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IMPACT OF BALSAM WOOLLY APHID DAMAGE ON FIR STANDS IN NEWFOUNDLAND

by G. PAGE

NEWFOUNDLAND FOREST RESEARCH CENTRE
ST. JOHN'S, NEWFOUNDLAND
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Impact of Balsam Woolly Aphid Damage on Fir Stands in Newfoundland.

by

G. Page

INTRODUCTION

The balsam woolly aphid[1] was introduced into eastern North America from Europe about the turn of the century (Balch 1952). It was discovered in Newfoundland in 1949, and since then has spread to most parts of the Island except the Northern Peninsula. The area of infestation now extends over more than 6000 square miles, with damage being most extensive in western Newfoundland.

Studies over the past 20 years have yielded a large amount of information on the life cycle of the aphid in Newfoundland (Carroll and Bryant, 1960), its effects on crown, branch, and stem morphology (Warren *et al*, 1967), and on cone and seed production (Schooley and Oldford, 1969). Studies have been carried out on the recovery of young stands damaged by the aphid (Schooley and Oldford, 1972), on the decay of stems killed by the insect (Hudak, 1969), and on possible methods of biological and chemical control (Hopewell and Bryant, 1969; Clark *et al*, 1971). In addition, the spread of infestation has been reported annually by the Forest Insect and Disease Survey (e.g. Clarke *et al*, 1971).

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[1] Balsam wooly aphid, *Adelges piceae* (Ratz.), attacks only true firs, *Abies* spp., represented by *Abies balsamea* (L.) Mill. in Newfoundland.

In 1970, all current research on the balsam woolly aphid at the Newfoundland Forest Research Centre was reviewed and reorganized in the form of a multidisciplinary program. A basic requirement that was identified within this program was the need for a study to determine the impact of aphid damage on the volume production of fir stands thus permitting an objective and quantitative evaluation of the practical significance of aphid damage to forestry in Newfoundland. The first phase of this study was carried out in western Newfoundland in 1971 and preliminary results have already been reported (Page, Hudak, and Banfield, 1972). Further work was carried out during 1972 in semi-mature and mature stands in several parts of the Island, and results are presented in this report. Information is given on the magnitude of volume losses resulting from aphid damage, and on the relationships between the occurrence and severity of damage and a number of site and stand characteristics.

STUDY AREAS

The 1972 study was carried out in 21 different locations across the Island. Transects were established at 13 locations, and a number of plots were measured in selected badly damaged stands at a further 8 locations (Table 1). Transects were situated near Logy Bay and Swift Current in eastern Newfoundland (Forest Section B.30; Rowe, 1959), at Lawrenceton, Badger, and Lloyd's River in central Newfoundland (Forest Section B.28a), and at Bonne Bay, Serpentine Lake, York Harbour, Fox Island River, Camp 33, Flat Bay Brook, Codroy Pond, and South Branch in western Newfoundland (Forest Section B.28b). Selected "bad damage"[2] plots

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[2] Individual sample plots located in selected stands having a very high proportion of severely damaged and aphid killed stems.

Table 1.- Location, number of years of aphid damage and age of sample stands.

Study areas	Number of sample plots	Number of years since aphid damage first recorded[a]	Average breast height age (years)[b] (year)
1972 Transects			
1) Logy Bay	10	22	50
2) Swift Current	10	10	33
3) Lawrenceton	10	11	66
4) Badger	8	8	54
5) Lloyd's River	3	11	57
6) Bonne Bay	10	8	58
7) Serpentine Lake	10	16	72
8) York Harbour	10	18	60
9) Fox Island River	10	17	54
10) Camp 33	10	13	65
11) Flat Bay Brook	10	22	55
12) Codroy Pond	12	24	49
13) South Branch	10	24	43
"Bad damage" plots			
14) Central Nfld. (Lewisporte, Embree, Lawrenceton, Eel Brook)	10	10-12	47
15) Western Nfld. (St. Fintans, Robinsons, Bottom Brook, Deer Lake)	8	16-24	48
1971 Transects[c]			
16) Pynn's Brook	104	16	41
17) Snug Harbour	105	18	54
18) Gillams	74	17	56

[a] Data from Forest Insect and Disease Survey records.

[b] Based on dominant and co-dominant stems in damaged portions of transects only.

[c] Data for 1971 transects are used in some of the analyses presented in this report.

were located near Lewisporte, Embree, Lawrenceton, and Eel Brook in central Newfoundland and near St. Fintan's, Robinsons, Bottom Brook, and Deer Lake in western Newfoundland. Data from transects established in 1971, at Pynn's Brook, Snug Harbour, and Gillams, were also used in some of the analyses. Locations of all study areas are shown in Fig. 1.

These study areas represent most of the climatic regions of the Island with the exception of the Northern Peninsula. Average age of the stands sampled ranged from 43 to 72 years at breast height except at Swift Current where stands averaged only 33 years of age; individual plot ages ranged from less than 20 up to 100 years. Most of the stands were composed predominantly of balsam fir, although a few plots where fir was only a minor stand component were also measured. A wide range of site conditions was sampled, but no wet sites were encountered. Aphid damage had been present in the study areas for from 8 to 24 years (Table 1).

METHODS

A total of 141, 1/10-acre sample plots were measured during 1972. Eighteen "bad damage" plots were in selected stands where very severe aphid damage had occurred. The remaining 123 plots were located at regular intervals along 13 transects in stands containing average levels of aphid damage (Table 1). Most transects contained 10 plots. However, 12 plots were measured on an exceptionally long transect at Codroy Pond, while only 8 and 3 plots were measured at Badger and Lloyd's River, respectively, because of the limited extent of aphid damage in those two areas.

