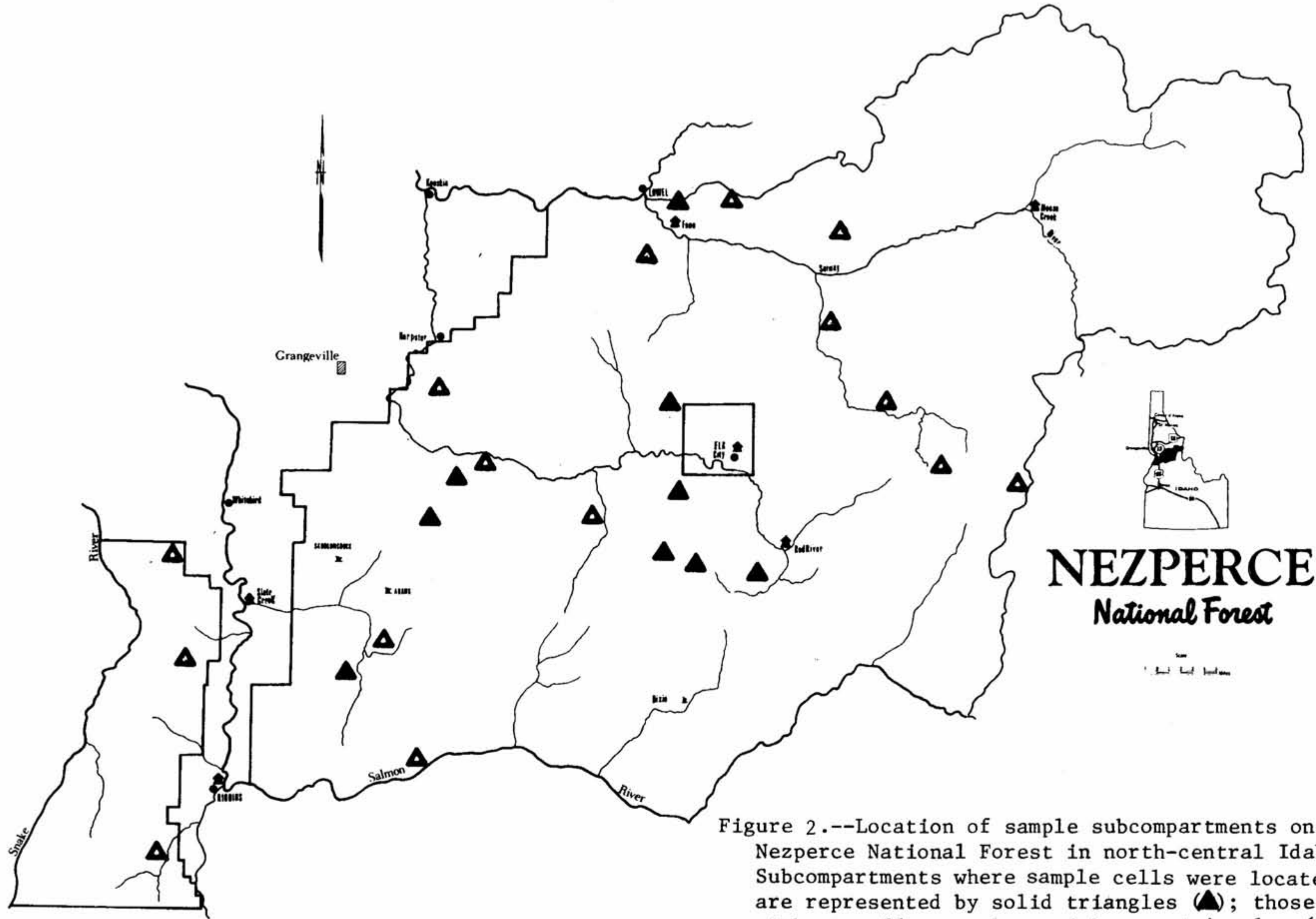

Figure 2.--Location of sample subcompartments on the Nezperce National Forest in north-central Idaho. Subcompartments where sample cells were located are represented by solid triangles (▲); those without cells are shown with open triangles (△).

