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TREE AND SITE CHARACTERISTICS RELATIVE TO PROGRESSIVE BALSAM WOOLLY APHID DAMAGE TO *ABIES* SPP., BRITISH COLUMBIA 1959-1970

by

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PACIFIC FOREST RESEARCH CENTRE
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INTERNAL REPORT BC-46

DEPARTMENT OF THE ENVIRONMENT
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INTRODUCTION

The balsam woolly aphid, *Adelges piceae* (Ratzburg) (Homoptera: Adelgidae), an important introduced pest of North American *Abies* species (Harris, 1968ab), occurs in a wide variety of forest situations in southwestern British Columbia. As part of a program of research on the insect, it was considered useful to document the progressing infestation at a number of localities so as to determine host and site preferences. Although there was extensive work on the epidemiology of the aphid in New Brunswick by Greenbank (1970), there was no knowledge of how this information might apply to the situation in British Columbia. Accordingly, a series of permanent study plots were established throughout the infested area and examined annually or biannually over a 12-year period; the observations are summarized here.

THE INSECT

Distribution

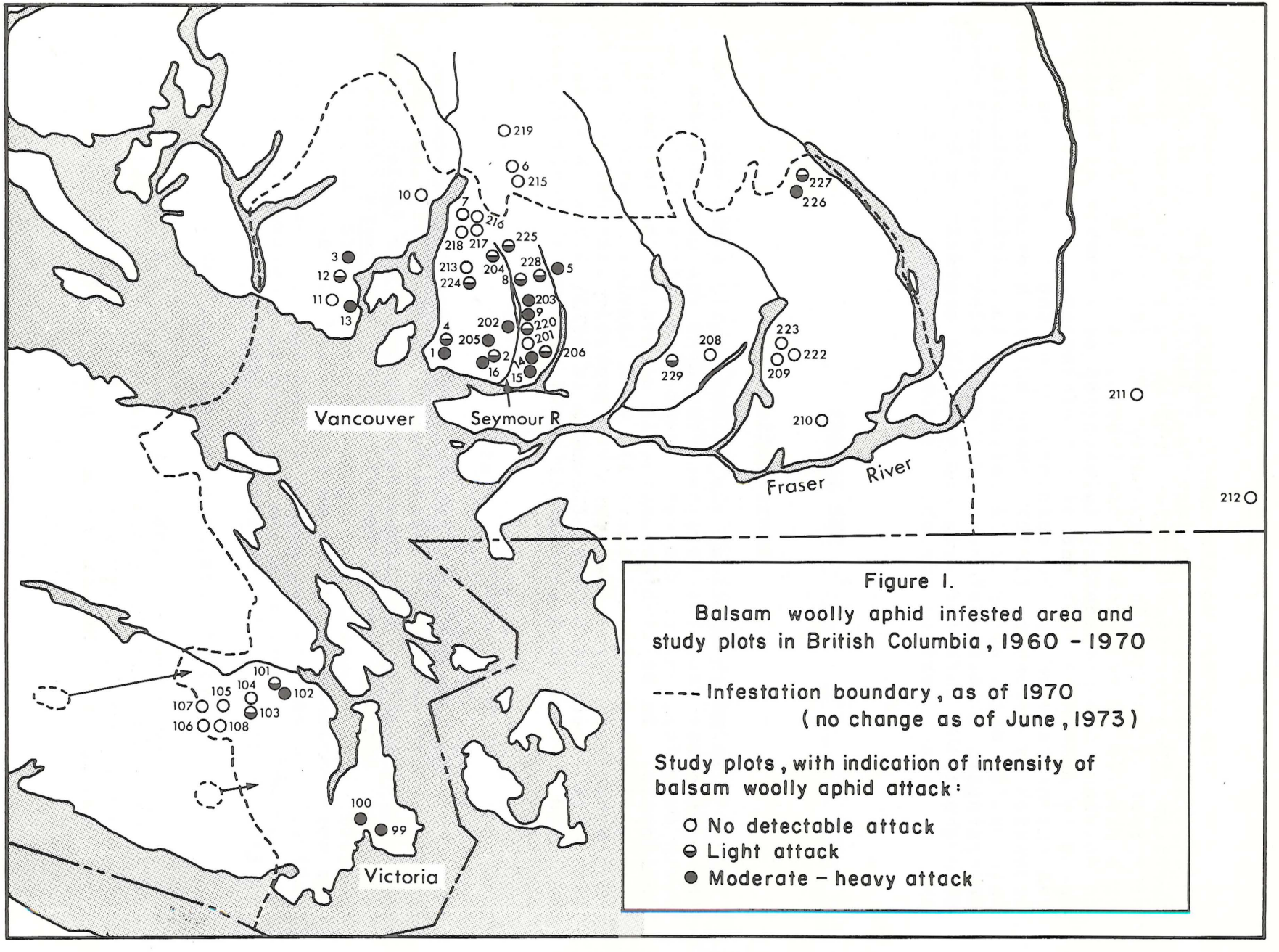
In North America, the balsam woolly aphid occurs on the east coast from the Maritime Provinces and Quebec south to North Carolina, and on the west coast from British Columbia to California. In British Columbia, it occurs in the southwest corner of the province (Figure 1), with heaviest damage occurring near Vancouver, where the aphid was probably introduced. It was first discovered in British Columbia in 1958, although it is believed to have been present in small numbers at least 20 years previously.

Hosts

In eastern North America, *Abies balsamea* (Linnaeus) is the common, severely infested host. In the west, amabilis fir (*Abies amabilis* (Douglas) Forbes), grand fir (*Abies grandis* (Douglas) Lindley) and alpine fir (*Abies lasiocarpa* (Hooker) Nuttall) are attacked. In British Columbia, amabilis fir is the most commonly attacked species. Grand fir seems more resistant to damage, but alpine fir is highly susceptible and is attacked in several of the few localities where the range of this host is within the infested area.

Description, Life History and Habits

The biology of the balsam woolly aphid has been studied in some detail by several workers, notably Balch (1952) in eastern Canada, Mitchell et al. (1961) in the Pacific Northwest States, and McMullen and Skovsgaard (1972) in British Columbia.


Vancouver
Seymour R
Fraser River
Victoria
Figure 1.
Balsam woolly aphid infested area and study plots in British Columbia, 1960 - 1970
---- Infestation boundary, as of 1970 (no change as of June, 1973)
Study plots, with indication of intensity of balsam woolly aphid attack:
No detectable attack
Light attack
Moderate - heavy attack

The pest is a tiny sucking insect occurring, sometimes in tremendous numbers, on the bark of the bole and branches. Individuals secrete a protective covering of white, waxy "wool" which makes them visible on the bark, particularly when in large numbers. Dispersal of this wingless pest is by wind in the egg and first-instar crawler stage. Only females are known. When these settle by chance on stem or branches of an Abies, they may become established on the bark, inserting feeding stylets and remaining there for the rest of their lives. There are two generations per year in British Columbia, although a third generation may become established (McMullen and Skovsgaard, 1972). A small number of native predators attack the balsam woolly aphid, but they do not appear to be a significant control factor (Clark et al., 1971).

Damage

In an infested stand, most trees have at least a small aphid population scattered throughout the crown, but the aphid is difficult to detect unless the infestation increases to the point where damage is evident. Crown attack results in branch swellings or "gout", causing sporadic but persistent mortality in a stand, and probably results in significant growth loss to affected trees.

When conditions on the bole, or weather, are favorable, large numbers may build up, giving a whitish appearance to the stem. Heavy "stem attack" may kill grand fir over a period of 5-10 years, or the attack may disappear and the trees recover. Amabilis fir is frequently killed less than 5 years after heavy attack, but may also recover. Alpine fir usually dies in the first year of attack.

The amount of damage within the infestation zone varies markedly; some areas are apparently free of aphid, whereas others suffer appreciable mortality. Areas of heaviest damage change with time, and are generally those with significant numbers of mature and overmature Abies; however, trees down to seedling size are attacked.

STUDY METHODS

Plot Establishment and Location

Beginning in 1959, study plots were established throughout the area infested by balsam woolly aphid (Figure 1) (Appendices I-A and I-B). The principal criteria for selection of plot locations were that:

1) they be within the infestation boundaries, either infested or uninfested, or just beyond the edge of the infestation, with imminent chance of attack;
2) there be a range of age, diameter and height;
3) there be a range of sites.

In addition, locations were favored that (a) contained reasonable compact groups of Abies suitable for convenient examination, (b) were readily accessible, and (c) had reasonable assurance that no logging would take place in the near future.

The majority of plots were established in 1961 and 1966, although some were set up in other years up to 1969. There were 52 plots, ranging in size from 0.1 to 2.8 acres. They included 26 to 610 trees each and, at the time of establishment, contained 5,791 trees (Appendix I-B). Plots established from 1959-65 comprised 50 randomly selected trees at a locality, but most of the subsequent plots included about 100 trees. Some trees subsequently were felled for detailed study, or were lost during road building, power-line construction or logging; in 1970, 3,659 trees were being observed. All three Abies species were represented; the most numerous was A. amabilis. Elevations ranged from 100 - 4,800 feet.

Tree-size data, including diameter at breast height (dbh), height (ht), age (of representative sample trees), widest crown width (cw) and dominance or crown class (cc), were collected once.

Infestation Rating of Trees and Plots

Balsam woolly aphid infestation data were recorded on individual trees at least once every 2 years, using four factors expressing the tree's general health or reaction to aphid attack: (1) stem attack, and (2) gout are the principal, direct symptoms of aphid population size; (3) per cent needle loss (or failure to grow new foliage normally) is one result of aphid feeding; (4) persistent attack often results in a broken, bent, bunched or otherwise malformed top; therefore, leader shape was recorded. Gout, needle loss and abnormal crown shape become evident several years after heavy attack. Stem attack is the most transient sign or symptom of infestation, although evidence (i.e. old wool) may remain several years after stem attack has declined. When only a trace of living aphid remained on the stem, the tree was considered to have recovered. Nevertheless, with periodic examinations intended, these four data provided the best indication of tree condition that could be collected.

A major source of error was in the assessment of gout injury, where swellings at branch nodes, often high in the crown, would be more or less visible, depending upon chance, experience and perseverence of the observers, and on lighting conditions, as affected by crown closure and weather. Gout could be obscured by lower branches, or could be confused with cones, lichens and other deformities by a ground observer. Tree fellings showed that gout is almost invariably widespread in an infested area; a positive record really means extensive or appreciable swellings are present, while a negative record in infested areas does not rule out light infestation. However,

it is assumed that correct observations on individual trees were made often enough to offset errors that might have occurred. Records of no gout, when it in fact might be there, and particularly of disappearing gout, are most susceptible to error; gout damage can actually disappear only as the tree "over-grows" this damage. Stem attack, however, can disappear in a single season.

The trees were rated for infestation and damage by combining the four factors. Stem attack and gout were the primary criteria, and one rating system was based on these alone (A-D) (Figure 2). A secondary system, also including defoliation and crown shape ratings, provided a total of 16 categories. The primary ratings ranged from uninfested (A) to heavily infested (D), with B and C considered intermediate and equivalent to each other. The secondary system was from 1-12 in increasing order of infestation, with the same number (e.g. 5 and 5') indicating equivalent ratings (total of 16) because there is no reason to believe that either gout or stem attack is more significant than the other. Data could be collected faster for the first system, but the second included additional factors worth examining in some cases. Rating A (1-4) indicates current non-susceptibility; abnormalities may be due to past attack or other causes. Ratings B and C (5-8 and 5'-8') could indicate less susceptibility, or an earlier point in time of infestation development. Rating D (9-12) indicates definite attack or infestation, with significant damage likely to result.

The plots were grouped into three categories[1/], according to a broad estimate of the degree of balsam woolly aphid infestation. One group consisted of plots with trees showing no signs of infestation up to the present (2,415 trees); the second group was designated as lightly infested (912 trees), and the third contained moderate to heavily infested plots, (1,812 trees).

Analysis of Infestation Data

Infestation Related to Tree Characteristics

Data were first examined to see if aphid incidence was related to any of the easily measurable tree characteristics. Maximum, minimum and average dbh, height, crown width and cw/dbh were calculated for each infestation rating for trees in each of the three categories of plots. Also, the trees in each tree rating were tallied by dbh, ht, cw and crown class. Crown width and the cw/dbh ratio mentioned above could vary with stand density

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1/ Categories are based on personal judgment, and are overall estimates based on numbers of trees infested and on intensity of infestation on individual trees.