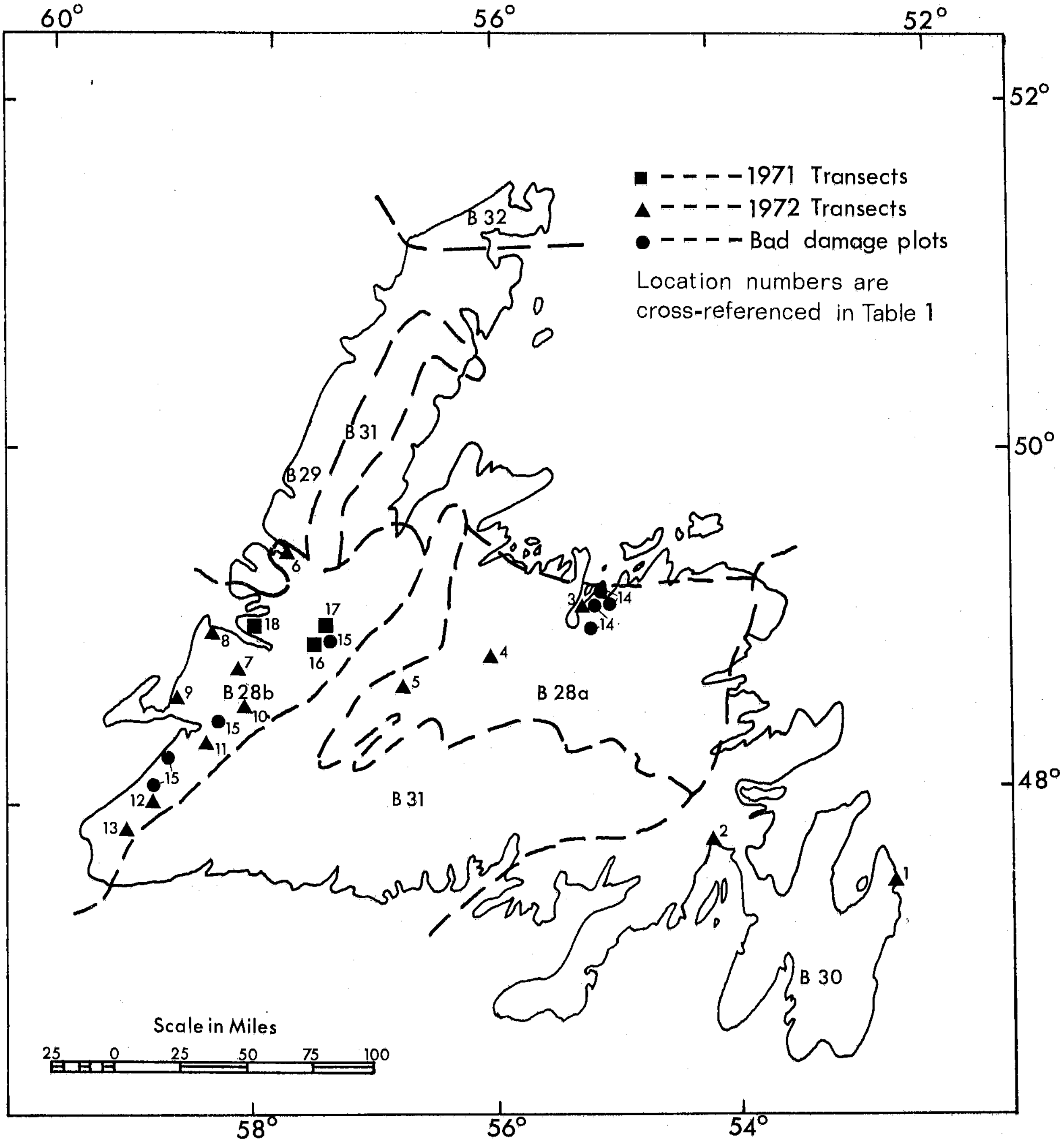

Figure 1. Island of Newfoundland, showing locations of stands sampled during 1971 and 1972.

The following information was collected from each sample plot:

All trees of more than 0.5 inches DBH were tallied by species and 1-inch DBH classes. In addition, the tally for living balsam fir stems was subdivided into four aphid damage classes (undamaged (U), light (L), moderate (M), severe (S)), according to the damage classification given in Appendix I. The tally for dead fir stems was subdivided into two classes (undamaged (D_U) and aphid damaged (D_A)). Trees presently in the light and moderate damage classes, showing well-marked recovery of vertical growth (either through renewed mainstem development or branch re-orientation), were tallied separately. The crown class, breast height age, breast height diameter, and total height was recorded for up to 5 trees in each of the above damage classes. A record was also made of elevation, aspect, percent slope, soil moisture regime (see Appendix II), soil type, soil texture, depth of H layer, and distance from the plot boundary to any major stand opening (up to a maximum of 50 feet).

Balsam fir height-diameter curves were prepared for each aphid damage class and for all damage classes combined. These curves were used, together with special volume tables prepared earlier for aphid damaged trees (Page, Schooley, and Hudak, 1970), to determine gross volumes for balsam fir on each sample plot. Gross volumes for other species were determined using the standard Newfoundland volume tables (Page, et al, 1971).

Relationships between number of living stems per acre and average DBH were determined for the aphid damaged sample plots and for the undamaged sample plots from the transects, and also for all the selected "bad damage" plots. The three sets of relationships were subsequently compared to determine whether aphid damage had caused any alteration in the normal relationship (i.e. whether there had been any changes in the degree of site utilization as a result of aphid damage). Relationships between number of living stems per acre and breast height age were also determined for aphid damaged and for undamaged plots from the transects, and compared to determine whether there had been any alteration of the normal pattern of stand development as a result of aphid damage.

Results of the tests listed above were used to determine whether or not any adjustments were necessary to convert observed diameters and numbers of stems per acre to their equivalents in these same stands in the absence of aphid damage. Normal (undamaged) height/diameter curves and volume tables for all species including fir were then used, together with actual or adjusted tally data, as appropriate, to derive a second volume estimation, the "undamaged equivalent" volume, for each of the sample plots on which aphid damage was recorded. Differences between the actual (damaged) and the "undamaged equivalent" volume estimates, for individual sample plots and for complete transects, were then determined to provide a measure of the impact of aphid damage on the volume production of the stands being investigated.

RESULTS

Aphid Damage Conditions

A wide variety of aphid damage conditions were recorded, including plots with no damage and plots with all stems damaged. This variation occurred both within and between transects. Table 2 shows the observed minimum, maximum, and mean distribution of fir stems among the five aphid damage classes for the eastern, central, and western parts of the Island, for the selected "bad damage" plots, and for the whole Island (all plots combined). Differences between the

% of B.F. stem in each plot ?
or % of stems with aphid damage ?

Table 2.- Observed minimum, maximum, and mean percent distribution of balsam fir by aphid damage classes, in terms of number of stems and basal area, based on plots in the low elevation (damaged) portions of transects only.

	Percent distribution of balsam fir by aphid damage classes														
		U			L			M			S			D_A	
Area	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Western Newfoundland (Forest Section B.28b)															
By number of stems	0	100	44	0	98	24	0	64	14	0	79	8	0	95	11
By basal area	0	100	42	0	91	20	0	70	17	0	75	13	0	93	9
Central Newfoundland (Forest Section B.28a)															
By number of stems	0	100	50	0	82	20	0	78	20	0	25	5	0	19	4
By basal area	0	100	48	0	90	19	0	84	19	0	31	8	0	24	4
Eastern Newfoundland (Forest Section B.30)															
By number of stems	0	100	67	0	95	10	0	52	10	0	78	10	0	40	5
By basal area	0	100	67	0	99	10	0	61	11	0	75	10	0	34	3
"Bad damage" plots															
By number of stems	0	0	0	0	14	3	1	65	27	10	81	47	3	56	23
By basal area	0	0	0	0	7	1	2	59	25	28	87	52	1	63	22
Whole Island (all plots)															
By number of stems	0	100	43	0	98	19	0	78	16	0	81	13	0	95	11
By basal area	0	100	41	0	99	16	0	84	17	0	87	17	0	93	9

regional averages shown in Table 2 were generally much less than differences between transects and between plots within transects.

In general, an increase in the incidence of aphid damage in a stand was associated with an increase in the proportion of more severely damaged stems in that stand (Table 3). Less than 20 percent of all fir stems were in the moderate, severe, and aphid-killed damage classes in plots which were less than 50 percent damaged. In contrast, more than 80 percent of all fir stems were in these three classes in plots where all stems were damaged.

An overall average of 7 percent of all fir stems in the light and moderate damage classes showed well-marked recovery symptoms; these trees represented about 4 percent of the total basal area (Table 4). Relatively high proportions of recovery were recorded at Logy Bay, South Branch, Flat Bay Brook, and Fox Island River. In contrast, very few trees showed recovery growth at Lloyd's River, Badger, Swift Current, Bonne Bay, York Harbour, Serpentine Lake, and Camp 33.

