DEVELOPMENT OF A SAMPLING METHOD FOR THE TWO-YEAR-CYCLE SPRUCE BUDWORM, CHORISTONEURA FUMIFERANA (CLEM.), IN BRITISH COLUMBIA. I. THE EGG STAGE.

by

J.W.E. Harris and D.K. Edwards

INTERIM REPORT

FOREST BIOLOGY LABORATORY

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Not for publication

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1.0 INTRODUCTION

The two-year-cycle spruce budworm, *Choristoneura fumiferana* (Clem.), is a serious defoliator of white spruce, *Picea glauca* (Moench.) Voss., and alpine fir, *Abies lasiocarpa* (Hook.) Nutt., in west-central British Columbia. Although its numbers had reached outbreak proportions earlier in areas at the southern end of Babine Lake, the two-year-cycle spruce budworm was first reported present in significant numbers around the northern end of Babine Lake in 1954. Aerial reconnaissance in 1958 by D. Collis, Forest Biology Ranger of the district, showed the outbreak covered an area of approximately 1,300 square miles (Figure 1). This was an increase of 400 square miles since 1956.

In the summer of 1958 an investigation was begun to develop a sampling method capable of providing an adequate estimate of populations of the budworm during different stages of the life cycle and to examine the relationship between estimates of population density and tree damage. In this study the numbers of individuals per square foot of foliage were compared and conclusions drawn as to how future sampling could be undertaken with regard to the choice of sample branch size and to the selection of branches from different locations within tree crowns.

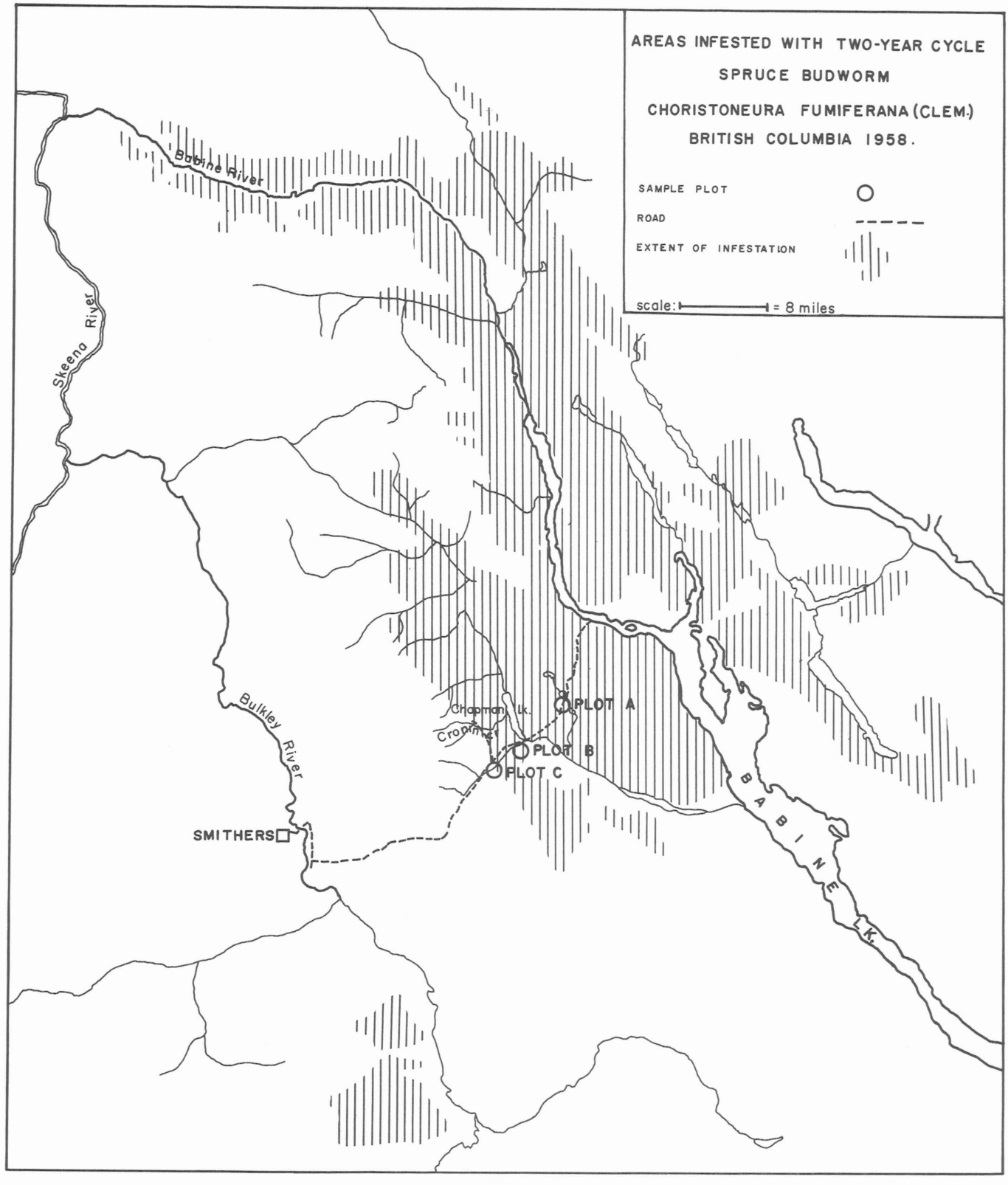
Spruce budworm adults are small, mottled, buff- to greyish-coloured moths having a wing expanse of approximately seven-eighths inch. The moth flight occurs in July and August, during which the eggs are laid in two rows, in the manner of overlapping scales, on the under surfaces of needles. The eggs hatch in about two weeks, and at least some of the first-instar larvae undergo wind dispersal with the aid of silken threads. They then seek hiding places at the bases of needles and in bark crevices on branches and on the bole where they spin tiny hibernacula. Within the hibernacula they overwinter as second instar larvae. In the spring, the larvae emerge and feed on the opening buds. They then overwinter a second time in the fourth instar and emerge from hibernation the following spring, when they do the major part of their damage to the host trees. Pupation occurs in June and emergence in July and August.

