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INTRA-TREE DISTRIBUTION OF LATE-INSTAR BIRCH
CASEBEARER LARVAE ON WHITE BIRCH

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NEWFOUNDLAND FOREST RESEARCH CENTRE
ST. JOHN'S, NEWFOUNDLAND
INFORMATION REPORT N-X-125

DECEMBER 1974

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INTRODUCTION

The birch casebearer (Coleophora fuscedinella Zeller¹) is a European insect, accidentally introduced to North America, and was first found in Maine in 1927. It had spread to New Brunswick by 1933, to Nova Scotia by 1937 (Reeks 1951), and to Ontario by 1944 (Raizenne 1952). It was discovered near Stephenville in western Newfoundland in 1953 on Manitoba maple (Acer negundo L.)². The insect spread rapidly eastward and was causing severe defoliation of white birch (Betula papyrifera Marsh.) in both western and central areas of the Island by 1968 (Warren & Singh 1969). By 1971 it had infested most of the white birch stands of the Island (Clark & Richardson 1972).

The life history and habits of the birch casebearer in the northeastern United States were reported by Salman (1929) and Gillespie (1932). Both authors reported five larval instars for this species, whereas in Newfoundland, only four instars occur. Here, eggs are laid in July on the underside of leaves. Larvae hatch in August and mine the leaf till early September. After molting they cut a case from the leaf epidermis, crawl to a different area of the leaf and feed till October. Prior to leaf fall they crawl to branch crotches, or to the base of leaf buds to overwinter. In spring after molting, they feed on the developing leaves,

¹Lepidoptera: Coleophoridae

²Cochran, S.G. 1970. The birch casebearer in Newfoundland. Can. For. Serv., St. John's, Newfoundland, Int. Rep. N-32.

molt again after a few days, and continue to feed till full grown, as fourth instar larvae in mid-June. The larvae pupate both on the host tree and on other vegetation and the adults emerge in July.

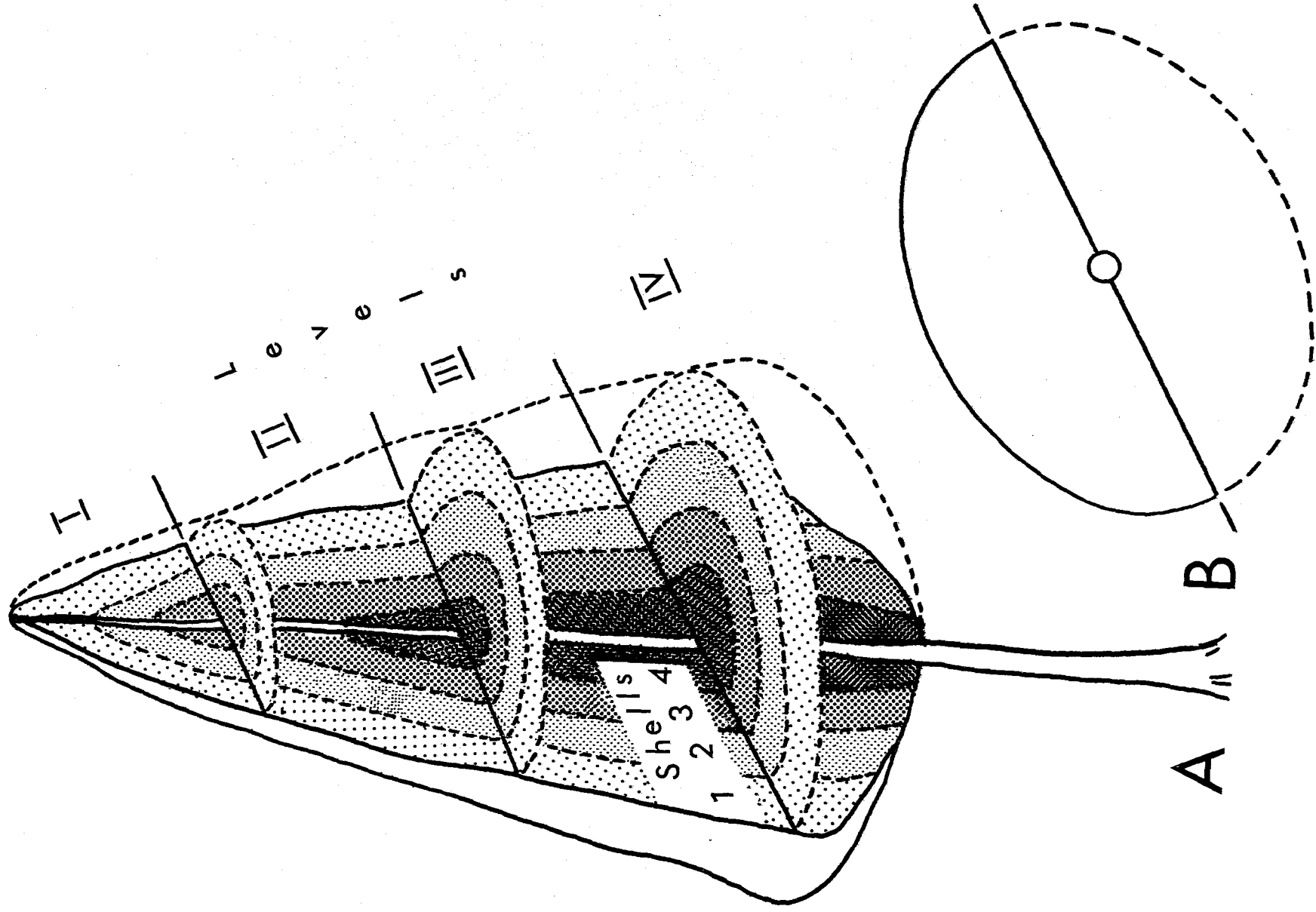
A dependable sampling system is needed for monitoring annual fluctuations in casebearer numbers and for evaluating factors influencing changes in population levels, including the impact of recently introduced parasites. This paper reports some preliminary data needed for the development of a sampling system: the distribution of leaf clusters and of late instar casebearer larvae within white birch crowns, the proportion of larvae within definitive crown strata, and estimates of the percent defoliation caused by a given number of larvae per leaf cluster.