Basic Mensurational Relationships

Differences between height/diameter curves for fir stems in the various aphid damage classes (including undamaged) were all small and inconsistent. One amalgamated curve for stems in all damage classes was therefore prepared (Appendix III) and used in the volume determinations.

Relationships between total number of living stems per acre and average DBH for damaged and undamaged plots from the transects, and for the "bad damage" plots, are shown in Figure 2. In the case of transect plots with average diameters of less than about 6 inches, the relationships for damaged and undamaged stands differ only marginally from one another. However, where average diameters are greater than 6 inches, the difference between damaged

tests of significance?

Table 3.- Average percent distribution of balsam fir by aphid damage classes, in terms of number of stems and basal area, according to overall incidence of damage.

Aphid damage class, and area	Percent of all fir stems damaged <25%[a]		25-49%		50-74%		75-99%		100%	
	No. stems	Basal area	No. stems	Basal area	No. stems	Basal area	No. stems	Basal area	No. stems	Basal area
Class U										
Western Nfd	89.8	98.9	60.5	54.8	35.0	34.1	9.2	7.9	0	0
Central Nfld.	85.4	77.3	-[b]	-[b]	25.9	-[b]	11.5	9.7	0	0
Eastern Nfld.	86.8	88.8	67.4	64.0	-	-	4.6	0.6	0	0
"Bad damage" plots	-[b]	-[b]	-	-	-	-	-[b]	-[b]	0	0
All plots	87.6	89.9	63.5	59.4	33.2	34.1	9.2	7.9	0	0
Class L										
Western Nfld.	5.3	0.7	28.8	21.9	48.0	40.2	54.1	50.8	30.0	17.7
Central Nfld.	14.6	22.7	-	-	64.7	-	55.9	57.8	24.3	20.2
Eastern Nfld.	3.7	3.7	10.6	11.7	-	-	95.5	99.4	11.9	9.5
"Bad damage" plots	-	-	-	-	-	-	-	-	3.1	1.1
All plots	5.4	5.3	21.0	19.1	51.3	40.2	56.7	54.1	19.2	12.0
Class M										
Western Nfld.	4.3	0.3	9.7	11.9	8.9	17.6	21.2	24.5	26.5	30.9
Central Nfld.	0	0	-	-	2.9	-	25.0	18.6	52.6	50.1
Eastern Nfld.	5.6	4.8	11.1	17.9	-	-	0	0	32.7	35.0
"Bad damage" plots	-	-	-	-	-	-	-	-	27.2	24.5
All plots	5.0	3.1	10.3	14.9	7.7	17.6	20.4	22.4	30.5	31.5
Class S										
Western Nfld.	1.3	0.6	2.7	9.2	4.2	4.7	9.8	17.6	19.1	27.1
Central Nfld.	0	0	-	-	4.4	-	5.3	9.6	13.2	19.9
Eastern Nfld.	1.3	0.7	3.3	2.6	-	-	0	0	44.1	45.6
"Bad damage" plots	-	-	-	-	-	-	-	-	46.4	52.1
All plots	1.2	0.6	3.0	5.9	4.2	4.7	8.7	15.4	29.1	35.7
Class D_A										
Western Nfld.	0	0	0.8	2.1	4.4	3.4	5.7	2.0	28.6	24.5
Central Nfld.	0	0	-	-	3.3	-	2.4	4.4	9.9	9.8
Eastern Nfld.	2.6	2.0	7.6	3.7	-	-	0	0	11.3	10.0
"Bad damage" plots	-	-	-	-	-	-	-	-	23.3	22.3
All plots	1.4	1.3	3.7	2.9	4.2	3.4	5.0	2.3	23.3	20.8

[a] Excluding plots with no damage

[b] No data available

Table 4.- Incidence of recovery of leader growth on trees in light and moderate damage classes[a]

Study area	Damage class L Percent stems with recovery[b]	Damage class L Percent of total basal area in recovery trees	Damage class M Percent stems with recovery[b]	Damage class M Percent of total basal area in recovery trees
Logy Bay	24.6	33.4	32.9	46.4
Swift Current	2.0	0.4	1.0	0.2
Lawrenceton	4.8	0.5	5.4	1.0
Badger	3.5	0.3	0	0
Lloyds River	0	0	0	0
Bonne Bay	2.7	0.5	1.6	0.2
Serpentine Lake	2.5	0.2	3.6	0.5
York Harbour	1.3	0.3	2.2	0.5
Fox Island River	9.1	4.5	9.1	2.9
Camp 33	5.4	0.9	0	0
Flat Bay Brook	17.0	10.7	9.5	5.8
Codroy Pond	6.9	1.4	6.1	0.7
South Branch	10.8	2.6	19.5	8.1
Western Nfld.	6.8	2.1	8.5	2.7
Central Nfld.	4.1	0.4	4.8	0.8
Eastern Nfld.	16.9	29.5	19.8	38.8
"Bad damage" plots	3.8	2.7	3.4	0.9
All plots	7.0	3.5	7.1	4.6

[a] Severely damaged trees which develop well-marked recovery of leader growth normally revert to the moderate damage class.

[b] Based on damaged plots only.