This report presents the results obtained from sampling the egg stage. Future reports will present analyses of succeeding stages in a single two-year life cycle.

2.0 METHODS

2.1 Field Procedures

The field work in the present study was carried out in August, 1958, on three plots located along the road between Smithers and Smithers Landing on Babine Lake. The locations of the plots are shown in Figure 1.


AREAS INFESTED WITH TWO-YEAR CYCLE
SPRUCE BUDWORM
CHORISTONEURA FUMIFERANA (CLEM.)
BRITISH COLUMBIA 1958.
SAMPLE PLOT
ROAD
EXTENT OF INFESTATION
scale: = 8 miles
Babine River
Skeena River
Bulkley River
Chapman Lk.
Cronin Cr.
PLOT A
PLOT B
PLOT C
SMITHERS
BABINE L.

Plot A is located on the east side of the road 5.3 miles northeast of the Chapman Lake bridge. The plot is stocked with an overstory of open growing alpine fir and white spruce averaging approximately 40 feet in height and 60 to 70 years old and an understory consisting mainly of white spruce with some alpine fir. A few mature white spruce over 100 feet high are present. The plot is on a 15 degree slope with a westerly aspect and ground cover consists of Alnus sp. (alder), Cornus canadensis L. (bunchberry), Pyrus sp. (mountain ash), Lycopodium probably complanatum L., and Linnaea borealis L.

Plot B is situated on the south side of the road 0.7 mile west of Chapman Lake. Although white spruce predominates in the area, within the plot itself there are about equal numbers of alpine fir and white spruce, the former averaging about 50 feet in height and the latter about 80 feet in height. The site is fairly moist, with McKendrick Creek flowing close to the southeast side of the plot, and the slope is slight. Ground vegetation consists principally of Equisetum, Ribes, and Oplopanax horridus (Sm.) Miq. (devil's club).

Plot C is located on the present fringe of the infestation 300 feet southwest of the junction of the Cronin Mine road with the Smithers-Babine Lake road and 4.2 miles by road southwest of Chapman Lake. Alpine fir and white spruce, averaging about 50' in height, are present in about equal numbers. A small creek flows through the plot close to the sample trees and ground vegetation consists of Ribes sp., Oplopanax horridus, and Alnus sp.

The three plots are almost equidistant, ranging in location from a position well within the general area of infestation (plot A) to a point on the present boundary (plot C). It was hoped, with this arrangement, to obtain samples of populations of different densities.

In each plot, trees typical of the surrounding stand were selected for sampling. The diameter, height, and a visual estimate of the current and total defoliation of each sample tree were recorded. Sample branches were obtained from eight overstory alpine fir and four overstory white spruce in plot A, and from four overstory alpine fir in each of plots B and C. All but four alpine fir, numbers five to eight on plot A, were felled. These four trees were left standing for future sampling studies, the branches being removed with the aid of a pole clipper and tree climbers. In addition, eight understory alpine fir, averaging 12 feet in height, were sampled in plot A, three branches being taken from each tree at approximately the mid-crown level on the sunlit side.

The crown of each tree was divided into upper, middle, and lower thirds, designated as levels a, b, and c, respectively. Three branches were selected from the center of each crown level, one each from the north, southwest, and southeast sides of the bole. Each branch, as it was removed from the tree, was tagged with a number denoting its position within the crown of the tree, the tree number and the plot. The length and greatest width of each branch was measured and the outer 18-inch section of each was removed and its width measured. The numbers of egg masses on the 18-inch tip and on the remainder of each branch were counted and the numbers of eggs per egg mass on two alpine fir from each of the three plots and on two white spruce from plot A were recorded.

2.2 Analysis of Data

Because the foliage surfaces of sample branches were considered to be triangular, the area of each branch and 18-inch branch tip was determined by multiplying the length of the sample by one-half the width. The number of egg masses found on each sample was then divided by the foliage area to give the number of egg masses per square foot.

Since the basic data were anormal, showing a right skewed frequency distribution, and since the 18-inch tip and whole branch population data showed heterogeneity of variance, the data were transformed logarithmically. Analyses of variance were performed on the transformed data to determine if there were significant variations in the numbers of egg masses per square foot of foliage with regard to sample trees, crown levels, directions, whole branch and 18-inch tip sampling methods, plots, species, and the understory and overstory. In these analyses trees were considered to be a random variable. Levels, directions, and methods were fixed variables and were thus tested against the first order interaction containing both the random variable trees and the factor being tested.

3.0 RESULTS AND CONCLUSIONS

3.1 Egg Masses Per Square Foot of Foliage

3.1.1 Variation Between Sample Trees

The data were analysed to determine if significant differences existed between the numbers of egg masses per square foot of foliage on different sample trees. Analyses were performed by species, plot, and sampling method (Tables I to VIII), and by species, plot, and crown level (Tables IX to XVI).

In general, the numbers of egg masses per square foot of foliage were significantly different between sample trees. Hence, when estimating populations of the two-year-cycle spruce budworm in the future, as large a number of trees as is economically possible should be sampled. These results agree with those found by Morris (1955) in his more intensive study of the one-year-cycle spruce budworm, Choristoneura fumiferana (Clem.), in New Brunswick.

3.1.2 Variation Between Branch Directions

Branch samples were taken from the north, southwest, and southeast directions at the three crown levels of each tree. No significant differences were found in the numbers of egg masses per square foot of foliage between directions. As concluded by Morris (1955), directional differences can be considered to be negligible and sample branches may be selected from any direction on the bole.

3.1.3 Variation Between Crown Levels

All analyses performed on the data (Tables I to VIII, XVII and XVIII) showed the numbers of egg masses per square foot of foliage to differ significantly between levels, agreeing with the results of Morris (1955).