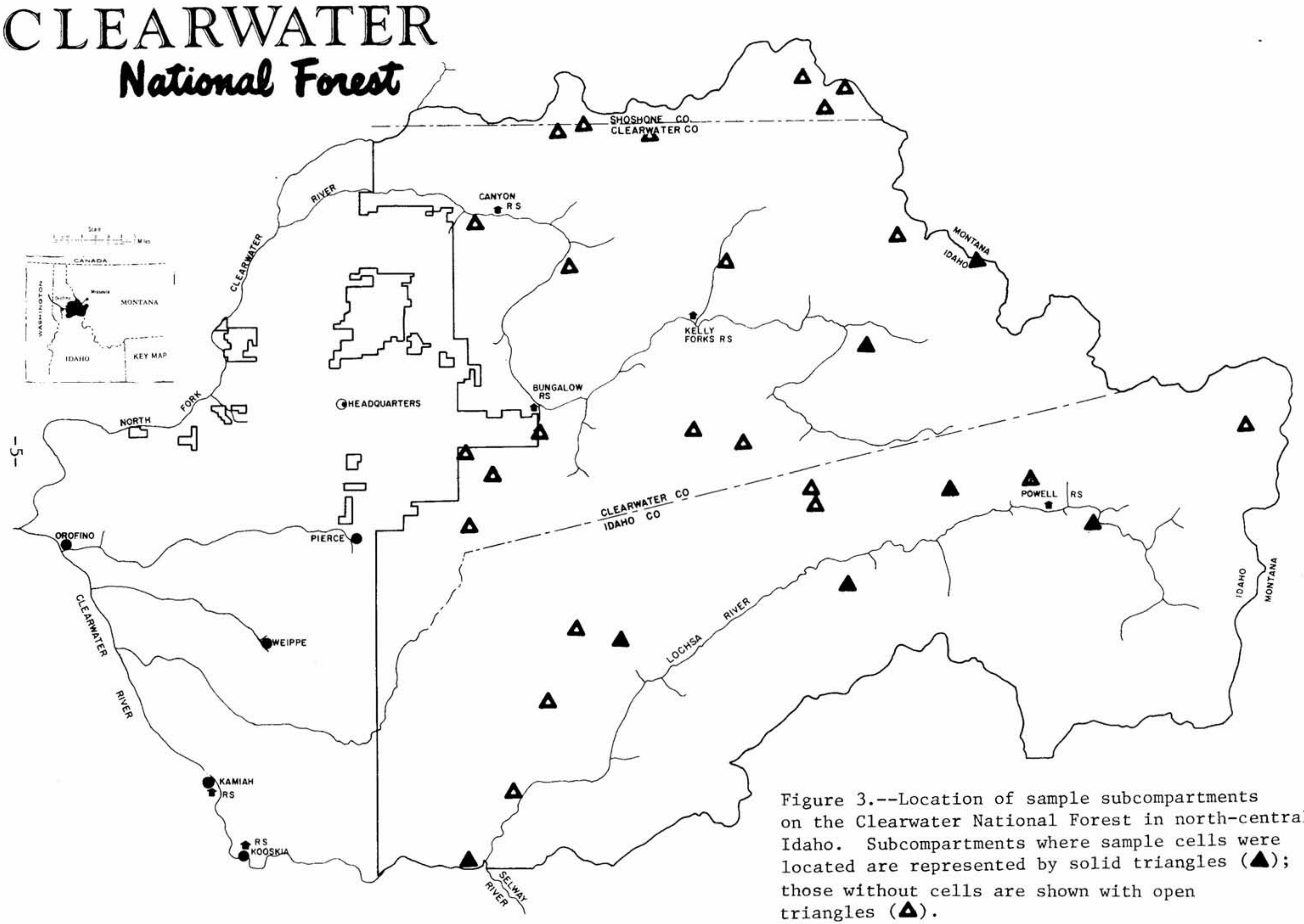

Figure 3.--Location of sample subcompartments on the Clearwater National Forest in north-central Idaho. Subcompartments where sample cells were located are represented by solid triangles (▲); those without cells are shown with open triangles (△).

Figure 4.--Bausch and Lomb zoom stereoscope used for photo interpretation.

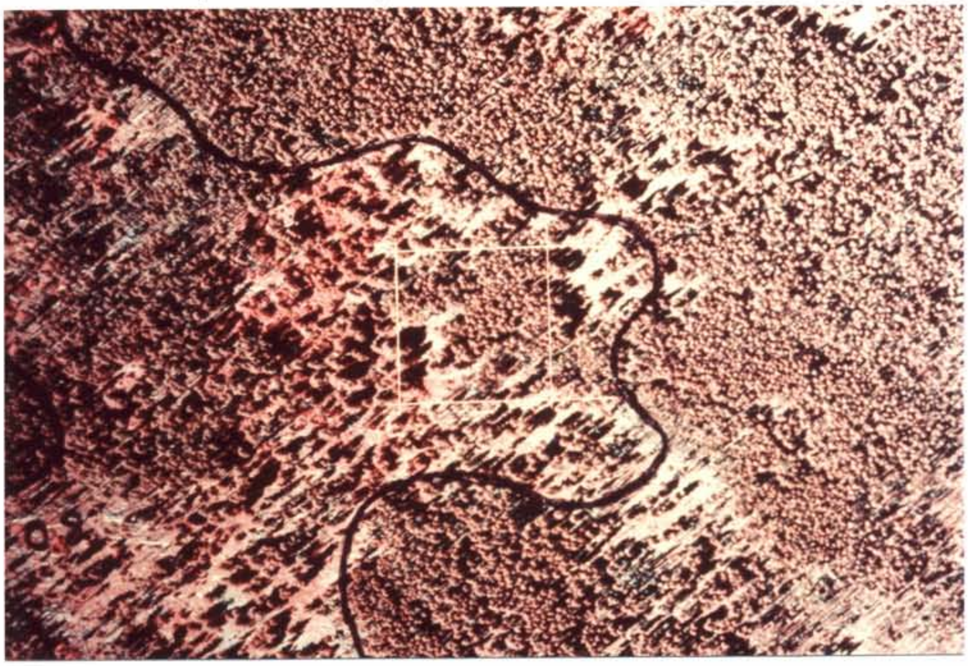

Figure 5.--Cell for ground checking delineated on 1:4,000 color infrared transparency. Stand boundaries are also outlined.

and assigned a damage code. [1/] Crown class and percent of live crown were also noted for current mortality. Aspect, elevation, position on slope, and forest habitat type were recorded for each surveyed cell, and one side boundary was measured on the ground for photo scale adjustment.