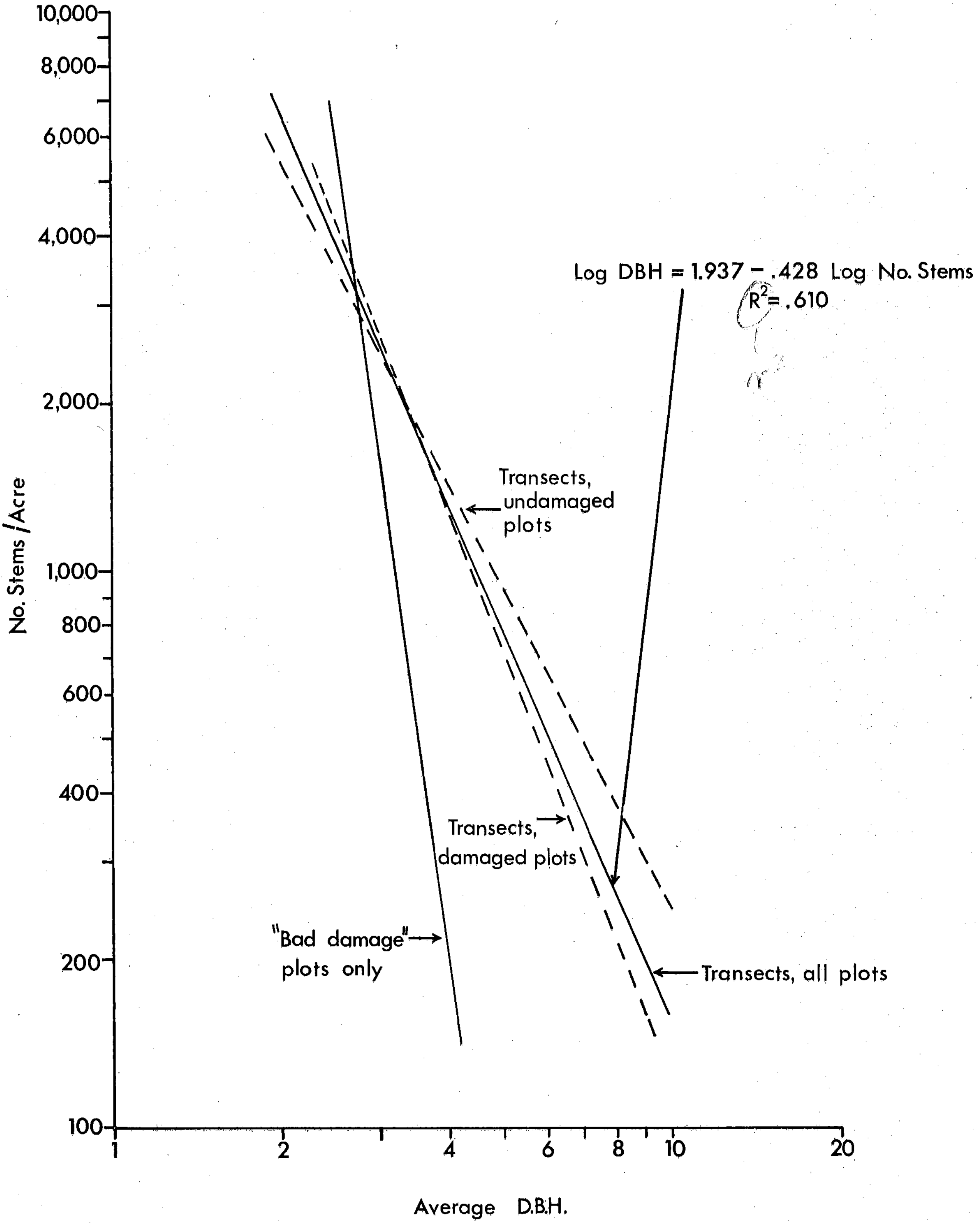

Figure 2. Number of living stems per acre/average DBH curves for damaged and undamaged transect plots, and "bad damage" plots.

~~[illegible]~~ – what standard?

and undamaged plots becomes sufficient to be of practical significance. The relationship for "bad damage" plots differs markedly from those for damaged and undamaged transect plots. Because of their marked divergence from the normal relationship between number of stems and average DBH, "bad damage" plots and those damaged transect plots with average diameters in excess of 6 inches received special adjustments prior to calculation of their "undamaged equivalent" volumes. The number of living fir stems in each of these plots was increased, in proportion to the average diameter of the plot, to the number that would be expected if the plot were undamaged. No adjustments of tally data were made for transect plots with average diameters of less than 6 inches.

Data for average numbers of living stems per acre in relation to age are presented in Table 5. Data for individual transects were very erratic because of differences in ages, species composition, and site conditions; therefore only whole Island data have been presented in Table 5. No consistent differences in numbers of stems are apparent between soil moisture classes, and the overall average number of stems per acre is 1,920 for both damaged and undamaged plots at an average age of 51 to 52 years. There is thus no evidence that stand development has been slowed as a result of aphid damage, and consequently no adjustments to tally data were necessary in this regard.

Test of significance

why not [illegible] important check

Conclusion not warranted

Volume Determinations

Volume tables were constructed for fir stems in each aphid damage class using the amalgamated height/diameter curve referred to above and standard volume equations for aphid damaged trees (Page, Schooley, and Hudak, 1970); tables produced are presented in Appendix III. Actual gross total and

Table 5.- Mean numbers of living stems per acre and mean breast height ages, by soil moisture classes, for damaged and undamaged plots (whole Island)[a]

	Number of living stems per acre	Mean breast height age(years)
Damaged Plots		
Dry and fresh sites	2060	47
Moist sites	1750	58
All sites	1920	51
Undamaged Plots		
Dry and fresh sites	1660	50
Moist sites	2180	54
All sites	1920	52

[a] Transects where only dry and fresh sites or only moist sites were recorded have been excluded from this table.

merchantable volumes for the balsam fir component of each sample plot were derived by applying these volume tables to the tally data for each aphid damage class. "Undamaged equivalent" volumes for the balsam fir component of each of these same sample plots were obtained by applying "undamaged" (Class U) volumes to all fir stems tallied, regardless of their present aphid damage class. In the case of "bad damage" plots and transect plots with average diameters in excess of 6 inches, adjusted tally data (adjusted as described above) were used in the "undamaged equivalent" volume calculations.

Actual and "undamaged equivalent" gross volume estimates for balsam fir, all softwoods, and all species, are presented in Tables 6-8. Volumes are listed for all plots and for damaged plots only, for each of the three regions of the Island and for the whole Island.

Small volume increases, averaging up to 3.5 percent were recorded as a result of aphid damage in eastern and central Newfoundland. This small increase reflects the high proportion of moderately damaged stems in many stands within these two regions (moderate damage increases the average volume of stems below 11 inches DBH; see Appendix III) and the generally low proportion of severely damaged and aphid killed stems. In western Newfoundland aphid damage has, in general, reached more severe levels, and has resulted in overall volume losses ranging from 3.0 percent based on total volume of all species up to 9.4 percent based on merchantable volume of balsam fir alone. Average volume losses in "bad damage" plots were about 25 percent.

Differences between actual and "undamaged equivalent" volume estimates for individual transect plots did not diverge greatly from the overall estimates quoted above. Losses or gains of more than 5 percent of the merchantable balsam fir volume were recorded on only 11 plots, mostly at Serpentine Lake and York Harbour where the stands contained a high proportion of severely damaged stems. Losses as high as 90 percent were recorded on some of the selected "bad damage" plots.

Site, Tree and Stand Factors Associated with Variations in Aphid Damage.

There is a strong association between elevation and the occurrence and severity of aphid damage in all sample areas. Severity of damage generally decreased with increasing elevation, and damage was entirely absent above elevations ranging from 160 feet at Swift Current to 1550 feet at York Harbour

Table 6.- Summary of actual and "undamaged equivalent" volumes of balsam fir.

	Total volumes (cu. ft.)				Merchantable volumes (cu. ft.)			
Area	Actual volume	"Undamaged equivalent" volume	Difference	% Difference	Actual volume	"Undamaged equivalent" volume	Difference	% Difference
Western Nfld.								
All plots	13,778	14,394	-616	-4.27%	11,710	12,411	-701	-5.65%
Damaged plots only	8,490	9,106	-616	-6.76%	6,738	7,439	-701	-9.42%
Central Nfld.								
All plots	2,409	2,359	+50	+2.11%	2,131	2,100	+31	+1.47%
Damaged plots only	1,462	1,412	+50	+3.54%	1,353	1,322	+31	+2.34%
Eastern Nfld.								
All plots	3,213	3.182	+31	+0.97%	2,478	2,461	+17	+0.69%
Damaged plots only	2,403	2,372	+31	+1.30%	1,903	1,886	+17	+0.90%
"Bad damage" plots								
All plots	2,538	3,370	-832	-24.68%	1,819	2,462	-643	-26.11%
Whole Island								
All plots	21,938	23,305	-1367	-5.86%	18,138	19,436	-1298	-6.67%
Damaged plots only	14,893	16,260	-1367	-8.40%	11,813	13,111	-1298	-9.90%

Table 7.- Summary of actual and "undamaged equivalent" softwood volumes.