Student's "t" tests were applied to the data to determine which of the levels had significantly different numbers of egg masses per square foot. The tests showed that, in general, while levels a and b were not significantly different from each other, level c had a significantly lower mean number of egg masses per square foot of foliage than the two upper crown levels. This probably resulted from the lower branches being less attractive to the ovipositing moths; this foliage is older, has fewer buds, and is more sheltered than that on the upper branches.

Since levels were significantly different, any estimate of the absolute density of a population would require representative samples from all levels in proportion to the amount of foliage in each. Estimates of relative densities (plot-to-plot or year-to-year), however, could be obtained by sampling any one of the crown levels. Since c, the lowest level, generally had significantly lower numbers of egg masses per square foot than the upper two levels, being apparently less favoured for oviposition, it is likely it will have greater variability in egg mass numbers due to varying local conditions such as tree vigour, crown density, and shading. Since level b, the mid-crown level, could be sampled with greater ease than level a, and generally had a mean number of egg masses per square foot lower than that of a but higher than that of c, sampling of this level would provide the best average estimate of population density.

3.1.4 Variation Between Whole Branch and 18-inch Tip Samples

The data were analysed comparing the whole branch sampling method with the 18-inch tip sampling method. Analyses were performed for white spruce and alpine fir in plots A, B, and C at levels b and c showing tree, direction, and method variance (Tables IX to XVI). Crown level a was not included in this analysis since inspection of the data indicated an obvious lack of differences between the number of egg masses per square foot on whole branches and on their 18-inch tips. This resulted from the fact that many a branches were 18-inches or less in length.

Generally, the numbers of egg masses per square foot for the 18-inch tip exceeded those for the whole branch, indicating that the exposed outer ends of branches were more readily reached by ovipositing moths or that the newer needles were more attractive oviposition sites. At crown level c on plot B, however, the numbers of egg masses per square foot of foliage were significantly lower on the tip than on the whole branch (Table XIV).

It would appear, on the basis of this study, that 18-inch tips would be as satisfactory a sampling unit to show population trends as would whole branches. Morris (1955) stated that a sample smaller than a whole branch, or its longitudinal one-half, is unlikely to be suitable for the measurement of absolute population numbers. He pointed out that it would be difficult to obtain a relationship between the areas of the basal components of the branches and their egg mass populations and the areas of, and populations on, the tips. Wilson (1959), in a study of the one-year-cycle spruce budworm in Minnesota, found that if the apical 15-inch portions of all shoots on sample branches were counted, the total number of eggs on the branches could be approximated by raising the 15-inch tip figures by 16 per cent.

3.1.5 Variation Between Plots

An analysis of variance of the numbers of egg masses per square foot of foliage obtained from alpine fir at crown levels a, b, and c in plots A, B, and C was performed (Table XVII). No significant differences in egg mass numbers on alpine fir were found between plots.

There was a trend toward larger mean numbers of egg masses per square foot in plot C than in plots A and B. The infestation in plot C is comparatively recent, existing on the boundary of the present large-scale infestation. At the time of emergence, the foliage, having just been fed upon by the late instar larvae, and particularly in areas where defoliation has continued for a number of years, was in poor condition and offered a minimum of suitable oviposition sites. This may have resulted in the adult moths tending to seek out trees at the edge of the infestation which had not suffered heavy defoliation in the current and previous years. Also, the trees in plot C may have been somewhat more vigorous because the site was more wet and therefore more attractive to the budworm moths than those of A and B.

3.1.6 Variation Between Species

A comparison of the numbers of egg masses per square foot of whole branch foliage obtained from alpine fir and spruce at crown levels a, b, and c in plot A showed no significant differences between the two tree species (Table XVIII). The mean number of egg masses per unit area was slightly higher on white spruce than on alpine fir.

3.1.7 Variation Between Overstory and Understory

The data obtained from eight understory alpine fir trees were taken from three branches located midway up the sunlit side of each tree. Analysis showed that the numbers of egg masses per square foot of branch surface were lower on the understory trees; the difference was significant when compared with egg mass counts on overstory crown b samples.

It may be possible to use the understory to obtain an estimate of the egg population on the overstory. This would be desirable, particularly in very tall stands, where only the lower crown level of the overstory can be reached for sampling. However, it would be necessary to study the corresponding relationship between understory and overstory egg populations in a variety of infestation densities. The ratio between the understory and overstory populations might change with differing degrees of infestation density. It is also possible that in the lighter infestations few, if any, eggs would be found on the understory.

3.2 Number of Eggs per Egg Mass

The differences in egg numbers per egg mass on different plots, like the numbers of egg masses per square foot (Section 3.1.5), seem to be related to the differences in the age of the infestation between plots. The mean numbers of eggs per egg mass obtained from two white spruce (30.83) and from two

alpine fir (33.29) in plot A were lower than the mean numbers from two alpine fir in plots B (51.87) and C (45.19) (Table XXI). There was little difference in the means of white spruce and alpine fir in plot A. Since plot A was at the center of the infestation and plots B and C at the periphery, there may be greater numbers of eggs per mass in relatively new infestation areas.

3.3 Defoliation Estimates

Defoliation of current foliage growth was almost 100 per cent in all plots (Table XXII). Most branch tips presented a blunted appearance with an enlargement or swelling of the twig at the end. The only new growth present on heavily infested trees was in the lower crown section. One tree only was found in which the current defoliation was light throughout (plot B, alpine fir 1). This tree was not deficient in egg masses, however. Estimates of total defoliation averaged around 15 per cent.