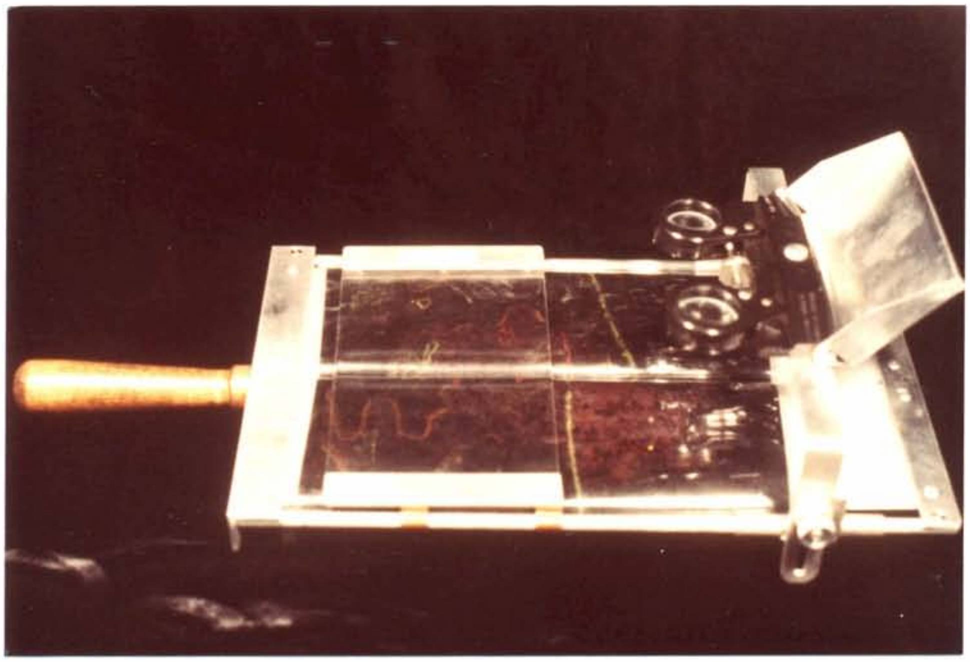

Figure 6.--Photo field viewer used in conjunction with the Abrams CB-1 stereoscope for field delineation of 0.4 ha cells to be surveyed for incidence of root disease damage.

Each dead or dying tree was examined for symptoms typical of root disease including thin crown, chlorotic foliage, and excessive cone production. Proximity to nearby root disease centers was also noted. Suspected root-diseased trees were examined more closely by exposing the cambium and sapwood at the root collar and at least one lateral root. Evidence of root disease such as mycelial fans, resin streaking, wood staining, and decay was noted. Evidence of bark beetle attacks was also recorded. If pathogens could not be identified in the field, wood samples were collected for laboratory isolation of fungi.

1/ Damage codes are defined in the Northern Region's Forest Insect and Disease Damage Survey System (Bousfield 1980) and indicate degree of damage, individual pest responsible, and approximate time of mortality. Codes are described in the appendix.

Data collected from on-the-ground surveys were used in expansion formulas to obtain total Forest estimates. Total number of trees per hectare in each mortality class was calculated. An estimate of the total number of trees killed by root disease was obtained by multiplying per hectare estimates by the total commercial area of each Forest. These Forest-wide estimates included current root disease mortality, older root disease mortality, and total mortality from all causes. Volume loss estimates for each mortality class were projected using volume tables from the Northern Region's Timber Sale Preparation Handbook (FSH 2409.21). Volume estimates were accumulated by mortality class and expanded in the same manner as number of trees. Standard errors were calculated for each mortality class. Correlation coefficients comparing numbers of trees from photo interpretation with those from ground surveys were also calculated. Percentage of total tree mortality associated with root diseases was also calculated.

RESULTS AND DISCUSSION

We estimate current tree mortality associated with root disease at about 762,000 trees for the Nezperce National Forest and 49,000 trees for the Clearwater National Forest (tables 1 and 2). Root diseases account for about 35 percent of all estimated mortality for both Forests. Root disease caused mortality also accounts for more than 825,000 m^3 (2,900 M ft^3) of the current volume loss within commercial forest stands on the Nezperce National Forest. Current root disease volume losses for the Clearwater National Forest are estimated at about 8,000 m^3 (284 M ft^3). Root diseases account for approximately 26 percent and 33 percent of all estimated volume loss on the Nezperce and Clearwater National Forests, respectively.

Unit area loss estimates for the Nezperce National Forest are 1.9 trees/ha/yr (0.8 trees/A/yr) and 2.1 m^3/ha/yr (29.6 ft^3/A/yr); estimates for the Clearwater are 0.1 trees/ha/yr (0.04 trees/A/yr) and 0.02 m^3/ha/yr (0.23 ft^3/A/yr). These values likely underestimate the amount of root disease present. For example, Wallace and Bloomberg (1981) recently found that about half of the number of root-diseased trees could be determined from above ground indicators. Therefore, many root-diseased trees were probably undetected during our survey.

Correlation coefficients (r), measuring degree of association between photo interpretations and ground surveys for the Nezperce National Forest, were 0.66 for total mortality and 0.58 for root disease mortality; those for the Clearwater were 0.64 and 0.10 for total mortality and root disease mortality, respectively. This poor correlation between photo and ground counts and the relatively large standard errors for estimated mortality (tables 1 and 2) were probably due to errors in accurately interpreting photos for root disease mortality and accurately detecting root disease on the ground. For example, it was difficult to establish cause of tree death from the photographs when mortality was not associated with distinct root disease centers. This was especially difficult on the Clearwater National Forest where extensive mortality due to white pine blister rust (*Cronartium ribicola* Fisch.) was commonly found. Scattered root disease mortality often resembled blister rust mortality and was interpreted as such. Root disease centers within the

Table 1.--Estimates of annual conifer mortality associated with root diseases on the Nezperce National Forest.

Mortality class 1/	Total no. trees (thousands)		Standard error	Trees/ ha 2/	Volume (thousand m^3)		Standard error	Volume/ ha (m^3) 2/
Current root disease	761.7	±	275.2	1.9	825.1	±	342.8	2.1
Past root disease	11,505.3	±	5,315.2	28.9	3,650.7	±	3,072.8	9.2
Total 3/ mortality	34,028.0	±	11,174.2	85.3	17,428.8	±	5,510.1	43.7

1/ Current root disease includes trees with red foliage that were killed within the past year. Past root disease includes trees without foliage but still standing. Total mortality accounts for all causes of mortality.
2/ Values are for commercial forest only (398,742 ha).
3/ All root disease associated mortality (current and past) represents 36 percent of total tree mortality and 26 percent of total volume loss.