	Total volumes (cu. ft.)				Merchantable volumes (cu. ft.)			
Area	Actual volume	"Undamaged equivalent" volume	Difference	% Difference	Actual volume	"Undamaged equivalent" volume	Difference	% Difference
Western Nfld.								
All plots	16,107	16,723	-616	-3.68%	13,435	14,136	-701	-4.95%
Damaged plots only	10,018	10,634	-616	-5.79%	8,285	8,986	-701	-7.80%
Central Nfld.								
All plots	3,449	3,399	+50	+1.47%	2,880	2,849	+31	+1.08%
Damaged plots only	2,264	2,214	+50	+2.25%	1,913	1,882	+31	+1.64%
Eastern Nfld.								
All plots	3,723	3,692	+31	+0.83%	2,950	2,933	+17	+0.57%
Damaged plots only	2,633	2,602	+31	+1.29%	1,949	1,932	+17	+0.87%
"Bad damage" plots								
All plots	2,740	3,572	-832	-23.29%	1,963	2,606	-643	-24.67%
Whole Island								
All plots	26,018	27,385	-1367	-4.99%	21,226	22,524	-1298	-5.76%
Damaged plots only	17,654	19,021	-1367	-7.18%	14,068	15,366	-1298	-8.44%

Table 8.- Summary of actual and "undamaged equivalent" volumes (all species).

	Total volumes (cu. ft.)				Merchantable volumes (cu. ft.)			
Area	Actual volume	"Undamaged equivalent" volume	Difference	% Difference	Actual volume	"Undamaged equivalent" volume	Difference	% Difference
Western Nfld.								
All plots	20,267	20,883	-616	-2.95%	17,078	17,779	-701	-3.94%
Damaged plots only	13,224	13,840	-616	-4.45%	11,082	11,783	-701	-5.95%
Central Nfld.								
All plots	3,989	3,939	+50	+1.27%	3,254	3,223	+31	+0.96%
Damaged plots only	2,308	2,258	+50	+2.21%	1,903	1,872	+31	+1.66%
Eastern Nfld.								
All plots	3,969	3,938	+31	+0.79%	2,950	2,933	+17	+0.58%
Damaged plots only	2,816	2,785	+31	+1.11%	2,175	2,158	+17	+0.79%
"Bad damage" plots								
All plots	3,103	3,935	-832	-21.14%	2,209	2,852	-643	-22.55%
Whole Island								
All plots	31,328	32,695	-1367	-4.18%	25,491	26,789	-1298	-4.84%
Damaged plots only	21,451	22,818	-1367	-5.99%	17,369	18,667	-1298	-6.94%

(Table 9). In addition, all selected "bad damage" plots were at elevations of less than 500 feet and all but two at less than 300 feet. The maximum elevation at which damage occurred in each area appeared to be associated with the age of the stands, the length of time damage had been present in the area, and the degree of shelter provided by surrounding hills. Study areas were therefore split into 3 groups on the basis of average stand age and period of damage so as to permit analyses of the relationships between the maximum elevation of aphid damaged stands and the height of surrounding hills:

<u>Group A</u> contained areas where the average age of the stands was more than 45 years at breast height and where damage had been present for 15 or more years (Logy Bay, Snug Harbour, York Harbour, Serpentine Lake, Gillams, Fox Island River, Codroy Pond, Flat Bay Brook). n = 8

<u>Group B</u> contained areas where the average age was more than 45 years and damage had been present for less than 15 years <u>or</u> where average age was less than 45 years and damage had been present for 15 or more years (Lawrenceton, Lloyd's River, Badger, Pynn's Brook, Camp 33, South Branch[3]). n = 6

Explain why these are equivalent

<u>Group C</u> contained areas where the average age was less than 45 years and damage had been present for less than 15 years (only Swift Current fell into this group and therefore no analysis was possible). n = 1

delete the group no C

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[3] Bonne Bay should also belong to this group, however the data for this area were clearly anomolous and were therefore omitted from these analyses. The anomoly may be due to the location of the transect at what appears to be the present geographical boundary of the outbreak area, or it may be due to the very severe winter climate in the area.

X not valid reasons for omitting

Table 9.- Maximum elevations of aphid damaged stands in relation to height of surrounding hills.

Area	Highest elevation (feet) of surrounding hills within 3 miles of sample area[a]	Maximum elevation (feet) of severe aphid damage	Maximum elevation (feet) of all aphid damage
Group A	< 45, heavy damage		
Logy Bay	575	470	500
Snug Harbour	1150	640	700
York Harbour	2300	1300	1550
Serpentine Lake	2100	1080	1450
Gillams	1100	610	820
Fox Island River	1250	600	700
Codroy Pond	1750	930	950
Flat Bay Brook	1350	750	800
Group B	> 45 = little damage		
Lawrenceton	550	420	440
Lloyd's River	1800	550	590
Badger	700	430	530
Pynn's Brook	1250	480	650
Camp 33	1150	450	500
South Branch	1900	560	620
Other Areas			
Swift Current	900	110	160
Bonne Bay	2250	200	300

[a] Based in each case only on the block of hills in which the transect was situated.

Results are shown in Figure 3. Very good relationships are apparent between the maximum elevation of damaged stands and the degree of shelter provided by surrounding topography(height of surrounding hills). Distances of 2, 3 and 4 miles from the transects were tested on the X-axis; all gave good results, but those for 3 miles were generally the best and most consistent.

Circular reasoning (see Fig)

Because of this overriding relationship between aphid damage and elevation, all other site and stand characteristics were examined in relation to aphid damage on the basis of sample plots from the lower (damaged) portion of each transect only. Because of the small number of plots per transect, results are presented on a whole Island basis only.

Damage was more severe on dry and fresh sites than on moist sites, and more severe on well-drained soils (podzols, brunisols, and lithosols) than on poorly drained soils (gleysols and organic soils) (Table 10). There were at least 20 percent more stems in damage classes M, S, and D_A on drier, well drained sites than on moist, poorly drained sites.

There is also some evidence of relationships between the severity of aphid damage and percent slope, depth of the surface humus layer, and texture of the upper mineral soil. Damage was generally more severe on steep slopes and on sites with shallow humus layers and relatively coarse-textured soils. However, differences were less well marked than those for soil moisture regime and soil order. There was no evidence of any meaningful relationships between aphid damage and aspect or distance to stand opening.