4.0 SUMMARY

In August of 1958, three plots were set up near Babine Lake, B.C., to study sampling methods for the two-year-cycle spruce budworm, Choristoneura fumiferana (Clem.). Eight overstory alpine fir and four overstory white spruce were chosen in plot A and four overstory alpine fir were chosen in each of plots B and C. Counts were made for each tree of the number of egg masses per square foot of whole branch and 18-inch tip foliage on three branches taken from directions north, southwest, and southeast at crown levels upper, middle, and lower, denoted as levels a, b, and c, respectively. In addition, eight understory alpine fir were selected on plot A, with three branches being selected from the south side of each at mid-crown level. Visual estimates made on the plots showed that current defoliation was nearly 100 per cent on most trees sampled and total defoliation averaged 15 per cent.

The results of this study regarding inter-tree, directional, and level variability agree, in general, with those found by R.F. Morris (1955) in his more intensive study of the one-year-cycle spruce budworm, Choristoneura fumiferana (Clem.), in New Brunswick. The numbers of egg masses per square foot of foliage differ significantly between sample trees in most instances, indicating that samples should be taken from as large a number of trees as is economically possible. Branch direction apparently does not influence the number of egg masses per square foot of foliage and need not be considered when taking samples. Level c, the lower third of the crown, has a significantly lower mean number of egg masses per square foot than a and b, which do not differ significantly. A reliable estimation of population trends could be obtained by sampling at the mid-crown level.

The 18-inch tip branch sample provides an estimate of egg mass numbers which does not differ significantly from the results obtained when entire branches are examined and 18-inch tip samples would be suitable for obtaining an estimation of population trends. Egg population estimates from the three plots do not vary significantly nor do those comparing species. The understory contains a significantly lower number of egg masses than the overstory. The average number of eggs per egg mass varies from 30.83 on alpine fir in plot A to 51.87 on alpine fir in plot B.

5.0 ACKNOWLEDGMENTS

The writers are indebted to C. Reimer and P.M. Morse, Statistics Research Service, Research Branch, Department of Agriculture, Ottawa, and W. Bloomberg, Forest Biology Laboratory, Victoria, for their recommendations regarding the statistical methods employed, and to Dr. G.T. Silver, Survey Head, Forest Biology Laboratory, Victoria, under whose direction the project was undertaken.

6.0 REFERENCES

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Wilson, L.F. 1959. Branch "tip" sampling for determining abundance of spruce budworm egg masses. J. Econ. Ent. 52(4): 618-621.

TABLE I

Numbers of egg masses per square foot of foliage obtained from whole branch samples from eight alpine fir in Plot A at different crown levels and compass directions.

Tree Number	Direction	Crown level a	b	c	Sum
Alpine fir 1	N	2.6	3.4	0.0	6.0
	SW	8.6	3.3	2.3	14.2
	SE	4.9	4.2	2.1	11.2
	Sum	16.1	10.9	4.4	31.4
Alpine fir 2	N	9.2	6.9	1.4	17.5
	SW	10.2	4.0	4.9	19.1
	SE	4.5	4.4	4.5	13.4
	Sum	23.9	15.3	10.8	50.0
Alpine fir 3	N	2.9	5.2	4.2	12.3
	SW	4.7	3.5	0.9	9.1
	SE	6.4	2.2	0.9	9.5
	Sum	14.0	10.9	6.0	30.9
Alpine fir 4	N	1.9	4.3	2.0	8.2
	SW	6.7	6.6	3.0	16.3
	SE	1.5	5.8	0.9	8.2
	Sum	10.1	16.7	5.9	32.7
Alpine fir 5	N	8.1	9.6	2.2	19.9
	SW	7.8	6.4	4.3	18.5
	SE	8.7	12.3	0.4	21.4
	Sum	24.6	28.3	6.9	59.8
Alpine fir 6	N	9.1	13.6	3.7	26.4
	SW	20.2	14.0	2.0	36.2
	SE	11.3	6.9	2.4	20.6
	Sum	40.6	34.5	8.1	83.2
Alpine fir 7	N	10.7	7.8	1.2	19.7
	SW	22.4	13.1	4.3	39.8
	SE	15.0	18.1	1.7	34.8
	Sum	48.1	39.0	7.2	94.3
Alpine fir 8	N	8.0	1.1	2.0	11.1
	SW	5.5	3.6	2.0	11.1
	SE	5.4	5.2	0.8	11.4
	Sum	18.9	9.9	4.8	33.6

TABLE I (Continued)

Analysis of Variance (transformed logarithmically):

Source	D.F.	S.S.	M.S.	F
Tree	7	1.050	0.150	4.05**
Direction	2	0.287	0.143	2.60
Level	2	2.332	1.166	27.12**
T x L	14	0.607	0.043	1.16
D x T	14	0.773	0.055	1.49
L x D	4	0.244	0.061	1.65
T x L x D	28	1.041	0.037	
Total	71	6.334		

Student's "t":

Level	Mean egg masses per sq. ft.	Significance (transformed)
a	8.18	
b	6.89	
c	2.26	
a & b		0.33
a & c		6.41**
b & c		6.08**

** Significance at 1% level.

TABLE II

Numbers of egg masses per square foot of foliage obtained from 18-inch branch tips from eight alpine fir in Plot A at different crown levels and compass directions.

Tree Number	Direction	Crown level a	Crown level b	Crown level c	Sum
Alpine fir 1	N	2.6	3.4	0.0	6.0
	SW	8.6	3.0	2.1	13.7
	SE	4.9	2.8	1.5	9.2
	Sum	16.1	9.2	3.6	28.9
Alpine fir 2	N	9.2	6.5	2.5	18.2
	SW	10.2	1.9	3.5	15.6
	SE	4.5	4.8	5.6	14.9
	Sum	23.9	13.2	11.6	48.7
Alpine fir 3	N	2.9	11.6	9.9	24.4
	SW	7.4	5.8	0.0	13.2
	SE	0.9	4.5	3.8	9.2
	Sum	11.2	21.9	13.7	46.8
Alpine fir 4	N	1.9	4.6	1.4	7.9
	SW	6.9	8.8	0.8	16.5
	SE	1.5	5.9	0.0	7.4
	Sum	10.3	19.3	2.2	31.8
Alpine fir 5	N	8.0	6.4	1.1	15.5
	SW	0.0	5.4	4.6	10.0
	SE	8.7	14.3	0.0	23.0
	Sum	16.7	26.1	5.7	48.5
Alpine fir 6	N	11.7	14.0	6.0	31.7
	SW	22.1	5.1	1.1	28.3
	SE	11.2	6.7	0.0	17.9
	Sum	45.0	25.8	7.1	77.9
Alpine fir 7	N	16.8	8.5	2.6	27.9
	SW	21.9	6.3	6.9	35.1
	SE	20.8	35.4	1.4	57.6
	Sum	59.5	50.2	10.9	120.6
Alpine fir 8	N	8.0	1.5	0.0	9.5
	SW	4.0	8.7	3.2	15.9
	SE	5.4	4.1	0.0	9.5
	Sum	17.4	14.3	3.2	34.9