METHODS

Different population densities of the birch casebearer larvae were studied in two white birch stands in western Newfoundland in the spring of 1971. At Pasadena, 29 trees were sampled, and at Wild Cove Point, near Corner Brook, 37 trees were sampled. Sample trees varied from 10 to 18 feet in height, and averaged 13.1 feet.

The crown of each tree was divided along all three dimensions into crown strata. Vertical: into equal halves with the division plane oriented to coincide with the long axis of the elliptical-shaped crown in top view (Fig. 1:A, B). Horizontal: crown length was divided into quarters called levels (Fig. 1:I, II, III, IV). Radial: each level was divided into concentric 10-inch shells (measured horizontally) starting from the crown periphery (Fig. 1: 1,2,3,4). A crown stratum, or the sampling unit, therefore consisted of the branches, leaves, and insect cases of one shell of a given crown level in a given half of the tree.

Fig. 1. Division of birch crowns into maximum number of strata; vertically into crown halves (A and B), horizontally into four crown levels (I, II, III and IV), radially into shells (1, 2, 3 and 4).



Material from the crown strata were collected between June 2 and June 10, placed in plastic bags, stored in a freezer at 0°F and the number of insect cases and leaf clusters per sampling unit counted at a later date.

Percent defoliation of a tree was determined by sampling the remaining half of each tree on June 25, 1971 when percent defoliation was at a maximum. A sample consisted of 10 fully-developed leaves collected from the mid point of the outer shell of each crown level. A dot grid was used to determine percent defoliation following the method described by Benjamin, et al. (1968). Casebearer larvae do not feed on leaf veins, therefore, an estimate of the total available leaf surface was reduced by the proportion of vein area. The average vein area (16.3%) was obtained by measuring a separate sample of 100 leaves from each of three trees.

Trees were grouped into three arbitrary categories of population density by number of cases per foot of crown length; more than 500 cases per crown foot was termed "extreme"; 201 to 500 cases per foot-crown was termed "high"; and less than 200 cases "moderate".

In each tree category, one crown stratum from the outer shell was selected at random to determine the number of trees needed to stabilize the inter-tree variance of casebearer numbers when expressed in number of cases per leaf cluster.

The term "cases" as used in this report includes fourth-instar and third-instar larvae in their cases, a few empty third instar cases, and larvae in pupating position towards the end of the sampling period. The third instar case is left attached to the leaf when a new case is cut, and this case tends to remain on the leaf for up to several days. The term "leaf cluster" refers to all leaves emanating from either a lateral or a terminal bud.