Increasing levels of damage appear to be associated with increasing stand dominant heights (Table 11). Stands of less than 20 feet in height generally have lesser amounts of damage than stands taller than 20 feet, but

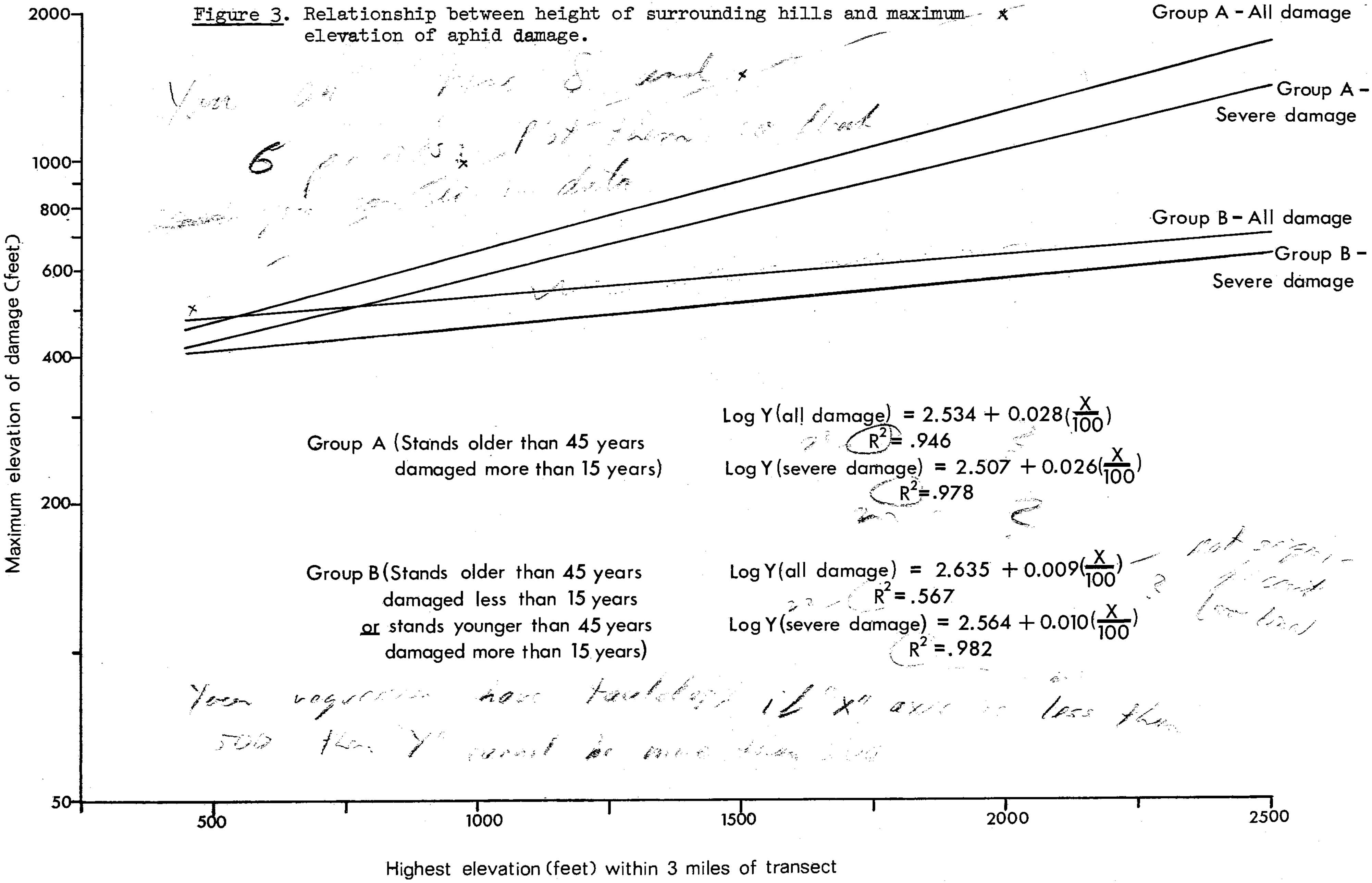

Figure 3. Relationship between height of surrounding hills and maximum elevation of aphid damage.

Group A (Stands older than 45 years damaged more than 15 years)

$$\text{Log Y(all damage)} = 2.534 + 0.028\left(\frac{X}{100}\right)$$

$$R^2 = .946$$

$$\text{Log Y(severe damage)} = 2.507 + 0.026\left(\frac{X}{100}\right)$$

$$R^2 = .978$$

Group B (Stands older than 45 years damaged less than 15 years or stands younger than 45 years damaged more than 15 years)

$$\text{Log Y(all damage)} = 2.635 + 0.009\left(\frac{X}{100}\right)$$

$$R^2 = .567$$

$$\text{Log Y(severe damage)} = 2.564 + 0.010\left(\frac{X}{100}\right)$$

$$R^2 = .982$$

Your [illegible] fine & and 6 points; plot them so that [illegible] data

not significant [illegible]

Your regression have troubles if "x" axis is less than 500 then Y cannot be more than [illegible]

Table 10.- Incidence of aphid damage by soil moisture classes and major soil orders (whole Island)[a]

		Percent distribution of stems by aphid damage classes					
	No. of plots	Class U	Class L	Class M	Class S	Class D_A	Classes M + S + D_A
Soil moisture classes							
Dry	6	15.6	15.7	24.6	16.0	28.2	68.7
Fresh	59	14.3	22.4	22.3	22.9	18.1	63.3
Moist	18	29.1	27.4	26.0	9.6	7.9	43.5
Dry & fresh	65	14.4	21.8	22.5	22.3	19.0	63.8
Moist	18	29.1	27.4	26.0	9.6	7.9	43.5
Major soil orders							
Lithosols	1	0	1.4	66.2	21.1	11.3	98.6
Podzols	49	16.0	23.3	21.8	21.6	17.3	60.7
Brunisols	19	8.3	21.6	25.9	22.8	21.3	70.1
Gleysols	13	40.0	26.2	19.4	7.6	6.9	33.9
Organic soils	1	0	12.5	51.2	9.5	26.8	87.5
Podzols, Brunisols & Lithosols	69	13.7	22.5	23.6	21.9	18.3	63.8
Gleysols & Organic soils	14	37.1	25.2	21.7	7.7	8.3	37.7

Tests of significance

Not needed

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[a] Based on plots from low elevation (damaged) portions of transects only.

Table 11.- Incidence of aphid damage by stand dominant height and age classes, and fir content (whole Island)[a]

	No. of plots	Percent distribution of stems by aphid damage classes					
		Class U	Class L	Class M	Class S	Class D_A	Classes M + S + D_A
Stand dominant height classes (feet)							
<20	3	27.3	20.0	14.9	24.4	13.4	52.7
21 - 40	63	19.0	21.7	23.0	21.8	14.6	59.3
41 - 60	17	10.7	28.2	26.0	10.3	24.8	61.1
Stand breast height age classes (years)							
21 - 40	12	27.4	17.6	18.7	28.3	8.1	55.0
41 - 60	44	17.6	20.7	25.3	21.3	15.1	61.8
61 - 80	23	9.5	31.7	22.2	12.8	23.7	58.8
81 -100	4	35.5	13.9	20.5	11.9	18.2	50.6
Balsam fir content of stands							
<20%	2	20.0	45.1	15.1	19.8	0	35.0
21 - 40%	7	51.4	25.9	12.0	7.4	3.4	22.7
41 - 60%	15	14.2	26.4	24.5	15.8	19.1	59.4
61 - 80%	27	4.2	23.4	30.8	22.2	19.5	72.4
81 -100%	32	23.0	19.0	19.4	21.6	17.0	58.0
<40%	9	44.4	30.1	12.7	10.1	2.6	25.5
>40%	74	14.4	22.1	24.6	20.6	18.3	63.5

[a] Based on plots from low elevation (damaged) portions of transects only.

differences are not very large. There is also some evidence of a relationship between aphid damage and stand age, especially with regard to the proportion ? ? Plots of undamaged stems and of stems in the aphid-killed damage class (Table 11). only 81 stands see [illegible] Stands of less than 40 years of age generally have somewhat less moderate and severe damage than stands of 40 to 80 years of age. There are also lesser amounts of damage in stands above 80 years of age, probably as a result of the location of these stands on moist, poorly drained sites; no stands of more than 80 years of age were recorded on well-drained sites.