TABLE II (Continued)

Analysis of Variance (transformed logarithmically):

Source	D.F.	S.S.	M.S.	F
Trees	7	1.534	0.219	1.29
Direction	2	0.086	0.043	
Level	2	3.205	1.602	18.00**
T x L	14	1.246	0.089	
D x T	14	0.919	0.066	
L x D	4	0.287	0.072	
T x L x D	28	4.723	0.169	
Total	71	12.000		

Student's "t":

Level	Mean egg masses per sq. ft.	Significance (transformed)
a	8.34	
b	7.50	
c	2.42	
a and b		0.08
a and c		5.24**
b and c		5.16**

** Significance at 1% level.

TABLE III

Numbers of egg masses per square foot of foliage obtained from whole branch samples from four white spruce in Plot A at different crown levels and compass directions.

Tree Number	Direction	Crown level a	Crown level b	Crown level c	Sum
White spruce 1	N	22.7	16.9	1.5	41.1
	SW	22.5	10.7	4.8	38.0
	SE	35.6	10.7	1.7	48.0
	Sum	80.8	38.3	8.0	127.1
White spruce 2	N	5.4	10.7	2.6	18.7
	SW	4.6	6.4	1.7	12.7
	SE	6.8	4.9	3.5	15.2
	Sum	16.8	22.0	7.8	46.6
White spruce 3	N	10.6	8.1	0.9	19.6
	SW	5.3	2.0	1.6	8.9
	SE	11.6	1.7	0.0	13.3
	Sum	27.5	11.8	2.5	41.8
White spruce 4	N	0.2	3.6	0.1	3.9
	SW	4.2	5.1	1.4	10.7
	SE	2.8	2.9	2.7	8.4
	Sum	7.2	11.6	4.2	23.0

TABLE III (Continued)

Analysis of Variance (transformed logarithmically):

Source	D.F.	S.S.	M.S.	F
Tree	3	1.469	0.490	25.79**
Direction	2	0.004	0.002	
Level	2	1.813	0.906	7.61*
T x L	6	0.713	0.119	6.26**
D x T	6	0.375	0.062	3.26*
L x D	4	0.296	0.074	3.89*
T x L x D	12	0.235	0.019	
Total	35	4.905		

Student's "t":

Level	Mean egg masses per sq. ft.	Significance (transformed)
a	11.02	
b	6.97	
c	1.87	
a and b		0.645
a and c		3.652*
b and c		3.007*

* Significance at 5% level.
** Significance at 1% level.

TABLE IV

Numbers of egg masses per square foot of foliage obtained from 18-inch branch tips from four white spruce in Plot A at different crown levels and compass directions.

Tree Number	Direction	Crown level			Sum
		a	b	c	
White spruce 1	N	17.1	22.0	2.0	41.1
	SW	11.8	16.0	16.0	43.8
	SE	36.5	38.4	0.0	74.9
	Sum	65.4	76.4	18.0	159.8
White spruce 2	N	3.8	10.7	5.3	19.8
	SW	1.2	5.3	0.0	6.5
	SE	8.9	1.8	2.0	12.7
	Sum	13.9	17.8	7.3	39.0
White spruce 3	N	12.5	13.2	0.0	25.7
	SW	5.3	0.0	1.1	6.4
	SE	12.5	2.2	0.0	14.7
	Sum	30.3	15.4	1.1	46.8
White spruce 4	N	0.0	1.5	0.0	1.5
	SW	6.2	6.9	0.0	13.1
	SE	2.0	2.7	5.3	10.0
	Sum	8.2	11.1	5.3	24.6

TABLE IV (Continued)

Analysis of Variance (transformed logarithmically):

Source	D.F.	S.S.	M.S.	F
Tree	3	2.192	0.731	4.27*
Direction	2	0.044	0.022	
Level	2	2.059	1.029	6.20*
T x L	6	0.811	0.135	
D x T	6	0.994	0.166	
L x D	4	0.324	0.081	
T x L x D	12	2.052	0.171	
Total	35	8.476		

Student's "t":

Level	Mean egg masses per sq. ft.	Significance (transformed)
a	9.82	
b	10.06	
c	2.64	
a and b		0.186
a and c		3.466*
c and b		3.280*

* Significance at 5% level.

TABLE V

Numbers of egg masses per square foot of foliage obtained from whole branch samples from four alpine fir in Plot B at different crown levels and compass directions.