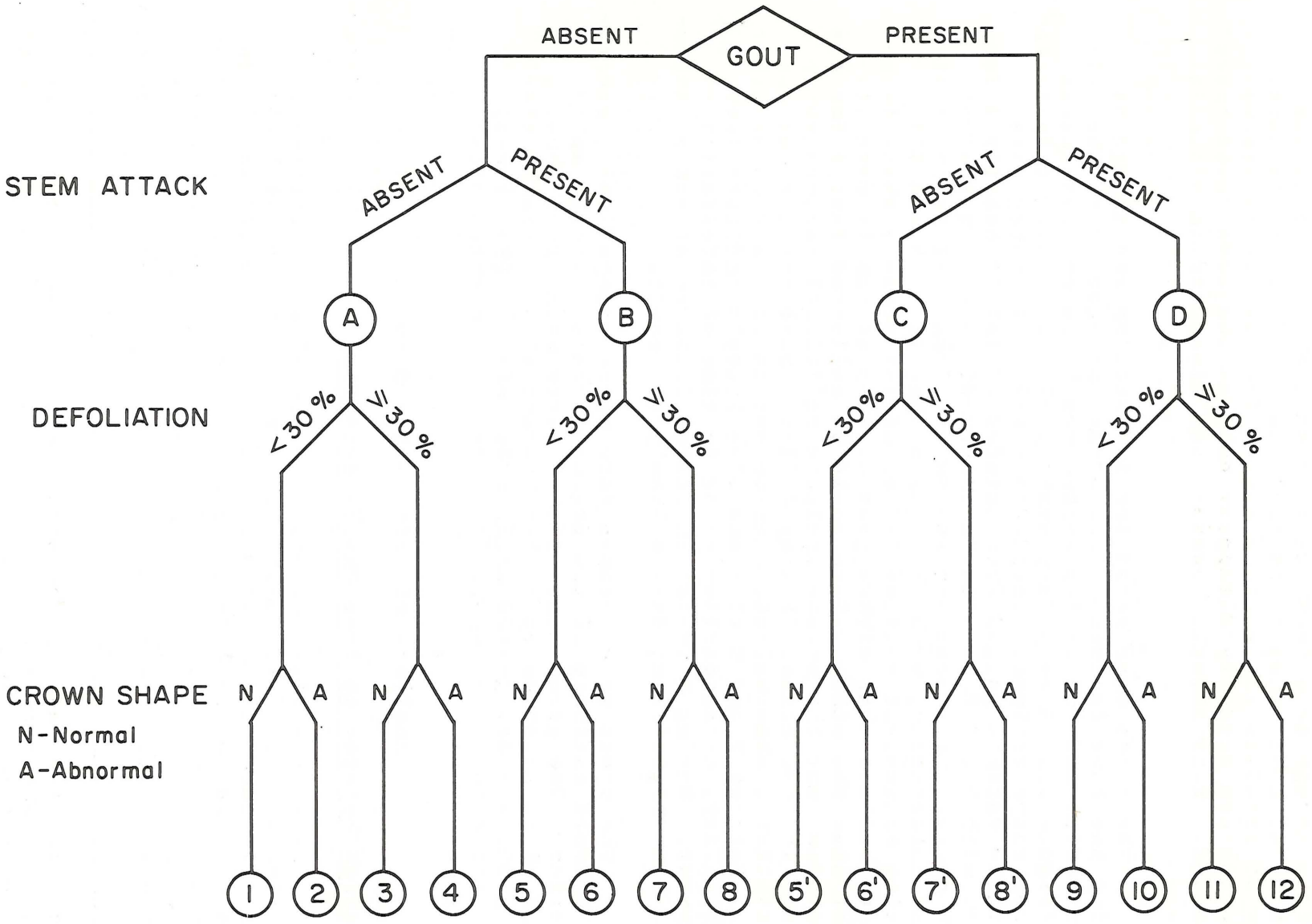

Figure 2. Balsam woolly aphid tree infestation rating categories. Ranges from uninfested to heavily infested in increasing numerical order. Ratings with like numbers are approximately equivalent.

(Smith et al., 1961), although this has not been demonstrated with Abies species. Trees in a dense stand should have a smaller cw/dbh ratio than those in more open-growing stands. The aphid develops best in a moderately open stand, or along stand edges where there is some protection from intense sunlight. Stocking affects aphid incidence because of the aphid's wind dispersal within a stand and because of the effect of stocking on microclimate and, therefore, on aphid development.

Infestation Changesover Time

A second part of the study involved observing changes in infestation that occurred during the period 1959 to 1970. Changes within the four major and 12 secondary ratings were examined. Further, because feeding in tree crowns resulted in gradual needle loss and subsequent failure to refoliate, such thinning of the foliage was used as a measure of declining tree health. The ultimate damage, of course, occurred when some trees died.

Infestation Related to Site

A third factor studied was the relationship of tree infestation and damage intensification to site. This was investigated, using the plant association classification of Krajina (1969) and Eis (1962). Three other site factors were measured for each plot; namely elevation, aspect and tree species composition.

Amabilis fir occurs in the wetter parts of the Coastal Western Hemlock Zone in the following associations. The Vaccinium-Moss association (Figure 3a) (Eis, 1962) (amabilis fir-western or mountain hemlock associations (Krajina, 1969)) occurs at higher, drier elevations, while the Blechnum or deer fern-western hemlock association (Figure 3b) occurs at lower elevations and is wet but well drained. The Ribes-Oplopanax association of Eis and devil's club-Sitka spruce site of Krajina are gravelly, very well-drained, good sites, tending to lower elevations (Figure 3c). Transitional situations occur frequently. Grand fir is found principally in the wetter parts of the Coastal Douglas-fir Zone in two associations, moss and swordfern (Krajina, 1969). Little is known about alpine fir sites (Figure 3d).

RESULTS

Infestation Related to Tree Characteristics

Tree Diameter, Height and Crown Width

Tree diameter, height, crown width and cw/dbh measurements were compared with annual infestation ratings (A, B, C

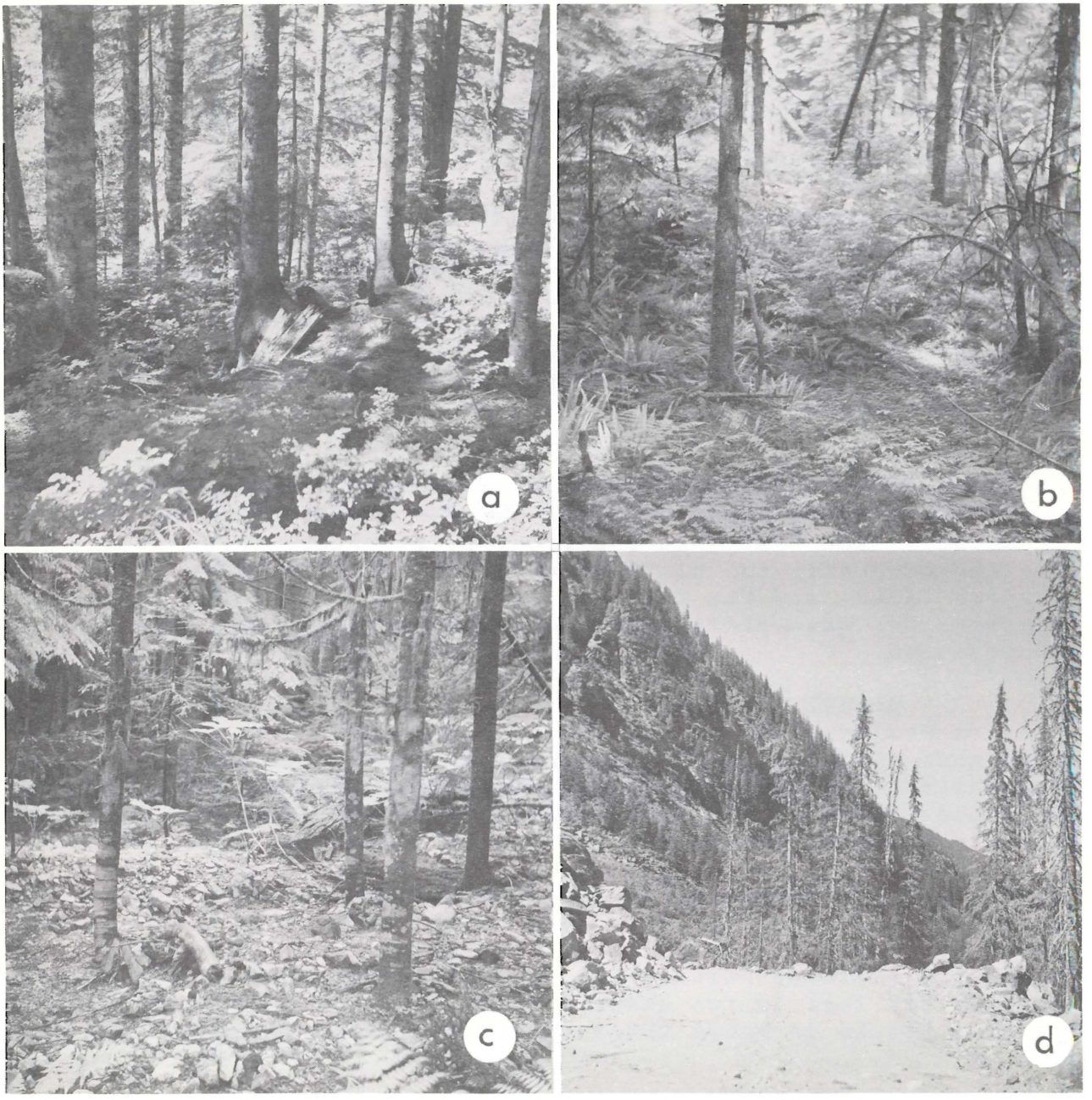

Figure 3. a-c. Representative amabilis fir sites in Seymour River Valley, near Vancouver.

a, Vaccinium-Moss association. b, Blechnum association. c, Ribes-Oplopanax association.

d. Alpine fir site where trees are growing on rock slides; Tretheway Creek (north of Harrison Lake). Heavy damage at some locations.

and D) of trees on infested plots (Appendix II) and summarized for the entire period 1961 to 1970 in Figure 4; average values were plotted.

On amabilis fir, there was some tendency for severity of infestation to increase with diameter, but there was no such trend with grand or alpine fir (Figure 4-1). The situation with respect to tree height (Figure 4-2) and crown width (Figure 4-3) was similar. Cw/dbh ratios increased as amabilis fir infestation decreased, indicating less infestation in a more open stand (Figure 4-4) contrary to expectations; however, alpine fir reacted as expected. Grand fir ratios did not seem to be related to infestation.

Infestation data from representative plots of the three Abies species were summarized by secondary infestation ratings for 2 years (Appendix III). The results with amabilis fir (Table 1) and grand fir again emphasized the considerable variability that existed. Generally, there appeared to be no relationships between tree factors and infestation rating. Tree height on plot 9, for example, seemed contrary to the usual trend, but larger average tree diameter and height did characterize trees suffering greatest damage on plots 13 and 14. On none of the selected amabilis and grand fir plots were there trends evident with cw and cw/dbh. Alpine fir, with rapid kill of almost all plot trees, seemed entirely free of the hoped for tree factor infestation trends.

The major symptoms of infestation, gout and stem attack, were examined separately from other factors. Gout damage was found on trees of all sizes. Stem attack, the more noticeable sign and more rapid tree killer, also affected all sizes of trees (down to 1 inch diameter class) but seemed to favor some; about 70% of the stem attacked amabilis, grand and alpine fir observed were 6-18 inches, 6-18 inches and 2-10 inches dbh, respectively (Figure 5).

Age

Age was determined for only a small proportion of trees on the plots. Of the amabilis fir dated, only 13 trees were suffering from stem attack and these ranged from 30 to 150 years old (Table 2). Gout, however, occurred over almost the entire range of age (30 to 370 years). Grand fir were stem attacked from 36 to 90 years and were gouted from 41 to 140 years. Alpine fir showed stem attack from 91 to 175 years, and gout from 86 to 195 years, the total range examined.

Infestation Related to Changes over Time

Generally, the percentage of trees changing infestation rating between examinations (usually every 2 years) was less than 10%. Considering amabilis fir, the most common changes

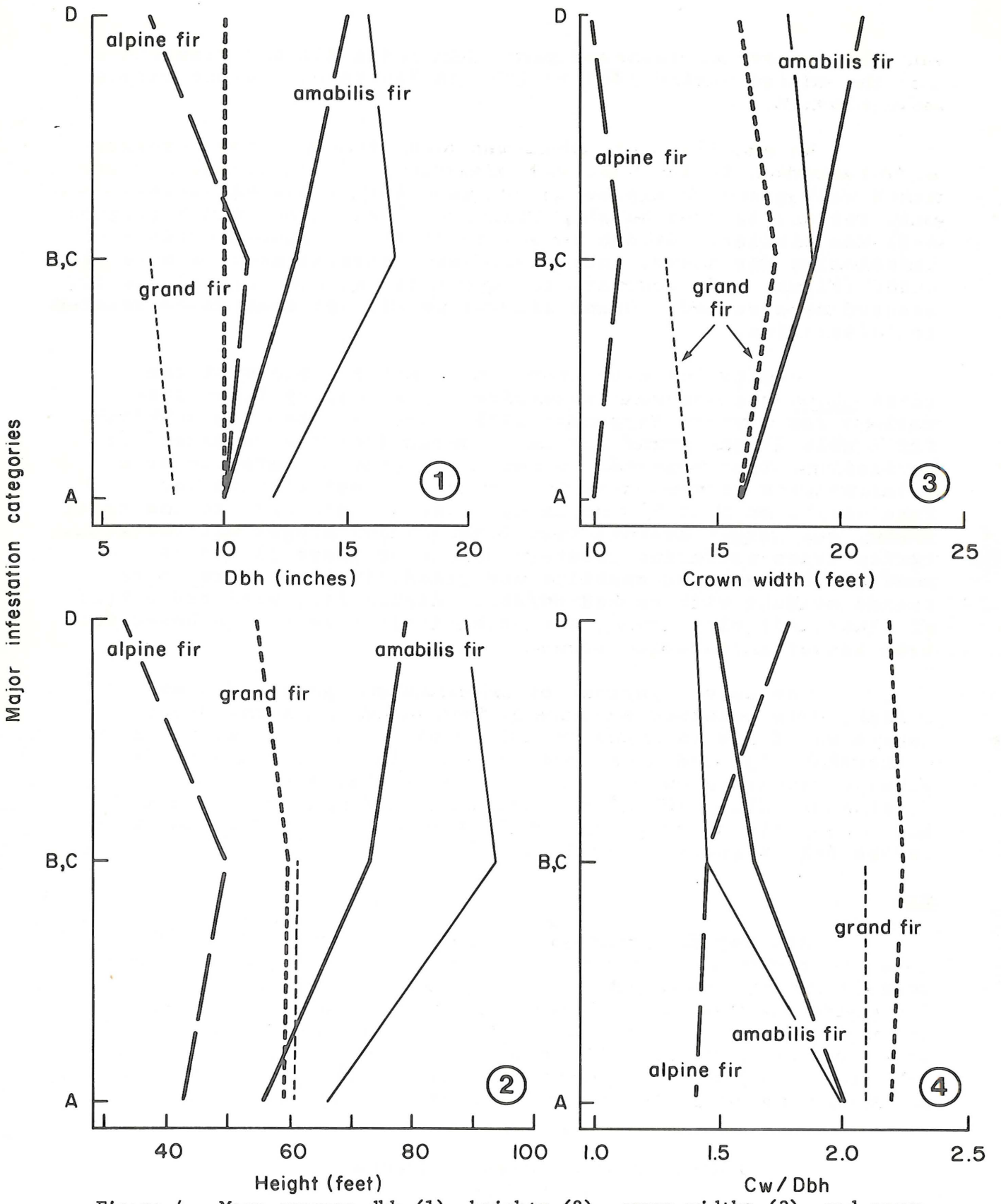

Figure 4. Mean average dbh (1), heights (2), crown widths (3), and crown width/dbh ratios (4) of trees in each major infestation category.