Percent data were transformed to $\arcsin \sqrt{\text{percent}}$ before analysis. Insect distribution data were analyzed in three forms: the absolute number of cases, the proportion of cases expressed as a percent of the total cases per tree, and the number of cases per leaf cluster.

RESULTS

At least 8 trees were needed in the "moderate" category to stabilize the inter-tree variance, 14 for the "high" category, and 10 for the "extreme" category. Therefore means presented have statistical validity because sample size was sufficient in all tree categories.

Distribution of leaf clusters

The distribution of leaf clusters, the food supply of the casebearer, is likely to affect the distribution of the insect. Leaf clusters were concentrated toward the periphery of the crown and towards the mid-crown (Fig. 2). The average number of leaf clusters for all sample trees in shell 2 of each crown level was about one-half that of shell 1 except in the top crown level where it was about one-third. The number of leaf clusters in shell 3 was about 0.4 that of shell 2 in each respective crown level. The number of leaf clusters in crown level II and III were approximately equal and comprise about 65% of the total leaf clusters.

Number of cases in crown strata

More cases occurred in the periphery of the tree than towards the centre and more occurred towards the top of the crown than towards the bottom in both areas and regardless of population density (Fig. 3). The magnitude of the differences between casebearer numbers in different crown strata suggests that the above pattern is consistent for the distribution of late-instar birch casebearer larvae.

Fig. 2. Number of leaf clusters in crown strata of white birch.