Table 2.--Estimates of annual conifer mortality associated with root diseases on the Clearwater National Forest.

Mortality class 1/	Total no. trees (thousands)		Standard error	Trees/ ha 2/	Volume (thousand m^3)		Standard error	Vol./ha/ (m^3) 2/
Current root disease	49.2	±	46.9	0.1	8.0	±	5.3	0.02
Past root disease	3,257.9	±	1,863.3	6.6	2,293.4	±	1,037.9	4.7
Total 3/ mortality	9,460.9	±	2,035.2	19.2	6,925.7	±	843.4	14.1

1/ Current root disease includes trees with red foliage that were killed within the past year. Past root disease includes trees without foliage but still standing. Total mortality accounts for all causes of mortality.
2/ Values are for commercial forest only (49,156 ha).
3/ All root disease (current and old) represents 35 percent of the total tree mortality and 26 percent of the total volume loss.

Clearwater National Forest were usually small in size (fig. 7) and difficult to detect on photos, whereas centers were usually larger and therefore easier to detect on the Nezperce National Forest.

Figure 7.--Typical root disease center on the Clearwater National Forest.

Another problem was that a substantial number of older snags resulting from root disease infection were not visible on the photos. This was especially common in uneven-aged stands where many snags were completely obscured by the canopy of larger overstory trees. Also, current root disease mortality was difficult to correlate because of the 1-year delay between aerial photography and ground data collection.

Inadequate diagnosis of root disease on the ground to correlate with photo estimates was another major problem. Field crews had problems identifying some root pathogens; time constraints also limited the amount of lateral root excavations possible for pathogen identification. If common root pathogen indicators, such as mycelial fans, were not encountered at the root crown, then root diseases were often excluded as a possible mortality factor. Many root-diseased trees may, therefore, have been classified as other or unknown mortality.

High sampling errors in this survey may be due to problems of identifying cause of mortality from aerial photographs, including omission errors during interpretation, and relatively small ground sample sizes necessary because of budget and time constraints. However, the information is valuable in establishing the relative importance of root diseases as a mortality factor within both Forests.

Our mortality estimates for the Nezperce National Forest were much higher than similar estimates made in 1973 by Timber Management (Forest Inventory System - FINSYS). For example, our figures for annual root disease mortality were 290 M m^3 (10.3 MM ft^3) higher than the FINSYS estimate for total mortality. On the other hand, our mortality estimates for the Clearwater National Forest were 88 M m^3 (3,108 M ft^3) lower than the FINSYS estimates. We suspect that problems explained above, especially confusion with detecting blister rust mortality on photos, were responsible for these discrepancies.

Since our estimate for current root disease mortality reflects only a 1-year sample, we calculated what the "average" annual losses would likely be by using the following procedure. Current root disease mortality and past root disease mortality were added together and divided by 15, the average number of years dead trees are thought to remain standing and be detectable from aerial photographs. Using this technique, we obtained values of 2.0 trees/ha/yr and 0.8 m^3/ha/yr associated with root disease mortality on the Nezperce National Forest and 0.5 trees/ha/yr and 0.3 m^3/ha/yr on the Clearwater National Forest. These estimates are higher than the current mortality figures listed in tables 1 and 2 and may be more accurate.

We estimated that scattered root disease mortality of at least one tree per acre, unassociated with distinct centers, occupied about 126,000 ha and 65,500 ha of commercial forest on the Nezperce and Clearwater National Forests, respectively. If these figures are combined with estimates of area occupied by large, active root disease centers on each Forest (James and Stewart 1981; Stewart and James 1983), we obtain over-all estimates of about 130,000 ha and 67,400 ha with root disease on the Nezperce and Clearwater National Forests, respectively. This represents about 33 percent of the commercial forest land on the Nezperce and 14 percent of the Clearwater National Forest.

Root pathogens were found on 100 percent of the ground-sampled cells within the Nezperce National Forest and on 61 percent of them in the Clearwater National Forest. Armillaria mellea Vahl. ex Fr. was the most often encountered root pathogen (tables 3 and 4). Other pathogens included Phaeolus schweinitzii (Fr.) Pat., Phellinus weirii (Murr.) Murr., Fomes annosus (Fr.) Cke., and Verticicladiella sp.. Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), grand fir (Abies grandis (Dougl.) Lindl.), and subalpine fir (Abies lasiocarpa (Hook.) Nutt.) were the most common hosts. Root diseases were also found, but less frequently, on Engelmann spruce (Picea engelmannii Parry), lodgepole pine (Pinus contorta Dougl.), ponderosa pine (Pinus ponderosa Laws.) and western larch (Larix occidentalis Nutt.).

Table 3.--Causes of conifer mortality in the Nezperce National Forest. 1/

Tree species	Root pathogens 2/ AM	PS	VS	Root disease/ bark beetle complexes	Bark beetles only	Other factors	Unknown causes
Douglas-fir	63	1	1	22	5	2	6
Grand fir	67	1	-	16	9	-	7
Subalpine fir	76	-	-	09	2	-	12
Engelmann spruce	29	-	-	46	21	-	4
Western redcedar	-	-	-	-	-	100	-
Lodgepole pine	31	-	-	43	14	1	10
Ponderosa pine	33	-	-	33	23	-	11
Western larch	11	-	-	31	42	5	11
Average percent occurrence	45	0.2	0.2	31	12	2	9

1/ Represents ground samples from nine subcompartments representing 398,742 ha of commercial forest land. Values in table are percent of sampled trees.

2/ AM = Armillaria mellea.
PS = Phaeolus schweinitzii.
VS = Verticicladiella sp.