Stands composed of more than 40 percent balsam fir show much more severe aphid damage than stands with a lower fir content (Table 11). There are over 35 percent more stems in damage classes M, S. and D_A in stands composed of more than 40 percent balsam fir than in stands with less than this proportion of fir. There is also some evidence of a relationship between damage and total balsam fir basal area. Stands where the balsam fir basal area exceeded 100 square feet per acre usually contained more severely damaged stems than those with less than this level of basal area.

Well-marked relationships have also been detected between aphid damage and several within-stand variables (Table 12), using individual tree data from only those plots in which all aphid damage classes were present.

There was an increase in average tree height, breast height age, breast height diameter, and crown class rating (dominance) with each successive increase in aphid damage from the undamaged to the severe damage level. In contrast, typical aphid-killed trees were smaller than those of any other damage class and had a low crown class rating.

Table 12.- Variation in average tree heights, ages, diameters, and crown classes by aphid damage classes (whole Island)[a]

Parameter	Aphid damage class				
	U	L	M	S	D_A
Average height (feet)	20.0	20.5	24.9	26.5	17.4
Average breast height age (years)	37.3	40.7	44.3	46.8	32.4
Average DBH (inches)	3.1	3.4	4.3	4.6	2.5
Average crown class rating[b]	2.1	2.1	2.5	2.4	1.5

[a] Based on plots having all aphid damage classes present.

[b] Derived by summation, using ratings of 1 for suppressed stems, 2 for intermediate stems, 3 for co-dominant stems, and 4 for dominant stems.

DISCUSSION

Results presented in this report are very similar to those presented earlier for three areas in western Newfoundland sampled in 1971 (Page, Hudak, and Banfield, 1972). Most of the results and their implications discussed in the earlier report have been confirmed by the 1972 data. Overall levels of aphid damage in the 1972 sample areas were, however, somewhat higher than those recorded in 1971 (Table 2). This difference is attributed to three major causes: (1) the older age [illegible] of many stands sampled in 1972; (2) the absence of wet sites in the 1972 sample areas; and (3) the deliberate inclusion of a number of "bad damage" plots in the 1972 data.

Nevertheless, mortality in the 1972 transect plots was, in general, light, and involved mostly small, suppressed stems (Table 12). The death of these trees probably resulted more from their position in the canopy than from aphid damage.

Should they then be included in analysis?

Most young stands (less than 20 years of age at breast height) showed only low accumulations of aphid damage. Semi-mature stands (about 20-45 years of age) showed somewhat greater accumulations, while mature and overmature stands (more than about 45 years of age) often contained the most severe levels of damage. Older stands also exhibited the lowest incidence of recovery.

More severe levels of damage were recorded on the drier, more freely-drained sites, and in taller, older stands with a high balsam fir content (Tables 10 and 11). It appears that the accumulation of greater amounts of damage in these stands may be a reflection of the greater degree of physiological stress (resulting from moisture deficiencies during the growing season, severe intra-stand competition, and in some cases over-maturity) that they experience. The accumulation of more severe damage on the taller, older stems within a stand is probably a reflection of the development of similar differential stress levels.

The length of time that an aphid infestation has been present in an area appears to affect the spread of damage both in a geographical and altitudinal sense. Climatic limitations also exert a major effect on the spread of damage at higher elevations, and a combination of length of period of attack and climate as expressed in terms of relative exposure (height of surrounding hills) appears to provide a very good measure of the upper altitudinal limits of damage in almost all areas of the Island that have been sampled (Figure 3). Specific climatic factors that limit aphid population build-up, and hence damage accumulation, are not known at present, but it appears that low winter temperatures, inadequate warmth during the growing season, and/or severe wind exposure may be involved. However, at lower elevations variations in the severity of aphid damage appear more closely related to site and stand differences than to climatic factors.

The site and stand characteristics associated with very severe damage in the selected "bad damage" plots reinforce all the above observations. All "bad damage" plots were located at elevations less than 500 feet, and all but two at less than 300 feet. All except one (the least severely damaged of the group) were on well-drained, fresh or dry sites, frequently on small knolls or very steep slopes. All had been damaged for more than 10 years, and most were above 40 years of age at breast height. They all were composed of more than 40 percent balsam fir; none of them showed much evidence of recovery growth.

Significant volume losses in areas sampled by transects were recorded only for western Newfoundland, where aphid damage is widespread and has been present for the longest period of time. Even in western Newfoundland, losses in the damaged portions of the stands averaged only 9 percent of the balsam fir merchantable volume and 6 percent of the merchantable volume of all species. However, the very high losses recorded on many of the selected "bad damage" plots and on parts of the Serpentine Lake and York Harbour transects illustrate the potential seriousness of aphid damage wherever susceptible sites and stands are coincident. A continuing management program to harvest all fir stands before they become overmature and to reduce the proportion of balsam fir in stands on the most susceptible sites appears necessary to ensure that such high hazard conditions do not develop over large areas.

SUMMARY AND CONCLUSIONS

(1) Aphid damage varied widely both within and between sample areas. Differences between average damage levels in the eastern, central, and western regions of the Island were generally much less than differences within sample areas.

(2) The greatest amounts of recovery growth were observed in semi-mature stands in areas where aphid damage had been present for at least 15 years. Mature and overmature stands, and stands damaged for less than about 10 years, showed little recovery growth.

are they not at their lim of heigh growth

(3) The incidence and severity of aphid damage decreased with increasing elevation, and damage was absent above a certain elevation (most commonly between 500 and 800 feet) in all sample areas. The presence of aphid damage at an elevation of more than 1000 feet appears to be primarily associated with mature stands, infestations of more than 15 years duration, and the occurrence of surrounding hills in excess of 1500 feet.

Fig 8 c 1800'

Regression may be invalid

(4) Variations in severity of damage at lower elevations are associated with site and stand characteristics. Dry or fresh, well-drained sites, and older, taller stands with a high balsam fir content usually show the greatest accumulations of damage.

(5) The most severe damage within any given stand usually occurred on the older, taller, most dominant stems. However, most aphid-killed stems, except in very badly damaged plots, were small and suppressed and appeared to have died more as a result of their position in the canopy than as a result of aphid damage.

(6) Mensurational relationships between tree height and diameter, and between number of stems per acre and age, were not significantly affected by aphid damage. The relationship between number of living stems per acre and average DBH was, however, altered for "bad damage" plots and for plots with an average diameter in excess of 6 inches.

no test of sign in text.

(7) Average volume losses in areas sampled by transects were generally small. However, very high losses, of up to 90 percent, were recorded in a few locations where susceptible sites and stands were coincident.

(8) More detailed information is needed on the development of aphid damage in young and semi-mature stands so as to derive a better understanding of the causal links between damage, aphid populations, site and stand conditions, and climate. Long term studies to investigate these interrelationships have already been initiated.

(9) The observed pattern of variation in aphid damage in relation to elevation, site conditions, stand age, and length of the period of attack, suggests that the construction of an aphid damage hazard rating system will be possible for the Island. Such a rating system could be used, together with inventory data, to delineate areas having the highest risk, both at the present time and in the future as stands mature. This would provide a logical and objective basis on which to assess the merits of any proposed aphid control measures. Work to develop such a rating system is continuing.