A-D, uninfested to heavily infested; B and C are approximately equivalent. Lightly infested plots are represented by thin graph lines, heavily infested ones by thick lines.

Table 1. Infestation rating categories[1] having the highest average dbh, ht, cw and cw/dbh in three representative amabilis fir sample plots (see Appendix III).

Tree measurement	Plot number					
	9		13		14	
	1965	1970	1966	1970	1965	1969
Avg dbh	2[2]	5'	11	7'	7'	5,8'
Avg ht	2	5'	8'	7'	7'	5
Avg cw	2	3,5'	7'	5',7'	7'	5
Avg cw/dbh	1	1	11	6'	8'	2

[1] 1-12, uninfested to heavy; ratings with like numbers are equivalent.

[2] Underlined ratings are apparently uninfested.

Table 2. Percent and total number of measured trees by age class with balsam woolly aphid attack recorded.

Age class	% of trees				Total no. of trees
	Stem attack only	Gout only	Stem attack & gout	Unattacked	
Amabilis fir					
31-50	4	32		64	25
51-100	4	27	2	68	180
101-150		22	1	77	197
151-200		18		82	112
201-250		16		84	51
251-300		27		73	22
301-350		28		72	18
351-485		6		94	18
Grand fir					
31-50		33	7	60	15
51-100	15	28	2	54	46
101-150		38		62	8
Alpine fir					
51-100		50	50		2
101-150	11	56	33		9
151-200	7	73	13	7	15

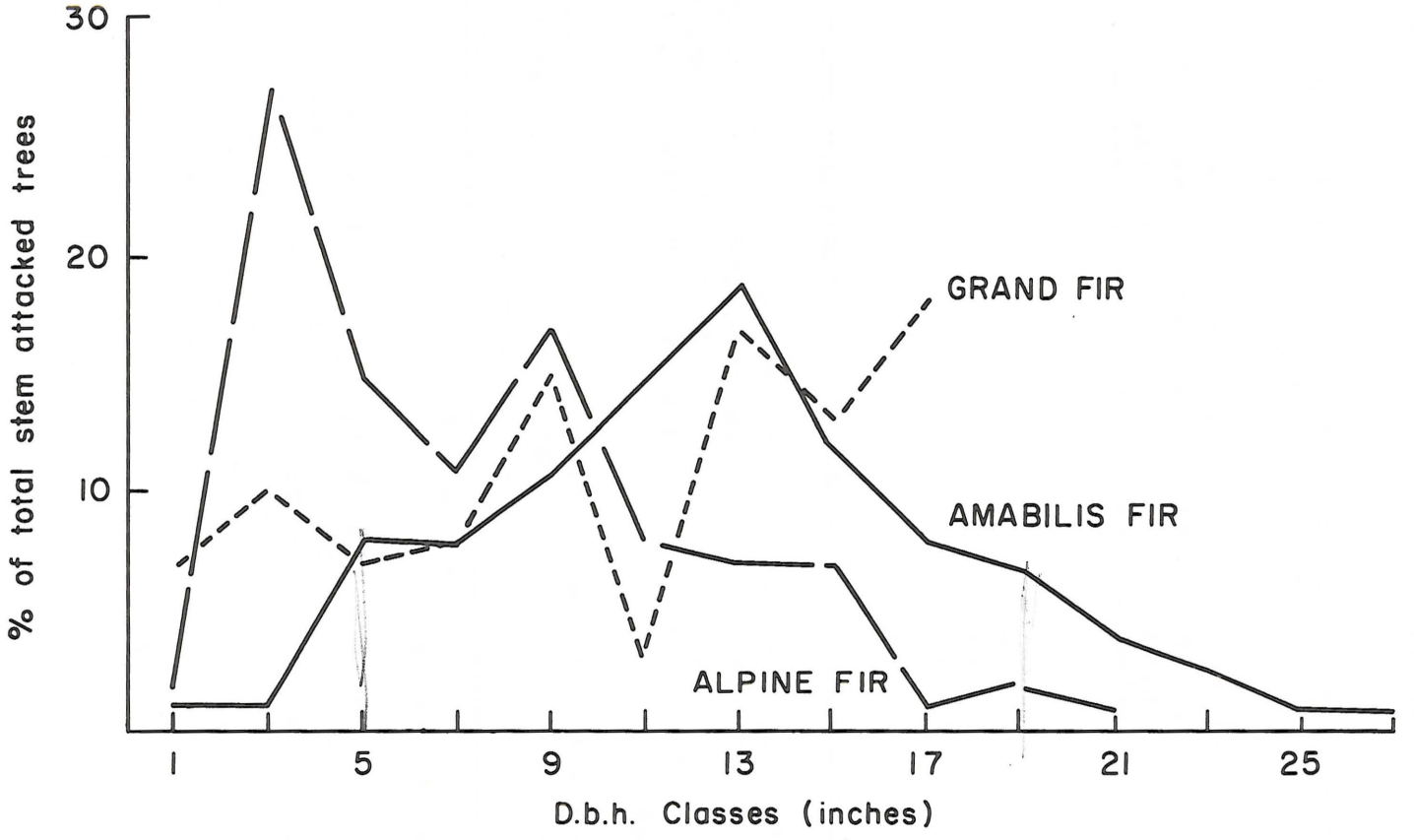

Figure 5. Percentage of total stem attacked[1/] trees occurring in each diameter class on selected[2/] sample plots.

[1/] Trees with medium to heavy stem attack (over 10 aphids/sq inch on part of bole).

[2/] Amabilis fir plots: 5,9,13,14,205; grand fir plots: 99, 100, 101,102; alpine fir plot: 226.

in major infestation category were from A (uninfested) to C (gouted, but no stem attack), but some changes from A to D (gout and stem attack) and from A to B (stem attack but not gouted) also occurred, as did notable changes in the reverse direction, from gouted to non-gouted and from stem attacked to uninfested.

Stem attack is the most easily detectable sign of attack. Some of the more pronounced changes were as follows:

Years	Per cent trees involved	Stem attack appearing (+) or disappearing (-)
1965-1966	5	-
1966-1967	5	+
1966-1968	5	-
1967-1969	14	-
1968-1969	18	+
1968-1970	7	-
1969-1970	17	-

The most significant changes are summarized in Table 3. Changes in amabilis fir were most numerous in 1964-1965 when 27% of the trees became gouted, and in 1965-1966 and 1967-1969 when, in each case, 22% of the trees examined no longer showed gout previously recorded.

In grand fir, the most common change was from stem attack to unattacked (Table 4). The largest single change was in 1965-66, when stem attack disappeared from 15% of the total trees on the plots. Grand fir recovered more readily from damage than amabilis fir; changes in the reverse direction, however, were still significant.

Alpine fir showed rapid changes, indicating that the aphid had a very marked effect on the stand (Table 5). In the first year of examination, only traces of aphid were found on the one infested plot (133 trees) sampled. By the second year, most of the trees were undergoing heavy attack. In 1969 and 1970, the number of living trees had dropped sharply and the damage continued. Recovery of alpine fir was the exception; in the second year of examination, four trees previously rated as gouted were not so rated again, but in subsequent years, all trees showed significant progressive damage.

Foliage Loss

Thinning of crowns due to balsam woolly aphid feeding generally increased as time passed. Average percentage needle loss was negligible for trees on uninfested plots, but increased to nearly 50% on some lightly infested amabilis fir plots (Figure 6)

Table 3. Major changes in yearly infestation ratings on amabilis fir study plots.

Year change	Major rating system[1]				Secondary rating system[2]			
	Total no. of trees	Rating change	No. of trees changing rating	% trees changing rating	Total no. of trees	Rating change	No. of trees changing rating	% trees changing rating
61-62	328	C-A	26	8				
		A-C[3]	17	5				
62-63	367	A-C	18	5				
63-64	340	A-C	20	6				
64-65	308	A-D	21	7				
		A-C	82	27				
		A-B	18	6				
65-66	860	C-A	189	22	781	6'-1	62	8
		B-A	45	5		5'-1	58	7
		A-C	55	6		2 -1	77	10
66-67	684	C-B	35	5	678	5'-1	56	8
		C-A	86	13		1 -5'	65	10
		A-C	174	17		1 -2	67	10
66-68	609	A-C	30	5	607	1 -2	90	15
		A-B	53	9				
67-68	86				86	1 -2	14	16
67-69	671	D-A	44	7	669	9 -1	34	5
		C-A	150	22		5'-1	88	13
		B-A	91	14		5 -1	61	9
						2 -1	46	7
68-69	98	A-B	17	17	98	2 -6	8	8
						1 -5	9	9
						1 -2	5	5
66-70	43	C-A	4	9	43	2 -1	5	12
		A-C	6	14		1 -2	5	12
68-70	632	C-A	36	6	627	2 -1	91	15
		B-A	42	7				
		A-C	62	10				

Table 3. (Concluded)

Year change	Major rating system[1] Total no. of trees	Rating change	No. of trees changing rating	% trees changing rating	Secondary rating system[2] Total no. of trees	Rating change	No. of trees changing rating	% trees changing rating
69-70	83	B-A	15	17	83	2 -4	7	8

1/ A-D = uninfested to heavy; B and C are equivalent.

2/ 1-12 = uninfested to heavy; ratings with like numbers are equivalent.

3/ Changes from apparently uninfested to definitely infested condition are underlined for emphasis.

Table 4. Major changes in yearly infestation ratings on grand fir study plots.

	Major rating system[1]				Secondary rating system[2]			
Year change	Total no. of trees	Rating change	No. of trees changing rating	% trees changing rating	Total no. of trees	Rating change	No. of trees changing rating	% trees changing rating
65-66	254	B-A	37	15	151	2 -6	10	7
		A-B[3]	20	8		2 -4	11	7
66-68	291	D-B	13	5	284	3 -2	12	4
		C-A	30	10		5 -1	16	6
		B-A	24	8		4 -2	10	4
		A-B	20	7		2 -1	17	6
						1 -2	14	5
68-69	70				70	2 -1	5	7
68-70	193	B-A	22	11	193	6 -2	11	6
		A-C	19	10		2 -1	19	10
		A-B	10	5				

[1] A-D = uninfested to heavy; B and C are equivalent.

[2] 1-12 = uninfested to heavy; ratings with like numbers are equivalent.

[3] Changes from apparently uninfested to definitely infested condition are underlined for emphasis.

Table 5. Major changes in yearly infestation ratings on alpine fir study plots.

Year change	Major rating system[1]				Secondary rating system[2]			
	Total no. of trees	Rating change	No. of trees changing rating	% trees changing rating	Total no. of trees	Rating change	No. of trees changing rating	% trees changing rating
67-68	133	C-D	11	8	133	5 -9	15	11
		B-D	28	21		1 -9	24	18
		A-D[3]	39	29		1 -5'	14	10
		A-C	25	19				
68-69	82	C-D	20	24	82	9 -12	8	10
						11 -9	16	20
						5'-11	9	11
69-70	82				82	11 -12	7	9
						9 -12	5	6
						9 -11	6	7

[1] A-D = uninfested to heavy; B and C are equivalent.

[2] 1-12 = uninfested to heavy; ratings with like numbers are equivalent.

[3] Changes from apparently uninfested to definitely infested condition are underlined for emphasis.