Although A. mellea was most often detected on root-diseased trees, we suspect, based on previous observations (Filip and Goheen 1982; Goheen et al. 1980; James and Goheen 1981), that other root pathogens were infecting trees previously colonized by Armillaria. Also, occurrence of P. schweinitzii was probably much greater than we estimated because it is difficult to detect, and trees severely infected with this fungus may often lack typical root disease crown symptoms (Dubreuil 1981; James 1981).

Table 4.--Causes of conifer mortality in the Clearwater National Forest. 1/

Tree species	Root pathogens 2/ AM	PS	PW	FA	Root disease/ bark beetle complexes	Bark beetles only	Other factors	Other diseases 3/ ET	CR
Douglas-fir	19	-	-	-	2	1	-	-	-
Grand fir	4	-	-	-	1	1	1	3	-
Subalpine fir	15	-	-	1	2	2	-	-	-
Engelmann spruce	2	-	-	-	-	-	-	-	-
Western redcedar	-	-	-	-	-	-	4	-	-
Lodgepole pine	6	3	-	-	2	2	-	-	-
Ponderosa pine	-	-	-	-	1	-	1	-	-
Western larch	3	14	1	-	-	-	2	-	-
Western white pine	-	-	-	-	-	2	-	-	9
Average percent occurrence	8	8	1	1	2	2	2	3	9

1/ Represents ground samples from seven subcompartments representing 492,156 ha of commercial forest land. Values in table are percent of sampled trees.

2/ AM = *Armillaria mellea*
PS = *Phaeolus schweinitzii*
PW = *Phellinus weirii*
FA = *Fomes annosus*

3/ ET = *Echinodontium tinctorium*
CR = *Cronartium ribicola*

Fomes annosus may also be widespread on the two Forests; recent observations indicate that the pathogen is common on portions of the Red River and Clearwater Ranger Districts of the Nezperce National Forest. Extent of occurrence of Verticicladiella sp. on the two Forests is unknown. The fungus was recently discovered on Douglas-fir in the nearby Nez Perce Indian Reservation (James 1983) and has been found with greater frequency in several areas of western Montana (Byler and James 1981; James and Byler 1981). The other major pathogen encountered, Phellinus weirii, is common on the Idaho Panhandle National Forests farther north (Williams and Leaphart 1978) and in portions of northwestern Montana (James et al. 1982). Recently the fungus has been discovered within portions of the Nezperce National Forest.

Signs of bark beetle attacks were often found on root-diseased trees. For example, 45 percent of the dead trees examined on the Nezperce National Forest were infected with A. mellea and 31 percent also had evidence of bark beetle attacks (table 3). Although several trees infested with bark beetles did not have apparent indicators of root disease at the root collar or adjacent lateral roots, we suspect, based on previous observations, that many of these trees may have been infected with root pathogens. Previous work has shown high correlations between root disease and bark beetle infestations for grand fir and subalpine fir (Ferrell and Smith 1976; Hertert et al. 1975; Lane and Goheen 1979) and Douglas-fir (Dubreuil 1981; Furniss et al. 1979). Therefore, we suspect that a majority of the beetle-infested trees we examined in these three species were likely root diseased.

Most ground-sampled stands on the Nezperce National Forest were in the Abies grandis climax series of habitat sites (Pfister et al. 1977) (see Appendix). Two each were in the Pseudotsuga menziesii and Thuja plicata Donn. series with four in the Abies lasiocarpa series. Sampled stands covered a wider range of habitat types on the Clearwater National Forest. For example, four stands were in the A. lasiocarpa series, three in the A. grandis series, two in the P. menziesii series, three in the T. plicata series, and two in the Tsuga mertensiana (Bong.) Can. series. Our previous survey of the Nezperce National Forest (James and Stewart 1981) indicated that root diseases were most commonly encountered on the P. menziesii series habitats. However, an insufficient number of plots have been surveyed thus far to adequately establish statistical relationships between habitat type and incidence of root disease.

CONCLUSIONS

Root diseases are an important cause of conifer mortality on both the Nezperce and Clearwater National Forests. They are widely distributed on many sites and warrant concern from forest managers.

Although the most frequent pathogen located was A. mellea, other pathogens such as P. schweinitzii, F. annosus, P. weirii, and possibly Verticicladiella sp. are also common. Most grand fir, subalpine fir, and Douglas-fir infested with bark beetles during nonepidemic periods are root diseased.

Most survey errors stemmed from the inability to consistently determine cause of tree mortality from aerial photographs. Problems of root disease diagnosis from ground inspection and photo interpretation errors combine to lower accuracy of mortality estimates. A photo survey in which mortality of all causes is combined during photo interpretation would reduce variability. Causes of mortality could then be determined from ground check data similar to Pest Damage Inventory sample systems used elsewhere (Hoskins and Norick 1982).

Our survey system was derived from bark beetle survey systems where ground verification of presence of beetles is easy compared with root pathogens. Photo counts are also more reliable for bark beetle mortality because recently killed trees retain most of their foliage and are bright red in color. Bark beetle surveys only estimate current mortality; hidden snags and smaller infected trees do not have to be accounted for.

Although accuracy of our estimates needs improvement, we feel the percentage of total tree mortality associated with root diseases is acceptably accurate when compared with previous observations. We plan to use these percentages to estimate root disease impact on other National Forests until more reliable data are available.