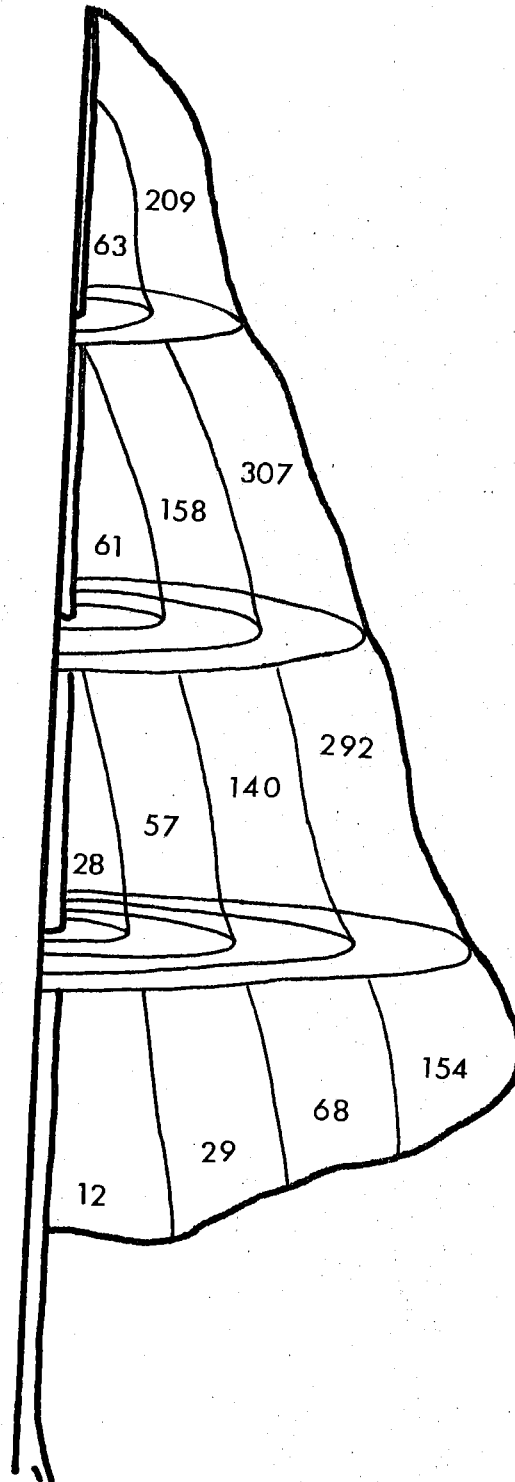
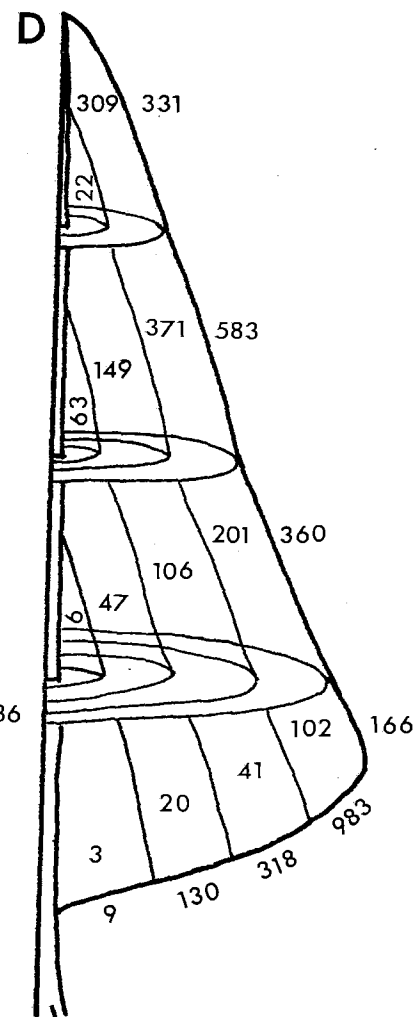
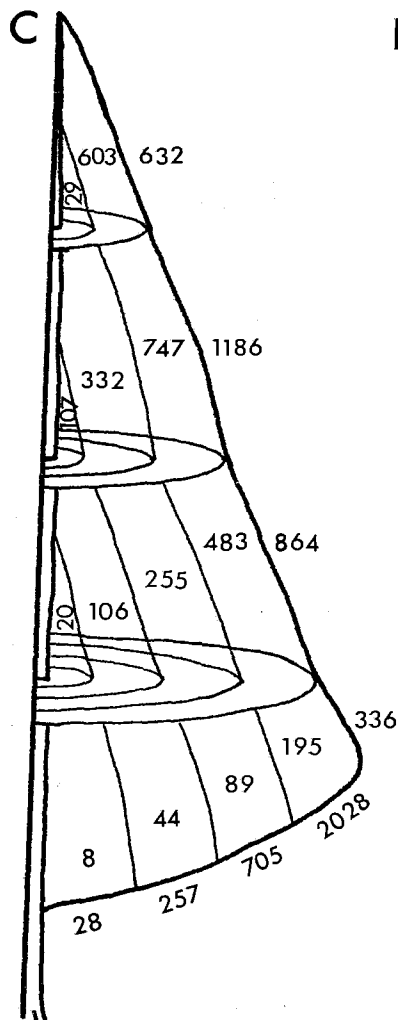
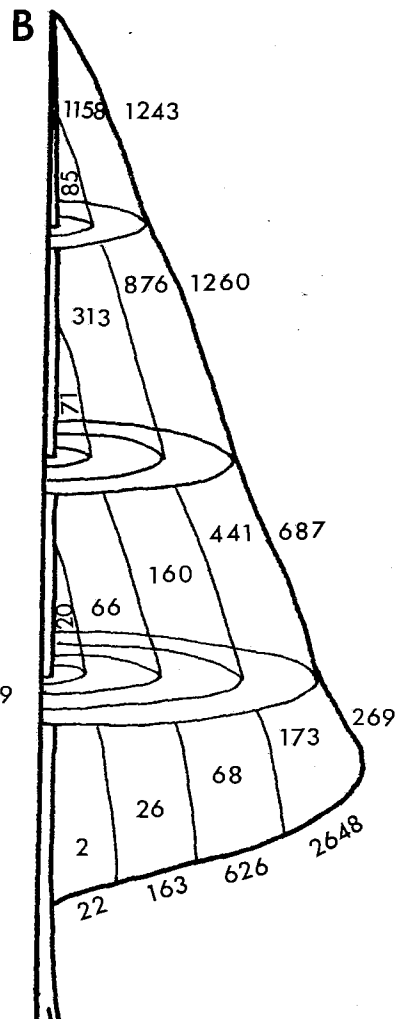
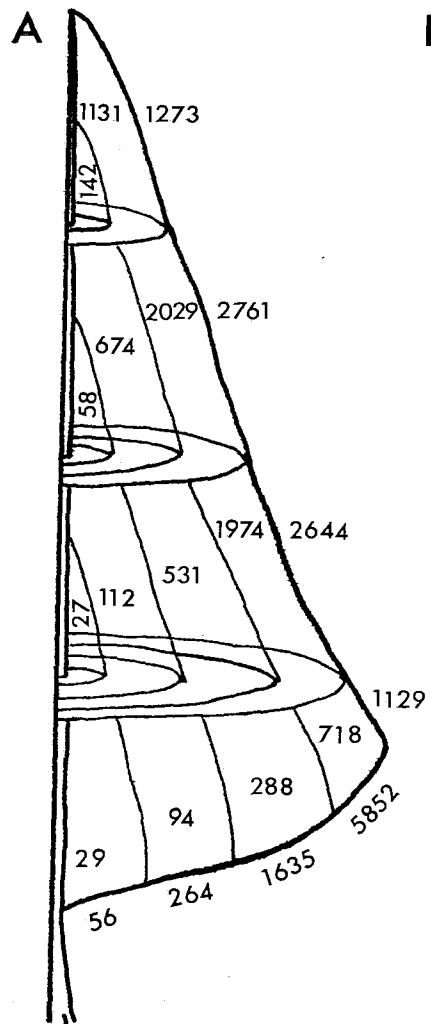