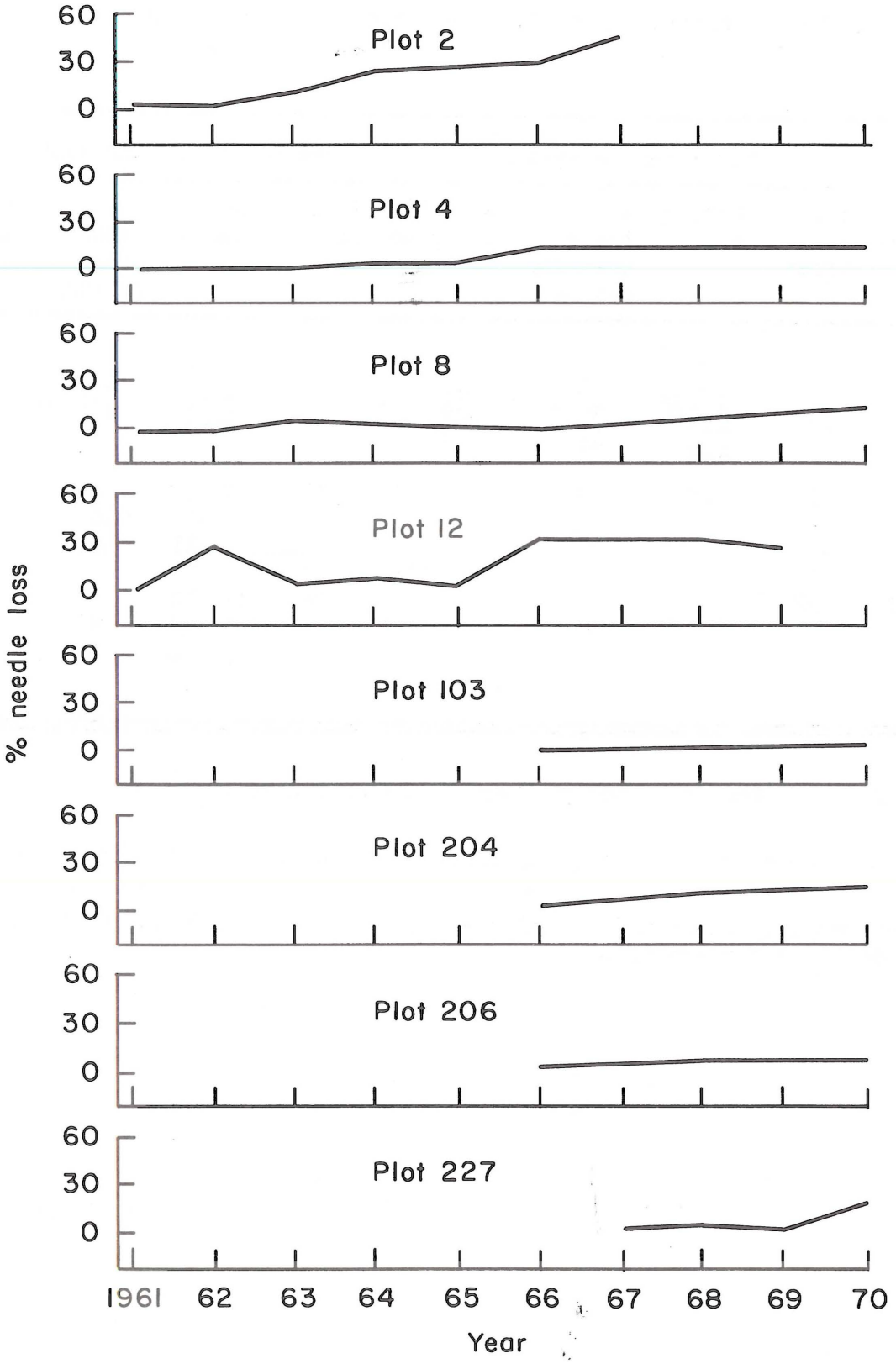

Figure 6. Average per cent needle loss in balsam woolly aphid long-term study plots in B.C., 1961-1970 (lightly infested amabilis fir).

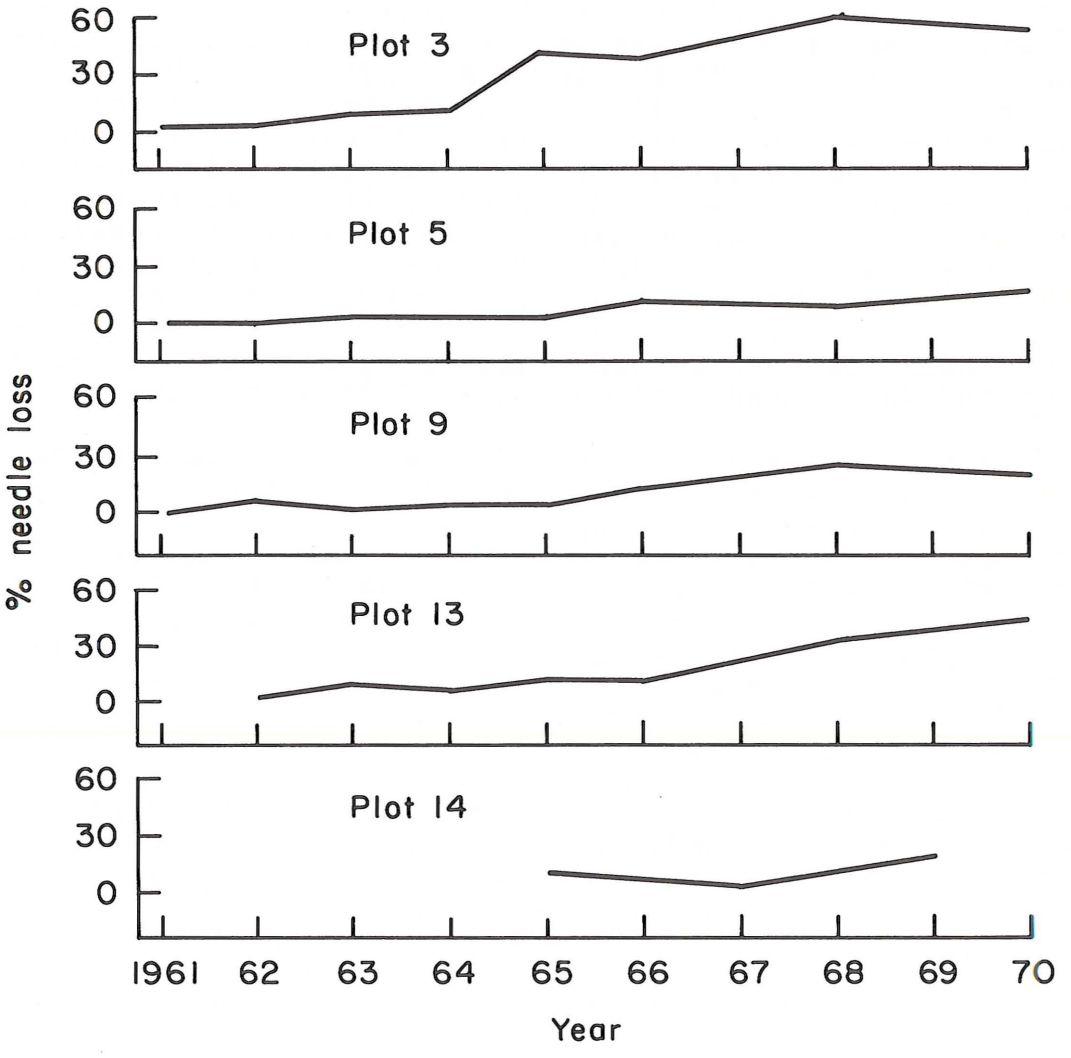

Figure 7. Average per cent needle loss in balsam woolly aphid long-term study plots in B.C., 1961-1970 (moderate-heavily infested amabilis fir).

and to 60% on one moderate-heavily infested plot (Figure 7). However, infested grand fir demonstrated less tendency for needle loss (Figure 8). Trees in the heavily infested alpine fir plot averaged almost 70% defoliation in the final year of examination (Figure 9), while an uninfested plot (plot 212) showed no defoliation.

Tree Mortality

Mortality over 10 years is summarized in Tables 6, 7 and 8, and detailed by plot in Appendix IV and by year in Appendix V. The natural mortality (tree killed/total trees on all plots combined) of amabilis fir on the uninfested plots during 10 years was 3.9% (Table 6, Appendix IV). Mortality credited to the balsam woolly aphid on lightly attacked amabilis fir plots averaged 4.2% while that credited to other natural causes, mostly unknown, was 6.3%. Similarly, moderate-heavily infested amabilis fir plots averaged 12.2% mortality caused by aphid and 11.9% by other causes. Moderate-heavily attacked grand fir suffered 14.4% mortality caused by aphid and 4.1% by other causes (there were no uninfested plots), and alpine fir 63.2% due to aphid. On the infested plot of the latter species there was no mortality clearly attributable to other causes; the uninfested plot exhibited 0.7% mortality.

A second measure of mortality was on an annual basis (Table 7). On uninfested amabilis fir, the natural average annual mortality was 1.2% (Appendix V-A). On lightly attacked plots (Appendix V-B), the average yearly mortality was 1.7% due to aphid (2.1% from other causes), and on heavily attacked plots (Appendix V-C), 4.1% (3.4% from other causes). For heavily attacked plots with grand fir, the average annual mortality was 2.7% from aphid and 1.0% from other causes; for alpine fir, the annual mortality on the infested plot was entirely due to aphid, and averaged 19.4%.

Volume losses were estimated for some of the plots in which the damage seemed heaviest. Significant wood volume losses occurred, with about one-third of the amabilis fir being destroyed by aphid over a 10-year period (Table 8).

Shortly after the aphid was discovered in British Columbia, two plots were established near what is believed to be the first infestation centre; because they were not examined in as much detail as was the main series established later, they were not discussed with the other. They suffered particularly heavy mortality (Table 9): over 12 years, a 57-tree plot on Seymour Mountain lost 84% of the trees to balsam woolly aphid attack, and a plot on Mt. Fromme suffered 66.7% mortality over the same period.

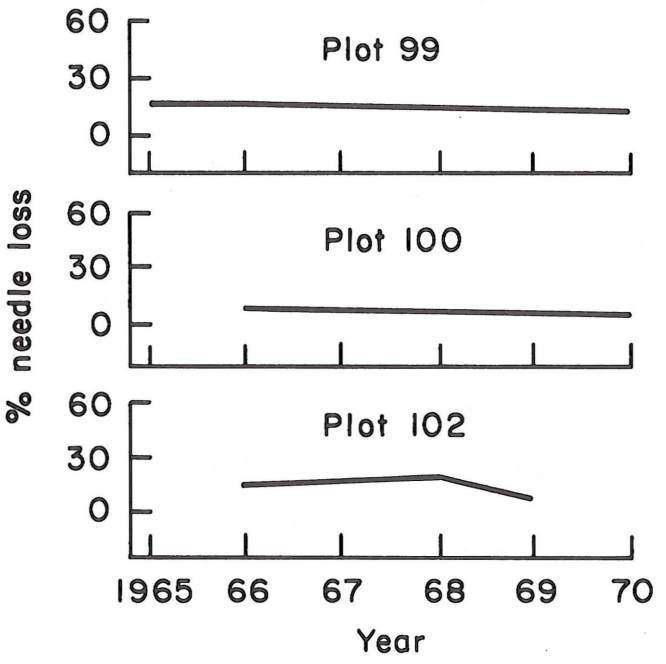

Figure 8. Average per cent needle loss in balsam woolly aphid long-term study plots in B. C., 1965-1970 (moderate to heavily infested grand fir).

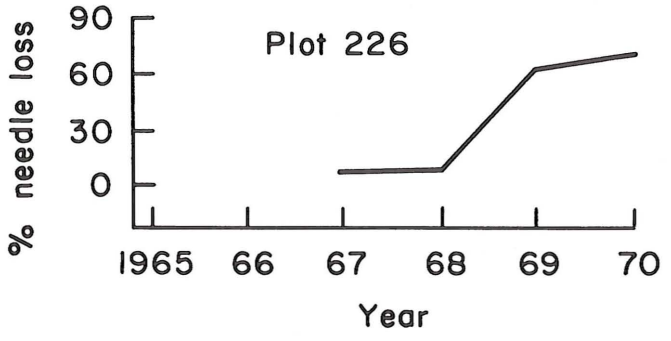

Figure 9. Average per cent needle loss in balsam woolly aphid long-term study plots in B.C., 1965-1970 (moderate to heavily infested alpine fir).

Table 6. Per cent tree mortality on study plots from 1960-1970.

Tree species	Intensity of infestation	No. of trees	Mortality (%)			
			Caused by aphid		Other causes	
			Average[1]	Range[2]	Average	Range
Amabilis fir	uninfested	2,628	0.0	0.0	3.9	0.0-17.4
	light	987	4.2	0.0-38.5	6.3	0.0-18.8
	moderate-heavy	1,319	12.2	0.0-45.0	11.9	0.0-21.1
Grand fir	light	41	0.0	0.0	0.0	0.0
	moderate-heavy	411	14.4	2.3-37.5	4.1	0.0-6.9
Alpine fir	uninfested	147	0.0	X	0.7	X
	moderate-heavy	144	63.2	X	0.0	X

X = 1 plot only ... no range

[1] $\frac{\text{Dead trees in all plots}}{\text{Total trees in all plots}} \times 100.$

[2] Lowest and highest % mortality (2 plots).