Tree Number	Direction	Crown level a	b	c	Sum
Alpine fir 1	N	6.6	0.7	0.5	7.8
	SW	0.7	0.9	0.2	1.8
	SE	4.6	3.6	3.3	11.5
	Sum	11.9	5.2	4.0	21.1
Alpine fir 2	N	3.0	5.4	1.1	9.5
	SW	3.3	4.5	0.2	8.0
	SE	1.8	3.8	2.0	7.6
	Sum	8.1	13.7	3.3	25.1
Alpine fir 3	N	3.6	2.6	0.0	6.2
	SW	4.7	1.2	0.9	6.8
	SE	5.0	0.9	0.0	5.9
	Sum	13.3	4.7	0.9	18.9
Alpine fir 4	N	11.6	4.7	4.3	20.6
	SW	5.9	6.2	2.1	14.2
	SE	7.3	14.9	0.8	23.0
	Sum	24.8	25.8	7.2	57.8

TABLE V (Continued)

Analysis of Variance (transformed logarithmically):

Source	D.F.	S.S.	M.S.	F
Tree	3	0.840	0.280	6.36**
Direction	2	0.103	0.051	1.00
Level	2	1.173	0.586	10.67*
T x L	6	0.328	0.055	1.25
D x T	6	0.306	0.051	1.16
L x D	4	0.051	0.012	
T x L x D	12	0.527	0.044	
Total	35	3.328		

Student's "t":

Level	Mean egg masses per sq. ft.	Significance (transformed)
a	4.84	
b	4.12	
c	1.28	
a and b		1.05
a and c		4.41**
c and b		3.36*

* Significance at 5% level.
** Significance at 1% level.

TABLE VI

Numbers of egg masses per square foot of foliage obtained from 18-inch branch tips from four alpine fir in Plot B at different crown levels and compass directions.

Tree Number	Direction	Crown level			Sum
		a	b	c	
Alpine fir 1	N	9.9	2.7	0.0	12.6
	SW	2.1	0.0	0.0	2.1
	SE	5.7	4.6	0.0	10.3
	Sum	17.7	7.3	0.0	25.0
Alpine fir 2	N	3.0	7.1	1.1	11.2
	SW	0.0	3.8	0.0	3.8
	SE	0.0	1.1	0.0	1.1
	Sum	3.0	12.0	1.1	16.1
Alpine fir 3	N	8.0	1.1	0.0	9.1
	SW	4.1	0.0	0.0	4.1
	SE	5.0	2.5	0.0	7.5
	Sum	17.1	3.6	0.0	20.7
Alpine fir 4	N	14.9	8.0	1.0	23.9
	SW	4.3	8.9	0.6	13.8
	SE	11.2	14.9	0.0	26.1
	Sum	30.4	31.8	1.6	63.8

TABLE VI (Continued)

Analysis of Variance (transformed logarithmically):

Source	D.F.	S.S.	M.S.	F
Tree	3	0.517	0.172	3.66*
Direction	2	0.526	0.263	3.41
Level	2	2.540	1.270	7.89*
T x L	6	0.968	0.161	3.42*
D x T	6	0.464	0.077	1.64
L x D	4	0.139	0.035	
T x L x D	12	0.566	0.047	
Total	35	5.720		

Student's "t"

Level	Mean egg masses per sq. ft.	Significance (transformed)
a	5.68	
b	4.56	
c	0.22	
a and b		1.10
a and c		3.86**
c and b		2.76*

* Significance at 5% level.
** Significance at 1% level.

TABLE VII

Numbers of egg masses per square foot of foliage obtained from whole branch samples from four alpine fir in Plot C at different crown levels and compass directions.

Tree Number	Direction	Crown level			Sum
		a	b	c	
Alpine fir 1	N	12.0	4.5	1.7	18.2
	SW	12.0	2.4	4.2	18.6
	SE	11.2	4.0	2.8	18.0
	Sum	35.2	10.9	8.7	54.8
Alpine fir 2	N	8.4	3.2	0.4	12.0
	SW	7.0	3.5	0.4	10.9
	SE	4.5	5.6	8.3	18.4
	Sum	19.9	12.3	9.1	41.3
Alpine fir 3	N	12.8	3.0	0.0	15.8
	SW	17.3	4.8	0.6	22.7
	SE	10.4	4.5	0.9	15.8
	Sum	40.5	12.3	1.5	54.3
Alpine fir 4	N	0.7	5.6	7.6	13.9
	SW	0.8	2.0	2.0	4.8
	SE	14.4	2.9	2.3	19.6
	Sum	15.9	10.5	11.9	38.3

TABLE VII(Continued)

Analysis of Variance (transformed logarithmically):

Source	D.F.	S.S.	M.S.	F
Tree	3	0.136	0.045	
Direction	2	0.152	0.076	
Level	2	1.337	0.669	8.06*
T x L	6	0.953	0.159	1.91
D x T	6	0.243	0.040	
L x D	4	0.041	0.011	
T x L x D	12	0.993	0.083	
Total	35	3.855		

Student's "t"

Level	Mean egg masses per sq. ft.	Significance (transformed)
a	9.29	
b	3.83	
c	2.60	
a and b		1.54
a and c		2.90*
c and b		1.36

* Significance at 5% level.

TABLE VIII

Numbers of egg masses per square foot of foliage obtained from 18-inch branch tips from four alpine fir in Plot C at different crown levels and compass directions.

Tree Number	Direction	Crown level			Sum
		a	b	c	
Alpine fir 1	N	12.0	16.0	4.1	32.1
	SW	16.8	9.0	7.3	33.1
	SE	12.3	6.9	12.2	31.4
	Sum	41.1	31.9	23.6	96.6
Alpine fir 2	N	6.7	3.7	0.0	10.4
	SW	8.0	3.8	1.1	12.9
	SE	3.4	7.6	0.8	11.8
	Sum	18.1	15.1	1.9	35.1
Alpine fir 3	N	12.8	18.1	0.0	30.9
	SW	17.3	6.2	1.5	25.0
	SE	12.0	5.3	0.8	18.1
	Sum	42.1	29.6	2.3	74.0
Alpine fir 4	N	7.3	5.6	0.9	13.8
	SW	0.0	4.0	4.4	8.4
	SE	10.7	1.6	0.9	13.2
	Sum	18.0	11.2	6.2	35.4

TABLE VIII (Continued)

Analysis of Variance (transformed logarithmically):

Source	D.F.	S.S.	M.S.	F
Tree	3	1.253	0.418	5.57*
Direction	2	0.002	0.001	
Level	2	1.810	0.905	8.46*
T x L	6	0.643	0.107	1.43
D x T	6	0.108	0.018	
L x D	4	0.424	0.106	1.41
T x L x D	12	0.901	0.075	
Total	35	5.141		

Student's "t"

Level	Mean egg masses per sq. ft.	Significance (transformed)
a	9.94	
b	7.31	
c	2.83	
a and b		0.736
a and c		3.887**
c and b		3.150*

* Significance at 5% level.
** Significance at 1% level.