Fig. 3. Number of cases in crown strata of white birch. A. Pasadena, > 500 cases per foot crown; B. Pasadena, 201-500 cases per foot crown; C. Wild Cove Point, 201-500 cases per foot crown, D. Wild Cove Point, ≤ 200 cases per foot crown.



The number of cases was highest in the outer shell and number of cases decreased rapidly towards the centre in all tree categories. Also, more insects occurred in the two middle crown levels than in the other two crown levels in all tree categories except the "high" at Wild Cove Point when insect numbers remained quite high in the outer shell of the top crown level. For individual strata, the highest number of cases always occurred in the outer shell of level II and the second highest in outer shell of level I in all but the "extreme" category.

The number of cases in the crown strata were directly correlated ($P \leq .05$) to the total number in the tree only for some of the crown strata (Table 1). Most of these strata were in the outer shell (shell 1) and in the upper three levels. When all tree categories were combined, there was a direct correlation in most crown strata between numbers in the crown strata and numbers in the tree. The regression coefficients (r) were highest in the outer shell at all levels except in crown level III, where it was highest in the second shell.

Proportion of cases in crown strata

The largest proportion of cases occurred in the outer shell of one of the upper two crown levels in all tree categories except in the "extreme" category, where the proportion in the outer shell of crown level III was greater than that in crown level I (Fig. 4). The general pattern of higher proportions in the outer shells was consistent in all tree categories.