Table 7. Average annual per cent tree mortality on study plots from 1960-1970.

Tree species	Intensity of infestation	Mortality (%)	
		Caused by aphid	Other causes
Amabilis fir	Uninfested	-	1.2
	Light	1.7	2.1
	Moderate-heavy	4.1	3.4
Grand fir	Uninfested	-	-
	Light	0.0	0.0
	Moderate-heavy	2.7	1.0
Alpine fir	Uninfested	-	0.2
	Moderate-heavy	19.4	0.0

Table 8. Volume (cu ft) of living and dead trees on selected plots, 1961-1970.

Tree species	Plot No.	Observation period (years)	Living trees		Dead trees			
					Caused by aphid		Other causes	
			Volume (cu ft)	No. of trees	Volume (cu ft)	No. of trees	Volume (cu ft)	No. of trees
Amabilis fir	3	10	835	17	2119	27	195	11
	5	10	815	29	244	5	0	0
	9	10	707	37	902	12	1	1
	13	9	2486	30	2148	23	103	7
	14	5	4746	439	835	41	92	91
	202	5	2950	67	1223	17	2	4
	205	4	3635	114	1472	26	0	0
Totals			16174	733	8943	151	393	114
Grand fir	99	6	2923	106	129	7	0	0
	100	6	1965	93	183	4	1	2
	102	5	3754	92	829	35	0	0
Totals			8372	291	1141	46	1	2
Alpine fir	226	4	741	52	1298	90	0	0
All species			25287	1076	11397	287	394	116

Table 9. Tree mortality on special amabilis fir study plots on Mt. Seymour and Mt. Fromme.

Plot	Year	Total no. of trees	Mortality caused by aphid		Other mortality	
			No. of trees	%	No. of trees	%
15 Mt. Seymour	1959	57	-	-	-	-
	1964	57	26	45.6	5	8.8
	1967	26	15	27.7	-	-
	1971	11	7	63.6	-	-
	Total all years	57	48	84.2	5	8.8
16 Mt. Fromme	1959	57	-	-	-	-
	1964	57	17	29.8	5	8.8
	1967	35	14	14.0	-	-
	1971	21	7	33.3	-	-
	Total all years	57	38	66.7	5	8.8
Total both plots		114	86	75.4	10	8.8

Infestation Related to Stand Characteristics

Tree Dominance

Trees in all crown classes were attacked. In amabilis fir and grand fir, the frequency of attack was highest on dominant trees, slightly lower on codominant trees, and still lower on intermediate trees (Appendix VI). A trend with alpine fir was not apparent, mostly because all crown classes were readily attacked.

Site

Site data for amabilis fir are given in Appendix VII. The factors are, to some extent, related to each other. In this study, aphid attack on amabilis fir occurred only up to 3,000 feet elevation, although there were five apparently otherwise susceptible plots above this (Table 10). Out of 22 light to heavily damaged plots, three (14%) were at elevations higher than 2,000 ft and 19 (86%) were at 2,000 ft or lower.

Significant damage occurred on plots of all aspects (Table 11). Considering host tree species composition of the infested plots, 15 out of 18 had 75% or less amabilis fir (by number of stems). Of a total of 13 plots with more than 75% *Abies* stocking, however, only three were infested (Table 12).

Plots were on all five amabilis fir sites. Sixty-five per cent of the infested plots were in the Vaccinium-Moss/Blechnum associations (Table 13).

Grand fir plots were mostly in the moderate to heavily attacked category. All were at less than 300 ft elevation and were spread over the two major grand fir sites (moss and sword-fern). Only one alpine fir plot was infested; there, trees were growing on rock slides at about 1,400 ft elevation.

DISCUSSION AND CONCLUSIONS

The most significant result of this study was the discovery that a large variety of infestation situations occur. This indicates that a reduction of the balsam woolly aphid problem through manipulation of stand or site will not be simple, even if possible.

Comparison of the most easily measured tree parameters with occurrence of damage revealed, as was already suspected from empirical observations, that the balsam woolly aphid freely attacks trees of all sizes. Although there was some tendency for larger amabilis fir to be more heavily attacked, this was not pronounced, and trees could be stem attacked and/or gouted from seedling to overmature size. That the cw/dbh ratio tended to be smaller for more heavily infested amabilis fir suggested that,

Table 10. Number of amabilis fir plots at various elevations within the area where balsam woolly aphid is commonly found.

Infestation category 1/	Elevation (100 ft)							
	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40
U		1	2	2	5	3	3	2
L	2	5	2	2	1			
H	2	4		2		2		
L+H	4	9	2	4	1	2		

1/ U = uninfested; no aphid.
L = General incidence of aphid and related damage are light.
H = medium to heavy.

Table 11. Number of amabilis fir plots at various aspects within the area where balsam woolly aphid is commonly found.

Infestation category 1/	Aspect								
	Flat	N	NE	E	SE	S	SW	W	NW
U	5		1		4	4	1	1	4
L	4		1	3	1		2	1	1
H	4			1		1	1	3	1
L+H	8		1	4	1	1	3	4	2

1/ See Table 10.

Table 12. Number of amabilis fir plots with % Abies composition within the area where balsam woolly aphid is commonly found.

Infestation category 1/	% Abies			
	0-25	26-50	51-75	76-100
U		2	6	10
L		4	4	2
H	3	1	3	1
L+H	3	5	7	3

1/ See Table 10.

Table 13. Number of amabilis fir plots in sites identified by plant association within the area where balsam woolly aphid is commonly found.

Infestation category 1/	VM 2/	VM-B	B	B-RO	RO
U	10	1	1	2	
L	3	5	2		2
H	1	2	6	1	
L+H	4	7	8	1	2

1/ See Table 10.

2/ Plant association according to Eis (1962). VM = Vaccinium-Moss, VM/B = Vaccinium-Moss/Blechnum transitional association, B = Blechnum Association, B/RO = Blechnum/Ribes-Oplopanax transitional association, RO = Ribes-Oplopanax Association. Preceding are amabilis fir sites.

if Abies are similar in this respect to some other conifers and a small ratio indicates a dense stand, trees in denser stands are more heavily attacked. However, since this conclusion is contrary to the belief of many workers that moderate stand density (i.e., at stand edges, small openings, etc.) is most favorable to aphid, the relationship of cw/dbh to stand density would have to be confirmed with Abies before drawing more definite conclusions. That trees in the more dominant crown classes tended to be attacked more frequently probably was because of the probability of good wind dispersal in the upper, more exposed portions of the crowns of dominant and codominant trees.

Trends barely apparent with amabilis fir were even less clear with grand fir; here the smaller number of trees examined could have prevented the appearance of trends. With alpine fir, however, even though only a few trees were examined, it was apparent that they were highly susceptible to damage and mortality, regardless of size.

Since stem attack figures prominently in any detection survey because it is relatively easy to detect, this factor was examined closely. Amabilis and grand fir under 20 inches dbh and alpine fir under 10 inches were attacked most frequently in this study, so these trees could be featured in detection surveys. Larger trees have thicker bark, at least on the lower bole, so any attack must occur higher up, if at all.

Tree age did not seem to be an important factor in susceptibility to aphid infestation and damage; all ages were affected.

Changes in amabilis fir infestation rating occurred only to about 10% of trees in the annual or biannual examinations and there was no trend to greater or lesser infestation levels. Grand fir tended to recover, but nearly all infested alpine fir died. Foliage loss was a useful expression of tree decline.

Mortality was, of course, the most significant and easily identified damage. Mortality judged to be caused by the balsam woolly aphid added to that resulting from other causes. Recording that a tree died from aphid often involved personal judgment where there were no signs of heavy stem attack. When aphid had been present and no other reasons were apparent, the usual conclusion was that the aphid was at least a serious factor contributing to mortality and it was so recorded. However, that mortality attributed to causes other than aphid increased with infestation intensity on the plots leads one to suspect that undetected aphid played a part...the estimates of aphid-caused mortality were conservative ones.

On an annual basis, tree mortality was very small. Mortality attributed to the aphid about equalled that from other causes, and was in the neighborhood of 1-4% (total mortality 2-8%).

An exception was mortality of alpine fir in the single plot observed: mortality there averaged 19% per year. However, in some years, the situation was more serious: up to 19% of the amabilis fir died in 1968, and 38% of the alpine fir in 1969.

Over the 10-year period, mortality from both aphid and other causes totalled about 24% for amabilis fir but slightly less (18%) for grand fir. Impact of the aphid on alpine fir was considerable (63%) compared with nil estimated from natural causes.

The plot localities were selected in part because of the presence of Abies, ranging up to 92% of the total number of trees, so an indication of total Abies mortality is not meaningful with respect to the rest of the stand. Abies commonly make up only 10-20% of forest stands. In some areas, however, the trees killed were a significant loss. In one case, of the regular plot series, almost 40% of the amabilis fir died over 10 years; in the single infested alpine fir plot, where over 60% of the fir died, it was the only tree species present. The special Mt. Fromme and Mt. Seymour plots suffered 67% and 84% mortality, respectively, over 12 years, but these plots had only 23% and 13% Abies. These two areas are immediately north of Vancouver, and are believed to be at the center of the infestation; the stands appear to have suffered the most intensive damage.

From the point of view of a particular area, mortality can be very significant. The threat must be assessed by land managers in view of the losses and fire hazard created by standing dead timber, and such factors as per cent Abies in an area, accessibility for salvage logging, and watershed and recreational values. Current management recommendations have been to give priority to the logging of areas that are infested or are near infested areas, and which have appreciable amounts of Abies. Killed stands should, of course, be salvaged.

A measure of recent mortality, and average per cent tree defoliation, might be a useful way of recording damage for infestation intensity estimates.

An adequate comparison of aphid infestation with major site factors was not possible because there were insufficient plots on enough different sites for trends to be seen. The limited data, supported by some studies in the Pacific Northwest (Johnson and Wright, 1957; Mitchell, 1966), suggest that the greatest hazard to amabilis fir is on the better, well-drained sites at lower elevations. Even less of an indication of susceptibility is available for grand fir, but the plots with heavy infestation were again on good, low elevation sites with ample moisture and good drainage. Alpine fir sites, of course, cannot be compared because the only known infestation in the province is in a single area, where trees growing on rock slides at 1,400 ft elevation were very heavily attacked, but damage was not observed high on the ridges in the same valley.

This study has examined gross tree and site factors and demonstrated the progression of damage that results from infestation by this pest. As a follow-up to the existing study, more extensive site observations could now be carried out. This could be done by examining a large number of localities within the general area of infestation, both infested and uninfested, to study the relationship between site and damage. Since, from a single examination of an area, we are presently unable to determine whether it is resistant or simply has not been infested, and because it has been impossible to examine more than a limited number of plots annually, it might be advantageous to examine at least once a larger number of locations within each site. This might show trends not evident from smaller numbers of plots examined over a period of time. However, apparently more must be considered than just gross factors, such as tree size, and more information on the susceptibility of individual trees is needed to explain differences within sites. The object of a further study would be to determine if there are sites on which fir could grow and tolerate an acceptable level of damage from the balsam woolly aphid. It would also be useful to determine if some disease factors, such as root rots, may be influencing tree health directly or indirectly through their effect on tree vigor, and increasing susceptibility to the balsam woolly aphid.

In conclusion, it is evident that most trees are susceptible to attack by the balsam woolly aphid, and that there are no clear trends suggesting that gross tree, stand or site factors could be used to identify areas of different susceptibility to damage. It is probable that bark characteristics and lighting, where aphids develop most readily at locations on trees exposed to intermediate lighting, as well as several other factors (site quality, moisture, elevation, etc.), may be significant factors affecting the success of populations. These factors vary according to between-tree and within-tree density (horizontally and vertically within a stand), and if more were known about them, and about the effects of site, it might be possible to manipulate stand conditions in situations of intensive management so as to reduce populations and consequent damage.

SUMMARY

The balsam woolly aphid is an important pest of Abies in British Columbia. Tree, site and infestation data were taken at 52 localities, including almost 6,000 trees, during the period 1959 to 1970, in an attempt to detect relationships between these factors and to observe infestation progress. An infestation rating combining stem attack, gout, crown conditions and crown form was devised.

Infestation was related to tree and site characteristics, and studied over time. Results were extremely variable.

The balsam woolly aphid attacks trees of all ages and sizes, but there was a slight tendency for larger more dominant trees to be attacked more frequently. The trends were more apparent with amabilis fir than with grand fir; alpine fir, studied at a single site, was found to be highly susceptible to damage and mortality.

Limited infestation-site data suggested that the greatest hazard to amabilis fir, the most important of the tree species studied, was on the better, well-drained sites at lower elevations. Infestation was not found above 3,000 ft and there seemed to be no relationship to aspect.

Annual mortality due to aphid was generally small, but ranged from 3% on grand fir and 4% on amabilis fir to 19% per year on alpine fir. At individual localities, however, mortality of Abies over the period of examination ranged up to 84%. While overall damage was small, it was high enough in limited areas to cause concern, with logging of threatened and damaged areas being the principal course of action taken by the land manager.

Future work recommended is a follow-up to site observations already done, examining a larger number of localities to determine infestation-site relationships. Also, more information on the susceptibility of individual trees is needed to explain differences observed within sites. To date, no clear trends have been found that would suggest that tree, stand or site factors could be used to identify areas susceptible to or safe from the balsam woolly aphid.