ACKNOWLEDGEMENTS

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APPENDIX

1. Estimates of number of trees killed or volume affected (Hostetler and Young 1979).

$$\hat{Y} = \frac{A}{a_i m} \sum_{i=1}^{m} \frac{1}{P_i n_i} \sum_{j=1}^{n_i} \frac{A_{ij}}{a_{ijk}} \frac{1}{P_{ij} n_{ij}} \sum_{k=1}^{n_{ij}} \frac{K_{ijk}}{P_{ijk}}$$

$\hat{Y}$ = Total estimate of trees killed or volume affected

A = Acres in Forest

a_i = Acres in PSU subcompartments

m = Number of Primary Sample Units (PSU) - Subcompartments selected (9)

P_i = Probability of PSU

n_i = Number of Secondary Sample Units (SSU) - Stands (2)

A_{ij} = Area of SSU's

P_{ij} = Probability of SSU's

n_{ij} = Number of Tertiary Sample Units (TSU) - 1 acre cells (2)

a_{ijk} = Acres in TSU

K_{ijk} = Ground Truth Count

P_{ijk} = Probability of Ground Truth Cell

$$S.E.\hat{Y} = \frac{A}{(a_i)(m)}^{2} \frac{\sum_{i=1}^{m} \hat{Y}_i^{2} - \frac{\left(\sum_{i=1}^{m} \hat{Y}_i\right)^{2}}{m}}{m(m-1)}$$

$S.E.\hat{Y}$ = Standard Error of the Estimate

A = Number of acres in the Forest

A_i = Number of acres in subcompartments

$\hat{Y}_j$ = Estimate of number of trees in the subcompartments on Forest

m = Number of subcompartments selected for ground sampling in Forest

2. Relationship between photo counts and ground centers (Freeze 1697):

$$\Sigma XY - \frac{(\Sigma X)\ (\Sigma Y)}{n}$$

$$r = \Sigma X^2 - \frac{\Sigma (X)^2}{n_{ij}} \qquad \Sigma Y^2 - \frac{\Sigma (Y)^2}{n_{ij}}$$

r = Correlation coefficient.

X_i = Photo counts of dead trees.

Y_i = Ground counts of dead trees.

3. Estimate of acreage of root disease within commercial forest stands (Williams and Leaphart, 1978).

$$TRD_h = \frac{\sum_{i=1} D_{hi}/P_i}{\sum_{i=1} A_{hi}/P_i}$$

TRD_h = Weighted mean percentage of PI stratum h. All TRD_h are multiplied by acres in respective PI stratum. These are summed to give Forest-wide acres of root disease.

D_{hi} = Root disease area in PI stratum h and in subcompartment i.

A_{hi} = Area in PI stratum h and in subcompartment i.

P_i = Expansion probability number.

Table 5.--Losses from root diseases and other causes, Nezperce National Forest. [1]

Sampled subcompartment ID number	Tree species [2]		Pathogens [3] AM	PS	VS	Complex	Bark beetles (BB)	Other - fire, mechanical, animal damage	Unknown
317-3	GF	1					1		
12 stands	SAF	9	7				2		
227 ha	ES	4				3 AM/BB	1		
	LP	47					47		
	PP	3	1				2		
	L	1						1	
418-1	DF	57	26			25 AM/BB	6		
9 stands	GF	6	4			2 AM/BB			
210 ha	LP	1						1	
	PP	8				6 AM/BB	2		
419-5	DF	70	60		1	6 AM/BB	3	1	
7 stands	GS	7	4			1 AM/BB	2		
174 ha	ES	2	1				1		
	LP	7				1 AM/BB	6		
	PP	26	9			7 AM/BB	6		4
	L	3	2						1
511-3	GF	3	2				1		
15 stands	LP	129	27			45 AM/BB	8		49
142 ha	PP	1							1
703-2	DF	32	16			4 AM/BB	3	4	2
11 stands						3 AM/PS			
115 ha	GF	1	1						
	C	5						5	
	LP	1				1 AM/BB			
	PP	5	4			1 AM/BB			
809-6	DF	6	5						1
7 stands	GF	2	1						1
178 ha	SAF	114	87			11 AM/BB	1		15
	ES	10	3			6 AM/BB			1

Table 5 continued.

Sampled subcompartment ID number	Tree species 2/		Pathogens 3/ AM	PS	VS	Complex	Bark beetles (BB)	Other - fire, mechanical, animal damage	Unknown
821-1	DF	64	43		1	4 AM/BB	2	3	11
13 stands	GF	24	18			2 AM/BB			4
152 ha	LP	2							2
822-5	DF	89	52			32 AM/BB	1		4
9 stands	GF	25	16	1		6 AM/BB	2		
229 ha	ES	8	3			2 AM/BB	3		
	LP	4	3					1	
	L	68	6			22 AM/BB	30	3	7
831-3	DF	2	1			1 AM/BB			
8 stands	LP	336	136			182	15	1	2
168 ha									
Totals		1,183	538	1	2	372	145	20	105

1/ Values in table are number of trees.

2/ DF = Douglas-fir; GF = Grand fir; SAF = Subalpine fir; ES = Engelmann spruce; LP = Lodgepole pine; PP = ponderosa pine; C = cedar; L = larch.

3/ AM = *Armillaria mellea*; PS = *Polyporus schweinitzii*; VS = *Verticicladiella* sp.

Table 6.--Losses from root diseases and other causes, Clearwater National Forest. 1/

Sampled subcompartment ID number	Tree species 2/		Pathogens 3/ AM	PW	PS	FA	Complex	Bark beetles (BB)	Other - fire, mechanical, animal damage	Other diseases ET	CR
416-7	SAF	1	1								
6 stands	ES	1	1								
63 ha	LP	1	1								
422-2	SAF	6	3				1 AM/BB	2			
20 stands	LP	2	2								
211 ha	WP	6						2			6
14 stands	DF	2	2								
503-4	GF	5							1 animal	4	
260 ha											
521-2	GF	1					1 AM/BB				
6 stands	DF	14	12				2 AM/BB				
161 ha	PP	1					1 AM/BB				
620-2	DF	16	13				1 AM/BB	2			
16 stands	WP	8					2 AM/BR				6
200 ha											
628-9	GF	6	5					1			
17 stands	SAF	2	1			1					
265 ha	WP	1						1			
	PP	1							1 animal		
	C	6							6 fire		
	L	3							3 fire		

Table 6.--continued

Sampled subcompartment ID number	Tree species 2/		Pathogens 3/ AM	PW	PS	FA	Complex	Bark beetles (BB)	Other - fire, mechanical, animal damage	Other diseases ET	CR
634-2	GF	2	2								
15 stands	SAF	22	19				2 AM/BB	1			
227 ha	DF	3	3								
	LP	16	6		4		3 AM/BB	3			
	WP	3									3
	L	28	4	2	22						
Totals		159	77	2	26	1	13	12	11	4	15

1/ Values in table are number of trees.