LITERATURE CITED

Balch, R.E. 1952. Studies on the balsam woolly aphid, Adelges piceae (Ratz.) (Homoptera: Phylloxeridae) and its effects on balsam fir, Abies balsamea (L.) Mill. Can. Dept. Agric. Publ. 867. 76 pp.

Carroll, W.J. and D.G. Bryant. 1960. A review of the balsam woolly aphid in Newfoundland. For. Chron. 36(3); 278-290.

Clark, R.C., D.O. Greenbank, D.G. Bryant and J.W.E. Harris. 1971. Adelges piceae (Ratz.), balsam woolly aphid (Homoptera: adelgidae). In, Biological control programmes against insects and weeds in Canada 1959-1968. Technical Communication No. 4, Commonw. Inst. Biol. Control; 113-127.

Clarke, L.J., E.C. Banfield, W.J. Sutton, D.M. Stone, and D.S. O'Brien. 1971. Annual district report. Forest insect and disease survey, Newfoundland 1970. Can. Dept. Environment, Can. For. Serv., Information Rep. N-X-65. 24 pp.

Hills, G.A. 1952. The classification and evaluation of site for forestry. Ont. Dept. Lands Forests, Div. Res., Res. Rep. 24. 41 pp.

Hopewell, W.W. and D.G. Bryant. 1969. Chemical control of Adelges piceae (Homoptera, adelgidae) in Newfoundland, 1967. Can. Entom. 101(10); 1112-1114.

Hudak, J. 1969. Pathological condition of balsam woolly aphid infested fir in Newfoundland. Can. Dept. Fisheries & Forestry, For. Br., Internal Rep. N-17. 15 pp.

Page, G., J. Hudak, and E. Banfield. 1972. Impact of balsam woolly aphid damage on semi-mature fir stands in western Newfoundland. Can. Dept. Environment, Can. For. Serv., Internal Report N-48. 53 pp.

Page, G., H.O. Schooley, and J. Hudak. 1970. Effect of balsam woolly aphid attack on balsam fir tree volume relationships in western Newfoundland. Can. Dept. Fisheries & Forestry, Can. For. Serv., Information Rep. N-X-57. 14 pp & Appendices.

Page, G., A.J. Robinson, R.S. van Nostrand, and T.G. Honer. 1971. Volume tables for the major tree species of Newfoundland. Can. Dept. Environment, Can. For. Serv., Information Rep. N-X-67. 21 pp & Appendices.

Rowe, J.S. 1959. Forest regions of Canada, Can. Dept. North. Aff. Nat. Res. For. Br., Bulletin 123. 71 pp.

✓ Schooley, H.O. and L. Oldford. 1969. Effect of balsam woolly aphid damage on the reproductive potential of balsam fir. Can. Dept. Fisheries & Forestry, Can. For. Serv., Information Rep. N-X-35. 21 pp.

Schooley, H.O. and L. Oldford. 1972. Recovery of young balsam fir trees from damage caused by the balsam woolly aphid. Can. Dept. Environment, Can. For. Serv., Internal Rep. N-53. 18 pp.

Warren, G.L., W.C. Parrott, and S.G. Cochran. 1967. Balsam woolly aphid dispersal and damage in balsam fir stands in Newfoundland. Can. Dept. For. Rural Dev., For. Br., Information Report N-X-15. 63 pp.

APPENDIX I

APHID DAMAGE CLASSIFICATION[a]

Upper and lower crown branches

Undamaged	(1)	- no visible symptoms of aphid attack
Light a	(2)	- nodal swelling indistinct, apparent only at close examination of branches
Light b	(3)	- nodal swelling distinct, stunting or distortion of branches present
Medium	(4)	- nodal swelling prominent, branches thinly foliated, branch tips inhibited, but no symptoms of branch mortality
Severe a	(5)	- as in Medium, but branches bare of needles from tips up to 12 inches
Severe b	(6)	- as in Severe a, but branches bare of needles from tips to more than 12 inches
Dead ("Aphid killed")	(7)	- cambium dead at breast height, symptoms of aphid damage present in crown

Scan visually the upper and lower halves of crown. Based on the most prevalent symptom assign one of the above numerical damage ratings separately to each half of theccrown. Average these numerical ratings and assign an average damage rating for the whole tree according to the following class limits:

Range of average numerical gout class ($\bar{x}$)	Average damage to a tree	
$\bar{x} = 1$	Undamaged	(U)
$\bar{x} = 1.5 - 3.0$	Light	(L)
$\bar{x} = 3.5 - 4.5$	Medium	(M)
$\bar{x} = 5 - 6.5$	Severe	(S)
$\bar{x} = 7$	Dead ("Aphid killed")	(D_A)

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[a] This is the standard aphid damage classification system used for tree deterioration studies in Newfoundland, as described by Warren, Parrott, and Cochran, 1967.

APPENDIX II

SOIL MOISTURE CLASSIFICATION[a]

Soil Moisture Class	Major Characteristics
Dry	Capillary water available within profile during part of year only; profile drainage free to excessive, site drainage shedding. Usually associated with coarse-textured podzols or regosols.
Fresh	Continuously available capillary water within profile, possibly seasonal saturation at depths of more than one to two feet; profile drainage free to moderate, site drainage normal. Usually associated with medium-textured brunisols or podzols.
Moist	Profile seasonally saturated to within one foot of surface; profile drainage moderate or partly impeded, site drainage normal to receiving. Usually associated with fine-textured gleysols or gleyed brunisols or podzols.
Wet	Profile continuously saturated; profile drainage impeded, site drainage receiving. Usually associated with organic soils or gleysols with deep organic layers.

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[a] After Hills, 1952.

APPENDIX III

HEIGHT/DIAMETER RELATIONSHIP AND LOCAL VOLUME TABLES[a]

FOR BALSAM FIR STEMS

DBH Class	Av. height (feet) (all damage classes)	Total volume (cu. ft.)		Merchantable volume (cu. ft.)			
		Classes U, L, S, & D_A	Class M	Classes U & L	Class M	Class S	Class D_A
1	9	0.03	0.04	-	-	-	-
2	14	0.20	0.25	-	-	-	-
3	19	0.59	0.71	-	-	-	-
4	24	1.25	1.44	1.16	1.36	1.06	1.13
5	29	2.26	2.53	2.13	2.40	1.96	2.05
6	33	3.61	3.95	3.42	3.75	3.20	3.28
7	37	5.37	5.74	5.11	5.47	4.85	4.88
8	40	7.55	7.90	7.19	7.54	6.93	6.85
9	43	10.12	10.42	9.67	9.85	9.44	9.19
10	46	13.02	13.27	12.49	12.71	12.31	11.85
11	49	16.42	16.50	15.77	15.83	15.66	14.90
12	51	20.21	20.09	19.41	19.30	19.46	18.34
13	53	24.34	24.01	23.41	23.09	23.64	22.10
14	55	28.90	28.28	27.81	27.21	28.25	26.23
15	56	33.78	32.86	32.55	31.64	33.23	30.66

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[a] Derived from special volume tables for aphid damaged trees (Page, Schooley, and Hudak, 1970)