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APPENDICES

Appendix I-A. Site data for balsam woolly aphid long-term study plots in B.C., 1959-1970.

Plot no.	Location	Size (acres)	Elev (ft)	Aspect	% species composition[1]	Site classification[2]	Plot status[3]
1	Cypress Cr.	0.40	1,800	W	unknown	unknown	H. Logged in 1963.
2	Mt. Fromme	1.20	900	E	"	B	L. 15 trees logged in 1965.
3	Rainy R.	1.20	700	SW	"	B	H. 5 trees logged in 1964.
4	Cypress Cr.	0.60	1,900	SE	58wH, 36aF, 5wC, 1yC	VM-B	L
5	Indian R.	0.30	100	Flat	79aF, 21wH	B	H. 16 trees felled in 1967.
6	Raffuse Cr.	0.60	3,500	S	66aF, 34wH	B	U. Logged in 1965.
7	Britannia Cr.	0.20	2,500	S	50aF, 47wH, 3wC	unknown	U. Logged in 1969.
8	Seymour R. (upper)	0.30	900	Flat	57aF, 43wH	RO	L. 3 trees felled in 1970.
9	Seymour L.	0.40	800	NW	51wH, 48aF, 1wC	B-RO	H
10	Woodfibre	0.40	1,200	S	58aF, 40wH, 2wC	B-RO	U
11	Dakota Cr.	0.60	3,000	SE	63aF, 17wH, 20yC	VM	U
12	McNair Cr.	1.20	600	NE	66wH, 28aF, 5wC, 1D	unknown	L
13	Port Mellon Rd.	2.40	500	Flat	75wH, 20aF, 5wC	B	H

Appendix I-A. (Continued)

Plot no.	Location	Size (acres)	Elev (ft)	Aspect	% species composition[1/]	Site classification[2/]	Plot status[3/]
14	Seymour Mt.	1.60	2,700	W	unknown	VM-B	H
99	Forest Res. Centre	2.80	100	NE	unknown	M-S	H. 48 trees felled in 1968-1970.
100	Thetis L. Park	1.45	200	Flat	52gF, 42D, 6wC	S	H
101	Glenora	0.25	300	Flat	47gF, 26D, 18wC, 8wH, 11P	M-S	L. Felled in 1966.
102	Glenora	1.25	300	Flat	46gF, 22wC, 21wH, 11D	M-S	H. Logged in 1969.
103	Deerholme (Lois L.)	0.50	2,400	Flat	56aF, 27wH, 11wC, 6D	VM	L
104	Deerholme (Lois L.)	1.00	2,400	Flat	77aF, 16wH, 4wC, 3D	VM	U
105	Deerholme	0.25	2,500	NW	92aF, 6wH, 2wC	VM	U. Felled in 1968.
106	Deerholme	1.20	2,000	SE	71aF, 26wH, 3wC	VM	U. 102 trees logged in 1966, 71 felled in 1967.
107	Deerholme	0.50	2,300	NW	83aF, 17wH	VM	U
108	Deerholme	0.25	2,000	Flat	82aF, 18wH	VM	U
201	Seymour R.	0.25	700	Flat	46aF, 45wH, 9Y	VM-B	U. Felled in 1966.
202	Seymour R.	0.75	800	Flat	64aF, 36wH	B	H. 31 trees felled in 1966.
203	Seymour L.	1.25	800	W	51aF, 49wH	VM-B	H. 111 trees logged in 1966, 25 felled in 1966.

Appendix I-A. (Continued)

Plot no.	Location	Size (acres)	Elev (ft)	Aspect	% species composition[1]	Site classification[2]	Plot status[3]
204	Orchard Cr.	1.00	1,500	SW	52aF, 41wH, 6wC, 1Y	VM-B	L
205	Mt. Fromme	1.20	2,700	S	73aF, 27wH	VM	H. 26 trees felled in 1967, 49 logged in 1969.
206	Seymour Mt.	1.05	3,400	W	44aF, 32mH, 13yC, 6wH, 5wC	VM	L
208	Gold Cr.	1.00	600	NW	67aF, 33wH	VM	U
209	Lost Cr.	1.00	1,500	NW	89aF, 11wH	B	U. Logged in 1968.
210	Norrish Cr.	1.00	2,400	W	87aF, 13wH	VM	U
211	Sumallo R.	0.50	2,100	SW	41wC, 35aF, 21S, 2wH	unknown	U
212	Manning Park	1.00	3,800	Flat	51alF, 29S, 161P, 2mH, 2D	unknown	U
213	Capilano R. (upper)	1.00	1,100	Flat	66aF, 31wH, 3wC	B-RO	U
215	Raffuse Cr.	1.00	4,000	S	94aF, 4wH, 2mH	VM	U
216	Britannia Townsite	0.20	3,300	NE	90aF, 10wH	VM	U
217	Furry Cr.	0.30	2,700	SE	89aF, 11wH	VM	U
218	Furry Cr.	0.10	2,700	SE	74aF, 26wH	VM	U
219	Garibaldi Park	0.50	4,800	SE	87aF, 12mH, 1yC	unknown	U

Appendix I-A. (Concluded)

Plot no.	Location	Size (acres)	Elev (ft)	Aspect	% species composition[1]	Site classification[2]	Plot status[3]
220	Seymour R.	0.22	500	E	73aF, 27wH	B	L. Felled in 1967.
222	Lost Cr.	0.20	1,800	SW	82aF, 18wH	B	U
223	Lost Cr.	0.25	1,700	Flat	89aF, 11wH	B	U
224	Capilano R. (Upper)	0.10	900	SW	78aF, 22wH	VM-B	L. Logged in 1967.
225	Balfour Cr.	1.00	800	Flat	77aF, 23wH	RO	L. Logged in 1969.
226	Tretheway Cr.	0.75	1,400	SE	unknown	unknown	H
227	Tretheway Cr.	1.25	1,100	NW	52wH, 48aF	VM	L
228	Indian R.	0.30	100	Flat	unknown	VM-B	L
229	Katherine L.	0.40	1,700	E	unknown	VM-B	L
	Total	38.42					
Special plots:							
15	Seymour Mt.	1.00	1,800	Flat	73wH, 23aF, 4wC	B	H
16	Mt. Fromme	1.00	900	E	74wH, 13aF, 13wC	B	H
	Total	2.00					

1/ Tree abbreviations: aF-Abies amabilis, gF-Abies grandis, alF-Abies lasiocarpa, D-Pseudotsuga menziesii, wH-Tsuga heterophylla
mH-Tsuga mertensiana, Y-Taxus brevifolia, lP-Pinus contorta, wC-Thuja plicata,
yC-Chamaecyparis nootkatensis, S-Picea sp.

2/ Site abbreviations: B-Blechnum, VM-Vaccinium Moss, RO-Ribes-Oplopanax, M-Moss, S-Swordfern.

3/ Infestation and other information. Infestation light-L, moderate-heavy-H, uninfested-U. Year logged-e.g. logged-1969.

Appendix I-B. Host tree data for balsam woolly aphid long-term study plots in B.C., 1959-1970.

Plot no.	Tree species[1/]	Years examined	No. of trees		D.b.h. (inches)			Height (ft)			Age (years)				% trees in crown class				
			Examined first year	Remaining last year	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	No. trees examined	D	CD	I	S	O
1	aF	1961-62	62	62	38	10	2	145	46	7	-	-	-	-	-	-	-	-	-
2	aF	1961-67	48	17	36	19	6	135	104	50	-	-	-	-	13	75	8	4	0
3	aF	1961-66, 1968, 1970	60	23	28	14	1	138	80	7	137	93	63	11	18	41	17	24	0
4	aF	1961-66, 1970	50	41	28	12	2	145	68	6	335	247	150	7	19	15	19	45	2
5	aF	1961-66, 1968, 1970	50	29	25	12	4	120	71	18	26	54	72	10	29	24	41	6	0
6	aF	1961-63, 1965	50	47	45	15	4	-	-	-	-	-	-	-	-	-	-	-	-
7	aF	1961-63	50	50	19	10	3	105	60	14	-	-	-	-	10	28	34	28	0
8	aF	1961-66, 1968-1970	50	38	50	12	3	160	61	14	-	-	-	-	10	14	38	30	8
9	aF	1961-66, 1968, 1970	50	37	31	10	4	125	59	20	205	131	52	10	6	8	52	34	0
10	aF	1961-66, 1968, 1970	50	46	26	10	4	140	58	12	-	-	-	-	8	10	28	54	0
11	aF	1961-66, 1968, 1970	50	47	28	14	4	115	72	11	-	-	-	-	6	37	35	22	0
12	aF	1961-66, 1968, 1969	26	12	45	22	5	175	102	30	-	-	-	-	35	11	31	23	0
13	aF	1962-66, 1968, 1970	60	30	34	17	7	130	93	60	154	88	50	10	20	45	24	11	0

Appendix I-B. (Continued)

Plot no.	Tree species[1/]	Years examined	No. of trees		D.b.h. (inches)			Height (ft)			Age (years)				% trees in crown class				
			Examined first year	Remaining last year	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	No. trees examined	D	CD	I	S	O
14	aF	1965-67, 1969	610	439	37	7	1	154	36	5	194	91	30	23	2	7	36	55	0
99	gF	1965,1966, 1968,1970	173	109	27	12	2	105	47	7	-	-	-	-	9	34	27	15	14
100	gF	1965, 1966, 1968, 1970	102	93	24	8	1	113	46	7	138	77	42	20	6	30	14	50	0
101	gF	1966	41	41	15	8	3	102	62	28	122	83	60	13	-	-	-	-	-
102	gF	1966,1968, 1969	136	85	30	11	1	122	63	5	102	75	37	22	15	36	24	25	0
103	aF	1966,1968, 1970	128	128	12	4	1	93	23	5	149	125	98	9	0	7	9	84	0
104	aF	1966,1968, 1970	296	284	27	9	1	124	51	5	208	168	125	22	2	31	24	43	0
105	aF	1966,1968	120	111	23	6	2	115	35	6	287	202	111	22	11	11	22	56	0
106	aF	1966,1967, 1969	260	256	40	8	1	186	50	6	321	184	98	47	7	21	22	49	1
107	aF	1966,1968, 1970	174	173	30	7	1	132	36	6	306	186	96	20	12	15	31	42	0
108	aF	1967,1969	107	107	32	6	1	155	27	6	329	256	164	9	4	8	21	67	0
201	aF	1966	26	25	18	9	4	105	66	10	175	84	38	12	31	19	19	31	0
202	aF	1966,1968, 1970	124	92	41	10	1	198	57	6	230	142	70	25	11	15	46	28	0

Appendix I-B. (continued)

Plot no.	Tree species[1/]	Years examined	No. of trees		D.b.h. (inches)			Height (ft)			Age (Years)				% trees in crown class				
			Examined first year	Remaining last year	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	No trees examined	D	CD	I	S	O
203	aF	1966	136	128	37	9	2	198	57	7	168	114	36	40	13	28	27	32	0
204	aF	1966,1968, 1970	131	115	30	11	1	165	81	4	135	82	58	28	16	42	16	25	1
205	aF	1966,1967, 1969	167	139	33	11	1	141	54	7	345	124	53	52	20	43	23	13	1
206	aF	1966,1968, 1970	108	106	27	6	1	111	27	1	414	338	212	12	1	11	32	56	0
208	aF	1966,1968, 1970	139	138	18	7	1	82	50	9	116	64	37	20	2	28	30	39	1
209	aF	1966,1968	382	374	38	6	1	192	37	6	234	157	91	32	7	12	21	60	0
210	aF	1966,1968	126	121	33	19	9	156	112	58	159	138	121	21	3	83	14	0	0
211	aF?	1966,1968, 1970	34	34	55	28	2	173	135	30	166	82	64	10	3	85	6	6	0
212	a1F	1966,1968, 1970	147	146	13	6	1	73	38	9	212	91	59	20	0	30	45	25	0
213	aF	1966-70	188	173	47	6	1	172	30	6	177	114	56	20	4	14	41	41	0
215	aF	1966,1968, 1970	91	88	43	23	2	189	118	7	392	345	225	16	34	31	8	27	0
216	aF	1966,1968, 1970	109	90	15	8	4	91	59	24	85	60	46	21	5	55	25	15	0

Appendix I-B. (Concluded)

Plot no.	Tree species	Years examined 1/	No. of trees		D.b.h. (inches)			Height (ft)			Age (years)				% trees in crown class				
			Examined	Remaining	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	No. trees examined	D	CD	I	S	O
217	aF	1966,1968, 1970	97	90	27	10	1	146	66	6	199	121	100	20	6	32	28	34	0
218	aF	1966,1968, 1970	26	22	20	10	3	117	66	13	146	102	83	10	0	35	27	38	0
219	aF	1966,1968, 1970	106	103	43	12	2	151	56	9	477	271	153	18	5	20	33	42	0
220	aF	1967	48	45	35	20	2	167	62	9	266	218	157	5	6	27	17	50	0
222	aF	1967,1969	65	64	32	9	2	146	48	7	257	188	109	10	5	16	14	61	4
223	aF	1967,1969	82	81	33	6	1	161	33	6	235	160	123	8	6	32	28	34	0
224	aF	1967	29	27	41	9	2	170	50	7	242	179	127	3	4	15	11	59	11
225	aF	1967,1969	113	104	44	15	1	169	81	8	208	150	107	19	14	31	20	35	0
226	alF	1967-70	144	53	28	8	1	112	36	5	191	146	89	22	10	18	28	40	4
227	aF	1967-70	96	78	31	16	2	143	99	6	150	106	73	20	27	37	28	8	0
228	aF	1968,1970	44	39	24	11	1	85	45	7	131	97	59	8	18	20	36	18	7
229	aF	1969	116	116	17	8	2	91	41	10	-	-	-	-	18	27	38	17	0
	Total		5,677	4,896															
Special plots:																			
15	aF	1959,1964, 1967	57	11	25	12	2	-	-	-	-	-	-	-	47	47	0	6	0
16	aF	1959,1964, 1967	57	21	29	13	5	-	-	-	-	-	-	-	32	56	10	2	0
	Total		114	32															

1/ aF - Abies amabilis, gF - A. grandis, alF - A. lasiocarpa

Appendix II-A. Average d.b.h. of amabilis fir by infestation rating and year.