2/ GF = grand fir; DF = Douglas-fir; SAF = subalpine fir; ES = Engelmann spruce; LP = lodgepole pine; PP = ponderosa pine; WP = white pine; C = cedar; L = larch.

3/ AM = *Armillaria mellea*; PW = *Phellinus weirii*; PS = *Phaeolus schweinitzii*; FA = *Fomes annosus*; ET = *Echinodontium tinctorium*; CR = *Cronartium ribicola*

Table 7.--Habitat types of stands surveyed for root disease on the Nezperce National Forest.

Sample subcompartment	Stand	Habitat type
317-3	05	_Abies grandis-Xerophyllum tenax_
	09	_Abies grandis-Pachistima myrsinites_
418-1	05	_Abies grandis-Pachistima myrsinites_
	09	_Pseudotsuga menziesii-Physocarpus malvaceus_
419-5	03	_Abies grandis-Xerophyllum tenax_
	07	_Pseudotsuga menziesii-Physocarpus malvaceus_
511-3	06	_Abies grandis-Xerophyllum tenax_
	08	_Abies grandis-Xerophyllum tenax_
703-2	01	_Thuja plicata-Pachistima myrsinites_
	10	_Thuja plicata-Pachistima myrsinites_
809-6	06	_Abies lasiocarpa-Menziesii ferruginea_
	07	_Abies lasiocarpa-Menziesii ferruginea_
821-1	02	_Abies grandis-Pachistima myrsinites_
	10	_Abies grandis-Pachistima myrsinites_
822-5	01	_Abies grandis-Pachistima myrsinites_
831-3	01	_Abies lasiocarpa-Xerophyllum tenax_
	08	_Abies lasiocarpa-Xerophyllum tenax_

Table 8.--Habitat types of stands surveyed for root disease on the Clearwater National Forest.

Sample compartment	Stand	Habitat type
416-7	01	Tsuga mertensiana Menziesia ferruginea
	06	Tsuga mertensiana Menziesia ferruginea
422-2	03	Abies lasiocarpa Pachistima myrsinites
	18	Abies lasiocarpa Menziesia ferruginea
503-4	15	Abies lasiocarpa Xerophyllum tenax
	21	Abies grandis Pachistima myrsinites
521-2	35	Psuedotsuga menziesii Physocarpus malvaceus
	37	Psuedotsuga menziesii Physocarpus malvaceus
620-2	19	Abies grandis Pachistima myrsinites
	23	Abies grandis Pachistima myrsinites
628-9	04	Thuja plicata Pachistima myrsinites
	18	Thuja plicata Pachistima myrsinites
634-2	03	Thuja plicata Pachistima myrsinites
	11	Abies lasiocarpa Pachistima myrsinites

Table 9.--Subcompartment estimates of sample population, Nezperce National Forest.

Subcompartment identification number	Current root disease mortality		Old root-disease mortality		Total mortality (root disease & other causes)	
	# trees	Volume ft^3	# trees	Volume ft^3	# trees	Volume ft^3
317-3	2,118	40,236	2,782	51,934	123,632	966,405
418-1	11,402	64,592	20,935	512,808	56,632	1,706,763
419-5	2,297	4,135	314,818	2,820,117	240,705	1,925,938
511-3	666	1,331	23,679	154,769	995,267	10,337,709
702-2	0	0	80,241	641,416	639,618	15,169,953
809-6	4,496	257,300	399,338	4,829,703	265,515	7,634,580
821-1	11,137	589,038	38,852	771,047	131,724	1,948,386
822-5	23,707	830,456	22,383	648,444	183,714	10,316,844
831-3	6,803	30,844	44,444	185,089	165,666	671,945
Total estimate	761,712	29,134,670	11,505,739	128,909,189	34,027,970	615,424,095
Confidence interval 90%	± 511,893	± 22,514,013	± 9,886,280	± 108,501,830	± 20,783,927	± 361,894,897
Standard error $S\bar{x}$	275,211	12,104,308	5,315,204	58,334,317	11,174,154	194,567,149
Percent error	36%	42%	46%	45%	33%	32%

Table 9.--Subcompartment estimates of sample population, Nezperce National Forest.

Subcompartment identification number	Current root disease mortality # trees	Current root disease mortality Volume ft^3	Old root-disease mortality # trees	Old root-disease mortality Volume ft^3	Total mortality (root disease & other causes) # trees	Total mortality (root disease & other causes) Volume ft^3
317-3	2,118	40,236	2,782	51,934	123,632	966,405
418-1	11,402	64,592	20,935	512,808	56,632	1,706,763
419-5	2,297	4,135	314,818	2,820,117	240,705	1,925,938
511-3	666	1,331	23,679	154,769	995,267	10,337,709
702-2	0	0	80,241	641,416	639,618	15,169,953
809-6	4,496	257,300	399,338	4,829,703	265,515	7,634,580
821-1	11,137	589,038	38,852	771,047	131,724	1,948,386
822-5	23,707	830,456	22,383	648,444	183,714	10,316,844
831-3	6,803	30,844	44,444	185,089	165,666	671,945
Total estimate	761,712	29,134,670	11,505,739	128,909,189	34,027,970	615,424,095
Confidence interval 90%	± 511,893	± 22,514,013	± 9,886,280	± 108,501,830	± 20,783,927	± 361,894,897
Standard error $S\bar{x}$	275,211	12,104,308	5,315,204	58,334,317	11,174,154	194,567,149
Percent error	36%	42%	46%	45%	33%	32%

Table 10.--Subcompartment estimates of sample population, Clearwater National Forest.