TABLE IX

Analysis of variance of numbers of egg masses per square foot of foliage obtained from whole branch and from 18-inch tip samples at crown level b for eight alpine fir in Plot A (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Tree	7	1.597	0.228	16.29**
Direction	2	0.046	0.023	0.28
Method	1	0.002	0.002	0.05
T x D	14	1.156	0.083	5.39**
T x M	7	0.257	0.037	2.64
M x D	2	0.015	0.007	0.50
T x D x M	14	0.202	0.014	
Total	47	3.275		

* Significance at 5% level.
** Significance at 1% level.

TABLE X

Analysis of variance of numbers of egg masses per square foot of foliage obtained from whole branch and from 18-inch tip samples at crown level c for eight alpine fir in Plot A (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Tree	7	0.644	0.092	2.09
Direction	2	0.365	0.182	1.57
Method	1	0.025	0.025	0.57
T x D	14	1.623	0.116	2.64*
T x M	7	0.203	0.029	0.66
M x D	2	0.020	0.010	0.23
T x M x D	14	0.623	0.044	
Total	47	3.503		

* Significance at 5% level.

TABLE XI

Analysis of variance of numbers of egg masses per square foot of foliage obtained from whole branch and from 18-inch tip samples at crown level b for four spruce in Plot A (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Tree	3	1.669	0.556	14.75**
Direction	2	0.293	0.146	1.12
Method	1	0.000		
T x D	6	0.780	0.130	3.45
T x M	3	0.145	0.046	1.21
M x D	2	0.017	0.003	0.009
T x M x D	6	0.226	0.038	
Total	23	3.130		

** Significance at 1% level.

TABLE XII

Analysis of variance of numbers of egg masses per square foot of foliage obtained from whole branch and from 18-inch tip samples at crown level c for four spruce in Plot A (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Tree	3	0.537	0.179	2.54
Direction	2	0.060	0.030	1.25
Method	1	0.029	0.029	3.12
T x D	6	1.432	0.238	3.41
T x M	3	0.280	0.009	0.13
M x D	2	0.013	0.006	0.01
T x M x D	6	0.422	0.703	
Total	23	2.521		

TABLE XIII

Analysis of variance of numbers of egg masses per square foot of foliage obtained from whole branch and from 18-inch tip samples at crown level b for four alpine fir in Plot B (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Tree	3	1.557	0.519	15.26**
Direction	2	0.210	0.105	1.36
Method	1	0.001	0.001	0.006
T x D	6	0.465	0.077	2.26
T x M	3	0.050	0.016	0.47
M x D	2	0.060	0.030	0.88
T x M x D	6	0.205	0.034	
Total	23	2.548		

** Significance at 1% level.

TABLE XIV

Analysis of variance of numbers of egg masses per square foot of foliage obtained from whole branch and from 18-inch tip samples at crown level c for four alpine fir in plot B (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Tree	3	0.249	0.083	3.46
Direction	2	0.033	0.016	0.31
Method	1	0.301	0.301	18.81**
T x D	6	0.314	0.052	2.17
T x M	3	0.050	0.016	
M x D	2	0.042	0.021	
T x M x D	6	0.144	0.024	
Total	23	1.133		

** Significance at the 1% level.

TABLE XV

Analysis of variance of numbers of egg masses per square foot of foliage obtained from whole branch and from 18-inch tip samples at crown level b for four alpine fir in Plot C (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Tree	3	0.183	0.061	2.90
Direction	2	0.088	0.044	1.52
Method	1	0.207	0.207	4.50
T x D	6	0.172	0.029	1.38
T x M	3	0.138	0.046	2.19
M x D	2	0.066	0.033	1.57
T x M x D	6	0.124	0.021	
Total	23	0.978		

TABLE XVI

Analysis of variance of numbers of egg masses per square foot of foliage obtained from whole branch and from 18-inch tip samples at crown level c for four alpine fir in Plot C (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Tree	3	1.100	0.366	7.04*
Direction	2	0.216	0.108	1.86
Method	1	0.001	0.001	0.01
T x D	6	0.349	0.058	1.11
T x M	3	0.323	0.108	2.07
M x D	2	0.143	0.071	1.36
T x M x D	6	0.313	0.052	
Total	23	2.445		

* Significance at 5% level.

TABLE XVII

Analysis of variance of average numbers of egg masses per square foot of whole branch foliage obtained from alpine fir at different crown levels in Plots A, B, and C (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Between Tree				
Plot	2	0.303	0.151	3.68
Trees, within plots	9	0.370	0.041	
Within Tree				
Level	2	1.695	0.847	38.50**
Plot x Level	4	0.247	0.061	2.77
Tree x Level	18	0.398	0.022	
Total	35			

** Significance at 1% level.

TABLE XVIII

Analysis of variance of average numbers of egg masses per square foot of whole branch foliage obtained from Plot A alpine fir and white spruce at three crown levels (transformed logarithmically).

Source	D.F.	S.S.	M.S.	F
Between Trees				
Species	1	0.050	0.050	0.62
Trees, within species	6	0.484	0.080	
Within Trees				
Level	2	0.695	0.347	18.26**
Species x Level	2	0.080	0.040	2.42
Tree x Level	12	0.237	0.019	
Total	23	1.546		
Spruce and Fir, Inter-tree variability				
Alpine fir	3	0.070	0.023	
White spruce	3	0.357	0.119	5.17

** Significance at 1% level.

TABLE XIX

Numbers of egg masses per square foot of foliage on three branches from each of eight understory and eight overstory (crown b) alpine fir in Plot A.