Year	Lightly infested plots					Moderately-heavy infested plots				
	No. of trees	A[1/]	B	C	D	No. of trees	A	B	C	D
1961	173	12		24		160	11	17	18	
1962	169	13	17	24	23	219	12	15	19	26
1963	160	12	17	24		207	13	12	18	17
1964	144	12	17	23		197	12	13	16	19
1965	134	13	6	16		749	8	10	8	12
1966	502	8	17	16	20	1160	8	10	10	13
1967	268	14	17	20	14	698	7	11	8	11
1968	534	9	6	24		207	10	12	12	11
1969	208	16	15	26	10	565	8	12	19	
1970	565	9	6	16	13	203	9	10	16	13

1/ A-D = uninfested to heavy.

Appendix II-B. Average d.b.h. of grand fir by infestation rating and year.

Year	Lightly infested plots					Moderately-heavy infested plots				
	No. of trees	A[1/]	B	C	D	No. of trees	A	B	C	D
1965						257	9	13	9	10
1966	41	8	7			398	10	12	8	11
1968						328	10	12	8	9
1969						98	11	14	6	4
1970						211	10	11	10	16

1/ A-D = uninfested to heavy.

Appendix II-C. Average d.b.h. of alpine fir by infestation rating and year.

Year	No. of trees	A[1/]	B	C	D
1967	143	8	6	11	7
1968	133	11	20	9	6
1969	82			10	8
1970	95			7	8

1/ A-D = uninfested to heavy.

Appendix II-D. Average height of amabilis fir by infestation rating and year.

Year	Lightly infested plots					Moderately-heavy infested plots				
	No. of trees	A[1/]	B	C	D	No. of trees	A	B	C	D
1961	171	66		117		159	65	92	98	
1962	167	70	103	118	115	218	72	89	99	118
1963	160	69	103	118		207	74	70	94	95
1964	144	66	110	116		197	72	78	83	102
1965	134	73	34	82		749	42	55	44	64
1966	493	50	93	94	109	1154	47	60	51	61
1967	267	84	95	101	82	698	37	55	40	50
1968	527	55	33	123		203	60	76	70	62
1969	208	92	96	125	76	565	42	58	92	
1970	558	54	35	81	56	201	54	64	88	75

[1/] A-D = uninfested to heavy.

Appendix II-E. Average height of grand fir by infestation rating and year.

Year	Lightly infested plots					Moderately-heavy infested plots				
	No. of trees	A[1/]	B	C	D	No. of trees	A	B	C	D
1965						248	52	70	45	59
1966	25	62	63			375	57	71	52	63
1968						317	58	68	47	51
1969						95	66	81	38	23
1970						203	53	62	53	78

[1/] A-D = uninfested to heavy.

Appendix II-F. Average height of alpine fir by infestation rating and year.

Year	No. of trees	A[1/]	B	C	D
1967	141	35	29	47	33
1968	132	52	87	44	29
1969	82			44	35
1970	95			32	35

[1/] A-D = uninfested to heavy.

Appendix II-G. Average crown width of amabilis fir by infestation rating and year.

Year	Lightly infested plots					Moderately-heavy infested plots				
	No. of trees	A[1/]	B	C	D	No. of trees	A	B	C	D
1961	124	16		23		116	17	23	23	
1962	124	17	12	23		165	19	21	24	27
1963	122	16	12	23		162	19	19	24	24
1964	120	16	15	24		158	19	20	22	24
1965	118	17	15	18		687	13	16	13	18
1966	449	14	21	20	23	1084	14	18	14	17
1967	256	19	21	22	19	683	12	16	12	16
1968	502	15	13	22		205	17	20	18	19
1969	208	20	19	27	12	562	13	17	20	
1970	528	15	12	19	17	203	16	18	21	22

[1/] A-D = uninfested to heavy.

Appendix II-H. Average crown width of grand fir by infestation rating and year.

Year	Lightly infested plots					Moderately-heavy infested plots				
	No. of trees	A[1/]	B	C	D	No. of trees	A	B	C	D
1965						255	15	20	16	17
1966	40	14	13			375	16	19	14	17
1968						325	16	20	16	14
1969						96	16	20	10	11
1970						210	16	20	18	21

[1/] A-D = uninfested to heavy.

Appendix II-I. Average crown width of alpine fir by infestation rating and year.

Year	No. of trees	A[1/]	B	C	D
1967	139	9	11	12	11
1968	133	10	13	10	10
1969	82			10	10
1970	95			9	10

[1/] A-D = uninfested to heavy.

Appendix II-J. Average crown width/d.b.h. of amabilis fir by infestation rating and year.

Year	Lightly infested plots					Moderately-heavy infested plots				
	No. of trees	A[1/]	B	C	D	No. of trees	A	B	C	D
1961	124	2.0		1.1		116	2.0	1.4	1.4	
1962	124	2.1	0.7	1.1		165	1.8	1.6	1.2	1.0
1963	122	2.0	0.7	1.1		162	1.8	1.9	1.3	1.0
1964	120	2.0	0.9	1.2		158	1.8	1.8	1.5	1.1
1965	118	1.8	2.8	1.9		687	2.0	1.7	2.3	1.8
1966	449	2.5	1.5	1.5	1.2	1084	2.0	1.9	1.8	1.6
1967	256	1.8	1.5	1.7	1.9	683	2.0	1.6	2.0	1.5
1968	502	2.3	2.5	1.1		205	2.2	1.8	2.0	2.1
1969	208	1.6	1.4	1.0	1.2	562	1.9	1.6	1.2	
1970	528	2.3	2.7	1.5	1.4	203	2.4	2.0	1.5	1.8

[1/] A-D = uninfested to heavy.

Appendix II-K. Average crown width/d.b.h. of grand fir by infestation rating and year.

Year	Lightly infested plots					Moderately-heavy infested plots				
	No. of trees	A[1/]	B	C	D	No. of trees	A	B	C	D
1965						255	2.4	1.6	2.6	2.5
1966	40	2.1	2.1			375	2.2	1.6	2.7	2.0
1968						325	2.1	1.8	2.8	2.2
1969						96	1.9	1.8	3.1	2.8
1970						210	2.3	2.1	2.4	1.4

[1/] A-D = uninfested to heavy.

Appendix II-L. Average crown width/d.b.h. of alpine fir by infestation rating and year.

Year	No. of trees	A[1/]	B	C	D
1967	139	1.7	1.9	1.4	1.8
1968	133	1.2	0.6	1.5	1.9
1969	82			1.5	1.7
1970	95			1.8	1.7

[1/] A-D = uninfested to heavy.

Appendix III-A. Average tree measurements for heavily infested amabilis fir plots 9, 13, and 14 by infestation rating category.

Plot no.	Year	Tree data	Major rating system[1]					Secondary rating system[2]																
			A	B	C	D	No. of trees	1	2	3	4	5	5'	6	6'	7	7'	8	8'	9	10	11	12	No. of trees
9	1965	dbh	7	6	10	10	46	5	16			6	10		12					12	8			46
		ht	50	35	58	61	46	38	103			35	56		70					70	54			46
		cw	15	12	16	17	45	14	20			12	16		17					18	17			45
		cw/dbh	2.5	2.0	2.2	2.1	45	2.8	1.3			2.0	2.3		1.5					1.8	2.3			45
9	1970	dbh	8	8	14		39	7	8	15	5	8	23	8					12					39
		ht	50	53	71		39	46	61	85	34	55	115	53					63					39
		cw	16	17	18		39	16	14	24	13	19	24	17					16					39
		cw/dbh	2.4	2.4	1.7		39	2.5	2.0	1.9	2.5	2.4	1.0	2.4					1.8					39
13	1966	dbh	16	14	23	22	50	17	9			14	24			12	22		24	18		27		50
		ht	90	89	111	99	50	93	65			90	104			70	117		120	97		103		50
		cw	23	20	26	24	49	24	19			20	26			19	28		25	23		26		49
		cw/dbh	1.6	1.5	1.2	1.1	49	1.6	2.0			1.5	1.1			1.6	1.3		1.0	1.3		1.0		49
13	1970	dbh	14	16	19	14	41	11	18	12		16	19		11		20		18		14			41
		ht	84	100	97	95	41	72	100	75		100	107		82		96		96		95			41
		cw	21	20	24	22	41	17	23	23		20	23		23		24		23		22			41
		cw/dbh	1.6	1.3	1.4	1.6	41	1.6	1.4	1.9		1.3	1.3		2.0		1.3		1.4		1.6			41
14	1965	dbh	7	10	6	9	560	8	5	6	3	11	8	8	4	11	13	5	6	9	9	12	11	559
		ht	36	50	29	45	560	44	27	32	16	54	43	40	21	57	64	30	28	46	43	56	50	559
		cw	12	16	11	15	522	14	10		7	16	13	14	9	17	20	7	12	15	15	14	14	522
		cw/dbh	2.0	1.7	2.5	1.9	522	1.9	2.1		2.4	1.6	1.9	1.8	2.8	1.7	1.7	1.5	3.0	1.9	1.9	1.1	1.2	522
14	1969	dbh	8	12	10		437	9	4	8	9	12			8				12					437
		ht	40	62	51		437	45	22	40	36	62			46				56					437
		cw	13	17	13		436	14	9	14	15	17			12				14					436
		cw/dbh	2.0	1.5	1.3		436	1.8	2.7	2.1	1.7	1.5			1.5				1.1					436

1/ A-D = uninfested to heavy.
2/ 1-12 = uninfested to heavy; like numbers are equivalent.

Appendix III-B. Average tree measurements for heavily infested grand fir plots 99 and 1021-3 by infestation rating category.

Plot no.	Year	Tree data	Major rating system[1]					Secondary rating system[2]																
			A	B	C	D	No. of trees	1	2	3	4	5	5'	6	6'	7	7'	8	8'	9	10	11	12	No. of trees
99	1965	dbh	10	14	17	13	161	10	11	10	9	12	18	14	12			9		18	10			161
		ht	60	71	73	67	152	51	63	72	54	67	73	74				35		62	70			152
		cw	17	20	18	18	160	16	17	14	18	20	19	20	15			19		29	12			160
		cw/dbh	1.9	1.5	1.3	1.4	160	2.2	1.8	1.4	2.2	1.6	1.3	1.5	1.3			2.2		1.6	1.2			160
99	1970	dbh	12	11	11	11	115	11	12	24	16	8	8	12	13				10	11				115
		ht	63	60	65	61	107	48	66	105	77	44	44	69	71				71	61				107
		cw	18	19	17	12	115	21	18	24	18	18	16	20	18				14	12				115
		cw/dbh	1.7	2.0	1.7	1.1	115	2.1	1.7	1.0	1.4	2.7	2.7	1.7	1.5				1.4	1.1				115
1021-3	1966	dbh	12	12	9	10	133	13	8			14	8	5	5	14	9	8	11	11	5	13	12	126
		ht	68	74	57	59	128	74	51			80	45	56	33	72	57		73	58	34	87	77	122
		cw	17	17	12	15	123	19	13			17	12	13	10	18	8	22	13	16	10	21	17	121
		cw/dbh	1.9	1.8	2.5	2.2	123	1.8	2.0			1.5	3.0	2.8	3.1	1.3	2.0	2.7	1.4	2.4	2.6	1.6	1.2	121

1/ A-D = uninfested to heavy.

2/ 1-12 = uninfested to heavy; like numbers are equivalent.

Appendix III-C. Average tree measurements for heavily infested alpine fir plots 2261-2 by infestation rating category.

Plot no.	Year	Tree data	Major rating system[1]					Secondary rating system[2]																
			A	B	C	D	No. of trees	1	2	3	4	5	5'	6	6'	7	7'	8	8'	9	10	11	12	No. of trees
2261-2	1967	dbh	8	7	11	7	143	8	5	12	11	7	11	6	13		7	5	10	6	6	16		143
		ht	35	29	47	33	141	38	20	87	43	32	50	22	55		24	14	30	30	28	67		141
		cw	9	11	12	11	139	10	6	9	4	11	12	11	14		9	17	10	11	9	21		139
		cw/dbh	1.7	1.9	1.4	1.8	139	1.7	1.9	0.9	1.2	1.8	1.4	2.0	1.9		1.3	3.3	1.0	1.9	1.8	1.4		139
2261-2	1970	dbh			7	8	95						10				12		5	9	6	8	7	95
		ht			32	35	95						46				50		21	52	14	38	33	95
		cw			9	11	95						12				12		8	11	8	11	11	95
		cw/dbh			1.8	1.7	95						1.7				1.5		1.9	1.3	2.3	1.7	1.8	95

[1] A-D = uninfested to heavy.