Subcompartment identification number	Current root disease mortality		Old root-disease mortality		Total mortality (root disease & other causes)	
	# trees	Volume ft^3	# trees	Volume ft^3	# trees	Volume ft^3
416-7	0	0	14,625	269,847	148,192	1,567,120
422-2	0	0	41,590	427,546	182,491	2,528,213
503-4	0	0	15,336	1,041,814	113,266	2,093,582
521-2	3,695	12,565	7,325	1,264,816	28,145	4,219,375
620-2	154	9,681	899	77,384	39,644	3,494,943
628-9	0	0	17,085	120,450	155,715	2,504,675
634-2	0	0	158,011	3,133,502	72,683	2,723,654

Table 11.--Photo interpretation ground truth correlation, Nezperce National Forest.

Subcompartment and stand	Cell	Y RD-PI count 1/	X RD-Grnd truth 2/	Y Total-PI count 3/	X Total-Grnd truth 4/
317-3-5	2C	7	0	7	19
	5B	0	0	2	8
9	6E	14	10	15	38
	6G	7	3	9	38
418-1-5	1C	3	6	9	9
	4E	20	17	20	24
9	8F	6	12	6	14
	7C	16	16	16	18
419-5-3	5C	4	32	4	39
	3F	10	28	10	37
7	3C	2	3	2	8
	2C	0	6	2	11
511-3-6	8B	0	0	0	5
	8C	0	0	1	1
8	4G	0	0	3	41
	5G	14	69	19	80
702-2-1	5B	0	0	2	6
	6C	7	5	8	9
10	2H	9	15	9	17
	4F	0	1	0	6
809-6-6	3E	25	33	26	33
	7B	10	19	10	19
7	3G	12	22	12	30
	6D	0	7	2	22
821-1-2	2B	9	10	17	17
	6B	5	33	12	48
10	4E	0	0	1	2
	3G	3	16	16	19
822-5-1	7E	5	12	7	15
	2B	4	2	4	47
3	7H	21	24	21	37
	6B	24	62	24	81
831-3-01	5G	55	98	58	105
	6G	15	88	15	119
8	4C	24	28	25	32
	2H	18	74	19	73
		r^2 = .33		r^2 = .43	
		r = .58		4 = .66	

1/ Root disease - photo count

2/ Root disease - ground check count

3/ Total mortality - photo count

4/ Total mortality - ground check count

Table 12.--Photo interpretation ground truth correlation, Clearwater National Forest.

Subcompartment and stand	Cell	Y RD-PI count 1/	X RD-Grnd truth 2/	Y Total-PI count 3/	X Total-Grnd truth 4/
416-7- 1	3B	0	1	0	1
	4B	0	1	1	2
6	5B	0	0	0	0
	5C	0	0	0	0
422-2- 3	6B	0	0	1	4
18	3C	0	0	0	0
	4B	0	0	0	0
503-4-15	2C	0	0	1	0
	2D	0	0	0	0
21	4D	0	0	0	1
	5F	0	3	3	6
620-2-19	1C	0	0	0	0
	7G	12	8	14	9
21	2E	0	0	2	3
23	3H	9	2	10	10
628-9- 4	1H	0	0	0	0
	2D	0	0	2	4
18	5F	0	1	1	9
	5H	0	1	6	7
634-2- 3	2E	0	1	9	4
6	2B	0	42	9	46
11	2H	0	12	5	13
	2C	0	3	5	5
521-2-35	4C	0	1	1	1
	5E	3	0	3	2
37	2D	5	9	5	11
	2E	3	3	3	3
		r^2 = .0091		r^2 = .4135	
		r = .0955		r = .6430	

1/ Root disease - photo count

2/ Root disease - ground check count

3/ Total mortality - photo count

4/ Total mortality - ground check count

Table 13.--Damage codes for the Northern Region's Forest Insect and Disease Damage Survey System.

0 Healthy tree, no insect, disease, or damage
1 Unknown or natural mortality

Bark Beetles

2 Current beetle attack
3 Last year's attack
4 Older attack
5 Unsuccessful attack
6 Current strip attack
7 Older strip attack
8 Current secondary beetle attack
9 Older secondary beetle attack

Other Insect and Damaging Problems

40 Shoot damaging insects
41 Stem borers
42 Gall insects
43 Sucking insects (aphids and scales)
44 Webworms
45 Light winter damage
46 Moderate winter damage
47 Heavy winter damage
48 Animal damage
49 Spike tops
50 Other damaging agents

Disease

20 Mistletoe infected
21 Mistletoe mortality
22 Root disease infected
23 Current disease infected
24 Older root disease mortality
25 Branch canker and stem rust
26 Stem rust and branch canker
27 Mortality - stem rust
28 Light needle disease infection
29 Moderate needle disease infection
39 Heavy needle disease infection
31 Butt and stem decay

Disease Associates

60 *A. mellea* (current mortality)
61 *A. mellea* with beetles
62 *P. weirii*
63 *P. weirii* with beetles
64 *P. schweinitzii*
65 *P. schweinitzii* with beetles
66 *V. wagenerii*
67 *V. wagenerii* with beetles
68 *F. annosus*
69 *F. annosus* with beetles
70 Other disease species
71 Other species with beetles