Tree number	Overstory	Understory
Alpine fir 1	3.4	2.0
	3.3	1.3
	4.2	0.0
Alpine fir 2	6.9	0.0
	4.0	0.0
	4.4	0.0
Alpine fir 3	5.2	1.8
	3.5	0.8
	2.2	1.0
Alpine fir 4	4.3	0.0
	6.6	1.0
	5.8	0.0
Alpine fir 5	9.6	0.7
	6.4	2.2
	12.3	0.7
Alpine fir 6	13.6	0.8
	14.0	1.4
	6.9	1.1
Alpine fir 7	7.8	0.0
	13.1	0.0
	18.1	0.0
Alpine fir 8	1.1	5.8
	3.6	1.5
	5.2	2.3

Analysis:

Source	D.F.	S.S.	M.S.	F
Understory				
Inter-tree	7	0.527	0.075	4.69**
Intra-tree	16	0.262	0.016	
Overstory				
Inter-tree	7	2.691	0.384	29.54**
Intra-tree	16	0.221	0.013	
Understory vs. Overstory				
Inter-tree variance				5.12*

Student's 't': 4.31**

* Significance at 5% level.
** Significance at 1% level.

TABLE XX

Comparison of results obtained through analyses of egg mass data, two-year-cycle spruce budworm, 1958, Tables I-XIX

Comparison	Table number	Method	Species	Plot	Significance of factors								
					Tree	Direction	Level	Method	TL	TD	LD	TM	MD
Tree, level, & direction	I	Whole branch	Alpine fir	A	**	-	**		-	-	-		
	II	18-inch tip	Alpine fir	A	-	-	**		-	-	-		
	III	Whole branch	White spruce	A	**	-	*		**	*	*		
	IV	18-inch tip	White spruce	A	*	-	*		-	-	-		
	V	Whole branch	Alpine fir	B	**	-	*		-	-	-		
	VI	18-inch tip	Alpine fir	B	*	-	*		*	-	-		
	VII	Whole branch	Alpine fir	C	-	-	*		-	-	-		
	VIII	18-inch tip	Alpine fir	C	*	-	*		-	-	-		
Whole branch & 18-inch tip	IX	Branch & tip	b Alpine fir	A	**	-		-		**		-	-
	X	Branch & tip	c Alpine fir	A	--	-		-		*		-	-
	XI	Branch & tip	b White spruce	A	**	-		-		-		-	-
	XII	Branch & tip	c White spruce	A	-	-		-		-		-	-
	XIII	Branch & tip	b Alpine fir	B	**	-		-		-		-	-
	XIV	Branch & tip	c Alpine fir	B	-	-		**		-		-	-
	XV	Branch & tip	b Alpine fir	C	-	-		-		-		-	-
	XVI	Branch & tip	c Alpine fir	C	*	-		-		-		-	-
Plots	XVII	Between trees Within trees	Alpine fir		Plots Level ** Plot x Level								
Species	XVIII	Between trees Within trees		A	Species Trees, Within Species Level ** Species x Level								
Overstory & Understory	XIX	Understory vs. Overstory	Alpine fir	A	Inter-tree (Student's "t") **								

* Significance at 5% level.
** Significance at 1% level.

TABLE XXI

Numbers of eggs per egg mass obtained from trees in Plots A, B, and C.

Plot	Tree number	Number of eggs	Number of egg masses	Average number eggs per egg mass	
				On tree	On plot
A	White spruce 1	10,240	312	32.82	30.83
	White spruce 2	3,388	130	26.06	
	Alpine fir 1	956	35	27.31	33.29
	Alpine fir 2	2,073	56	37.01	
B	Alpine fir 1	2,613	54	48.38	51.87
	Alpine fir 2	3,769	69	54.62	
C	Alpine fir 1	9,069	212	42.77	45.19
	Alpine fir 2	6,296	128	49.18	

TABLE XXII

Defoliation estimates, with d.b.h. and height, for all trees sampled in plots A, B, and C, Babine Lake, 1958.

Plot	Tree no.	Description	Date sampled	D.B.H. (in.)	Height (ft.)	% Defoliation Current	% Defoliation Total
A	White spruce 1	Felled	August 7	11.5	47	100	20
	White spruce 2	"	"	8.5	54	99	20
	White spruce 3	"	"	6.3	36	95	15
	White spruce 4	"	"	10.5	57	95	20
	Alpine fir 1	"	"	6.0	34	95	20
	Alpine fir 2	"	"	7.5	47	100	20
	Alpine fir 3	"	"	8.5	45	100	20
	Alpine fir 4	"	"	9.5	50	99	40
	Alpine fir 5	Standing	"	7.0	30	95	50
	Alpine fir 6	"	"	9.0	40	95	30
	Alpine fir 7	"	"	8.0	47	95	10
	Alpine fir 8	"	"	5.5	35	95	10
	Alpine fir U-1	Understory	August 17	2.3	12	80	5
	Alpine fir U-2	"	"	1.5	9	98	15
	Alpine fir U-3	"	"	2.5	11	98	5
	Alpine fir U-4	"	"	1.8	11	100	15
	Alpine fir U-5	"	"	3.3	16	98	10
	Alpine fir U-6	"	"	1.8	10	98	10
	Alpine fir U-7	"	"	1.8	9	98	15
	Alpine fir U-8	"	"	2.5	13	98	10
B	Alpine fir 1	Felled	August 13	12.0	46	15	1
	Alpine fir 2	"	"	11.3	54	90	10
	Alpine fir 3	"	"	12.0	47	60	5
	Alpine fir 4	"	"	12.5	57	85	10
C	Alpine fir 1	"	August 11	12.6	54	100	10
	Alpine fir 2	"	"	13.4	59	100	10
	Alpine fir 3	"	"	10.7	47	99	15
	Alpine fir 4	"	"	14.3	48	100	10