[2] 1-12 = uninfested to heavy; like numbers are equivalent.

Appendix IV-A. Tree mortality on study plots experiencing no aphid attack, 1960-1970.

Tree species	Plot no.	Total no. of trees	Mortality	
			No. of trees	%
Amabilis fir	6	50	2	4.0
	7	50	0	0.0
	10	50	4	8.0
	11	50	3	6.0
	104	296	12	4.1
	105	120	9	7.5
	106	260	4	1.5
	107	174	1	0.6
	108	107	0	0.0
	201	26	1	3.8
	208	139	1	0.7
	209	382	8	2.1
	210	126	5	4.0
	211	34	0	0.0
	213	188	15	8.0
	215	91	3	3.3
	216	109	19	17.4
	217	97	7	7.2
	218	26	4	15.4
	219	106	3	2.8
	222	65	1	1.5
	223	82	1	1.2
	All plots	2628	103	3.9
Alpine fir	212	147	1	0.7
Grand fir	-	0.0	0.0	0.0
Total, all species		2775	104	3.7

Appendix IV-B. Tree mortality on study plots experiencing light aphid attack, 1960-1970.

Tree species	Plot no.	Total no. of trees	Mortality caused by aphid		Other Mortality	
			No. of trees	%	No. of trees	%
Amabilis fir	2	48	11	22.9	5	10.4
	4	50	2	4.0	7	14.0
	8	50	5	10.0	4	8.0
	12	26	10	38.5	4	15.4
	103	128	0	0.0	0	0.0
	204	131	3	2.3	13	9.9
	206	108	0	0.0	2	1.9
	220	48	3	6.2	0	0.0
	224	29	2	6.9	0	0.0
	225	113	0	0.0	9	8.0
	227	96	0	0.0	18	18.8
	228	44	5	11.4	0	0.0
	229	116	0	0.0	0	0.0
	All plots	987	41	4.2	62	6.3
Grand fir	101	41	0	0.0	0	0.0
Alpine fir	-	0	0	0.0	0	0.0
Total, all species		1,028	41	4.0	62	6.0

Appendix IV-C. Tree mortality on study plots experiencing heavy aphid attack, 1960-1970.

Tree species	Plot no.	Total no. of trees	Mortality caused by aphid		Other mortality	
			No. of trees	%	No. of trees	%
Amabilis fir	1	62	0	0.0	0	0.0
	3	60	27	45.0	5	8.3
	5	50	2	4.0	3	6.0
	9	50	11	22.0	2	4.0
	13	60	23	38.3	7	11.7
	14	610	41	6.7	129	21.1
	202	124	28	22.6	4	3.2
	203	136	3	2.2	5	3.7
	205	167	26	15.6	2	1.2
	All plots	1,319	161	12.2	157	11.9
Grand fir	99	173	4	2.3	12	6.9
	100	102	4	3.9	5	4.9
	102	136	51	37.5	0	0.0
	All plots	411	59	14.4	17	4.1
Alpine fir	226	144	91	63.2	0	0.0
Total, all species		1,874	311	16.6	174	9.3

Appendix V-A. Annual tree mortality on study plots experiencing no aphid attack.

Tree species	Year	Total no. of trees examined	Mortality caused by aphid		Other mortality	
			No. of trees	%	No. of trees	%
Amabilis fir	1961	200	-	-	1	0.5
	1962	199	-	-	3	1.0
	1963	195	-	-	3	1.6
	1964	94	-	-	0	0.0
	1965	142	-	-	1	0.7
	1966	2,110	-	-	11	0.5
	1967	462	-	-	2	0.4
	1968	1,841	-	-	54	2.9
	1969	390	-	-	10	2.6
	1970	1,304	-	-	18	1.3
Average for 10 years						1.2
Alpine fir	1966	147	-	-	0	0.0
	1968	147	-	-	1	0.7
	1970	146	-	-	0	0.0
Average for 5 years						0.2

Appendix V-B. Annual tree mortality on study plots experiencing light aphid attack.

Tree species	Year	Total no. of trees examined	Mortality caused by aphid		Other mortality	
			No. of trees	%	No. of trees	%
Amabilis fir	1961	174	4	2.3	2	1.1
	1962	168	4	2.4	6	3.6
	1963	158	6	3.7	2	1.3
	1964	150	1	0.7	4	2.7
	1965	145	5	3.4	2	1.4
	1966	481	1	0.2	5	1.0
	1967	347	6	1.7	4	1.2
	1968	432	8	1.8	19	4.4
	1969	325	0	0.0	7	2.2
	1970	566	6	1.1	11	1.9
	Average for 10 years			1.7		2.1
Grand fir	1966	41	0	0.0	0	0.0

Appendix V-C. Annual tree mortality on study plots experiencing moderate-heavy aphid attack.

Tree species	Year	Total no. of trees examined	Mortality caused by aphid		Other mortality	
			No. of trees	%	No. of trees	%
Amabilis fir	1961	222	0	0.0	1	0.5
	1962	282	3	1.1	4	1.4
	1963	212	1	0.5	4	1.9
	1964	207	1	0.5	6	2.9
	1965	805	8	1.0	51	6.3
	1966	1151	8	0.7	4	0.4
	1967	932	22	2.4	20	2.1
	1968	257	50	19.4	2	7.8
	1969	668	53	7.9	63	9.4
	1970	205	15	7.3	2	1.0
	Average for 10 years			4.1		3.4
Grand fir	1965	275	1	0.4	17	6.2
	1966	396	8	2.0	0	0.0
	1968	385	21	5.4	0	0.0
	1970	342	29	8.5	0	0.0
	Average for 6 years			2.7		1.0
Alpine fir	1967	144	5	3.5	0	0.0
	1968	139	6	4.3	0	0.0
	1969	133	51	38.3	0	0.0
	1970	92	29	31.5	0	0.0
	Average for 4 years			19.4		0.0

Appendix VI-A. Per cent amabilis fir in each dominance class by tree-infestation rating and year.

Year	Dominance classes[1]	Lightly infested plots					Moderately-heavy infested plots				
		A[2]	B	C	D	No. of trees	A	B	C	D	No. of trees
1961	1	38		62		29	50	29	21		28
	2	51		49		53	78	10	12		40
	3	90		10		39	93	4	4		56
	4	93		7		44	94		6		34
	5	100				5					
	1-5	70		30		170	82	9	9		158
1962	1	46	4	50		26	55	11	29	5	38
	2	71	4	23	2	52	86	6	8		66
	3	82		18		39	90	6	4		70
	4	98		2		44	93		7		41
	5	100				5					
	1-5	78	2	20	1	166	83	6	10	1	215
1963	1	42	4	54		26	51	10	28	10	39
	2	61	4	35		51	78	9	9	3	65
	3	82		18		39	78	15	3	3	65
	4	100				39	83	3	14		36
	5	100				4					
	1-5	74	2	25		159	74	10	12	4	205
1964	1	48		52		23	41	14	30	16	37
	2	55	2	43		40	69	10	16	5	61
	3	81		19		37	78	10	10	3	63
	4	100				39	77	3	20		35
	5	100				5					
	1-5	74	1	25		144	68	9	17	6	196
1965	1	50		50		22	15	10	39	37	41
	2	45		55		33	38	17	34	12	101
	3	75	3	22		36	42	23	20	14	277
	4	36	8	56		39	50	5	41	5	313
	5	100				4					
	1-5	53	3	44		134	43	14	32	11	732
1966	1	90	2	8		40	38	6	41	16	101
	2	81	3	12	4	113	46	8	36	11	224
	3	93		7		104	52	12	23	13	405
	4	98	1	2		236	70	2	26	2	409
	5	80		20		5					
	1-5	92	1	6	1	498	56	7	28	9	1139

Appendix VI-A - Concluded

Year	Dominance classes[1]	Lightly infested plots					Moderately-heavy infested plots				
		A[2]	B	C	D	No. of trees	A	B	C	D	No. of trees
1967	1	70	6	21	2	47	25	25	35	15	40
	2	83	6	10	1	89	38	29	19	14	110
	3	95	2	2	2	57	40	19	27	14	251
	4	85	5	9		74	65	1	31	3	280
	5										
	1-5	84	5	10	1	267	49	14	28	9	681
1968	1	88		12		60	32	29	29	11	28
	2	88	7	5		118	49	24	22	6	51
	3	89	9	2		125	45	24	21	10	82
	4	88	12			220	61	7	25	7	44
	5	100				9					
	1-5	89	8	3		532	48	21	23	8	205
1969	1	86	7	7		44	75	6	19		36
	2	87	12	1		67	89	3	8		91
	3	83	13	2	2	48	97	2	1		223
	4	98	2			49	100		1		201
	5										
	1-5	88	9	2	1	208	95	2	3		551
1970	1	70	1	24	4	67	39	11	43	7	28
	2	82	3	12	2	120	19	2	68	11	53
	3	85	3	9	3	128	66	6	23	5	83
	4	89	8	2	1	239	90	3	8		39
	5	71		29		7					
	1-5	84	5	9	2	561	55	5	34	6	203

[1] Dominance classes = 1, dominant; 2, codominant; 3, intermediate; 4, suppressed; 5, open.

[2] A-D = uninfested to heavy tree infestation ratings.

Appendix VI-B. Per cent grand and alpine fir trees in each dominance class by tree-infestation rating and year for moderately-heavy infested plots.

Year	Dominance classes 1/	Grand fir					Alpine fir				
		A 2/	B	C	D	No. of trees	A	B	C	D	No. of trees
1965	1	32	55	5	9	22					
	2	46	44	2	7	84					
	3	64	24	10	2	58					
	4	72	10	11	7	71					
	5	55	36	5	5	22					
	1-5	57	30	7	6	257					
1966	1	44	28	13	15	39					
	2	53	18	15	14	131					
	3	56	19	12	12	89					
	4	60	8	25	8	105					
	5	82	18			22					
	1-5	56	17	16	11	386					
1967	1								22	78	9
	2								35	65	17
	3								12	88	24
	4								26	74	38
	5								43	57	7
	1-5								25	75	95
1968	1	62	32	3	3	34	54	8	38		13
	2	62	29	6	3	111	52	12	28	8	25
	3	65	24	5	6	79	39	37	15	10	41
	4	75	10	11	3	87	68	16	11	5	57
	5	88	12			17	14	43	29	14	7
	1-5	67	22	7	4	328	53	22	18	7	143
1969	1	61	39			18		8	69	23	13
	2	64	30	6		33	24		29	48	21
	3	64	16	8	12	25	3		19	78	37
	4	64	14	23		22	5		22	73	55
	5								43	57	7
	1-5	63	24	9	3	98	7	1	28	65	133
1970	1	87	7		7	15			12	88	8
	2	50	20	20	11	66			27	73	15
	3	69	12	18		49			5	95	22
	4	73	10	16	2	63			19	81	31
	5	88	12			17			17	83	6
	1-5	67	13	15	4	210			16	84	82

1/ Dominance classes = 1, dominant; 2, codominant; 3, intermediate; 4, suppressed; 5, open.

2/ A-D = uninfested to heavy tree infestation ratings.

Appendix VII. Comparison of Site Criteria with Balsam Woolly Aphid Infestation for Amabilis Fir Plots Within Infestation Boundary.

	Elevation (ft)							Aspect									% Amabilis fir				Site				
Plot	0 - 500	501- 1000	1001- 1500	1501- 2000	2001- 2500	2501- 3000	3001- 3500	E	SE	S	SW	W	NW	N	NE	Flat	0- 25	26- 50	51- 75	76- 100	VM	VM/B	B	B/RO	RO
1				H								H													
2		L						L															L		
3		H									H												H		
4				L						L									L				L		
5	H															H				H			H		
7					O					O									O						
8		L														L			L						L
9		H											H						H						H
10			O							O									O						
11						O			O										O		O				
12		L													L				L						
13	H															H	H						H		
14						H						H											H		
15				H											H		H						H		
16		H						H									H						H		
103					L											L			L		L				
104					O											O				O	O				
105					O								O							O	O				
106				O					O										O		O				
107					O									O						O	O				
108				O												O				O	O				
201		O														O		O				O			
202		H														H			H				H		
203		H										H							H			H			
204			L								L								L			L			
205						H				H									H		H				
206							L					L						L			L				
208		O											O						O		O				
209			O										O							O	O		O		
210					O							O								O	O				
213			O													O			O			O			
216							O									O				O	O				

Appendix VII. (Concluded)

Plot	Elevation (ft)							Aspect									% Amabilis fir				Site				
	0 - 500	501- 1000	1001- 1500	1501- 2000	2001- 2500	2501- 3000	3001- 3500	E	SE	S	SW	W	NW	N	NE	Flat	0- 25	26- 50	51- 75	76- 100	VM	VM-B	B	B-RO	RO
217						0			0											0	0				
218						0			0										0		0				
220	L							L											L				L		
222				0							0									0			0		
223				0												0				0			0		
224		L									L								L				L		
225		L														L			L					L	
227			L										L					L			L				
228	L															L						L			
229				L				L														L			

0 = An unattacked plot.

L = A lightly attacked plot.

H = A moderate - heavily attacked plot.