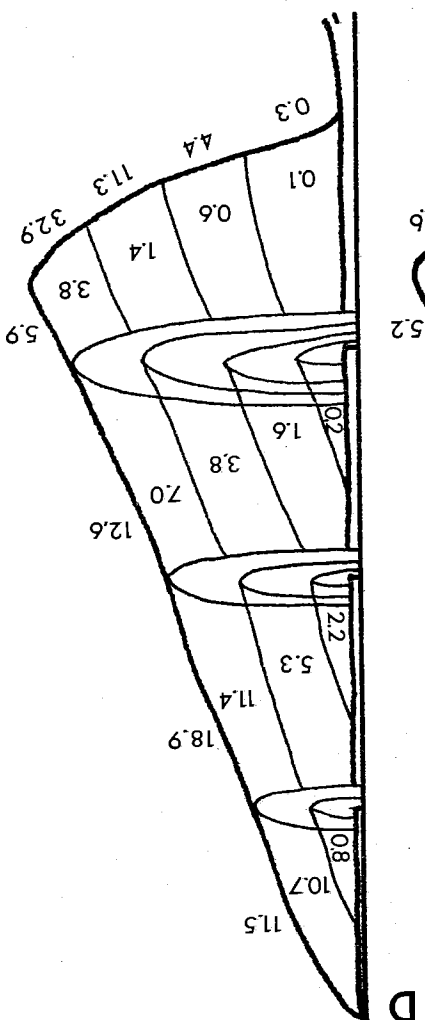
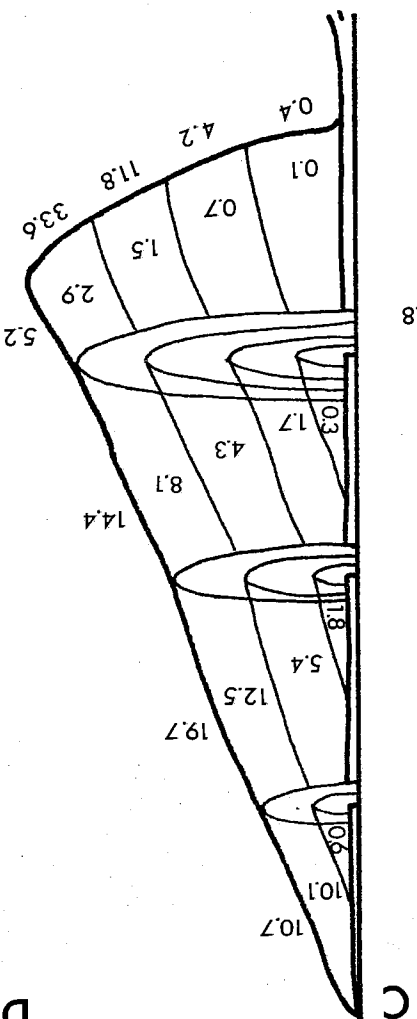
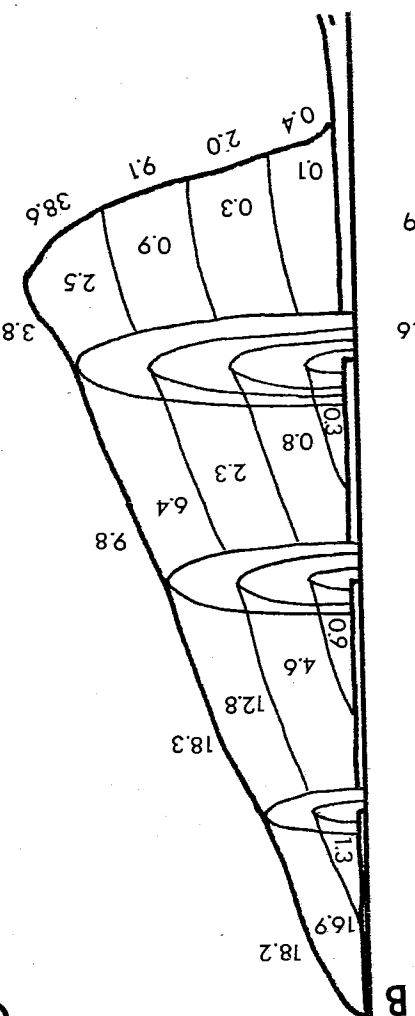
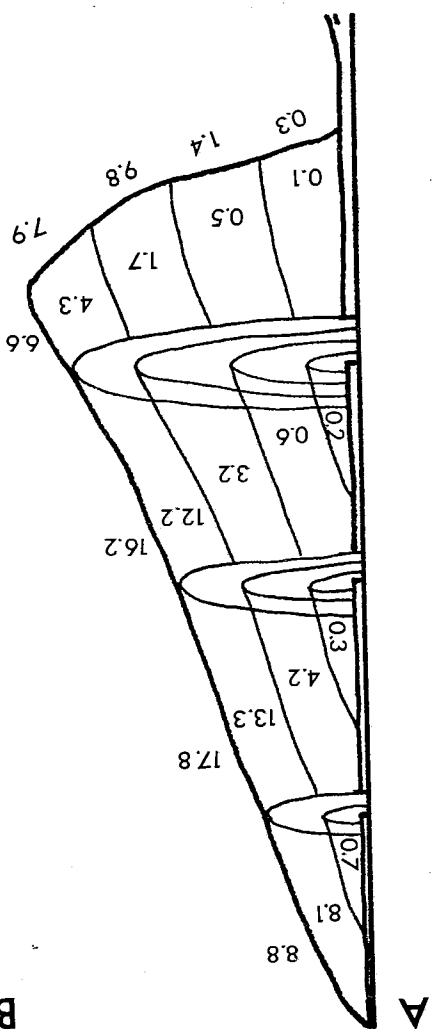
Based on the half-crown sample 64% to 78% of birch casebearer cases in a given tree are found in the outer 10-inch shell, and 88% to 96% of the cases in the 20-inch periphery. The proportion of insects decreases rapidly towards

Table 1.- Significant ($P \leq .05$) coefficients of linear regression (r) of number of cases in crown strata (X) and total number of cases per tree (Y)*.

Crown stratum	Pasadena ≥ 500 cases per ft. crown (d.f. = 9)	Pasadena 201-500 cases per ft. crown (d.f. = 12)	Wild Cove Point 201-500 cases per ft. crown (d.f. = 16)	Wild Cove Point ≤ 200 cases per ft. crown (d.f. = 13)	All trees (d.f. = 56)
	<u>Extreme</u>	<u>High</u>	<u>High</u>	<u>Moderate</u>	
I-1	-	.76	-	.65	.47
I-2	- (6)	- (6)	- (4)	- (4)	- (20)
II-1	.46	-	.61	.80	.83
II-2	.71 (9)	-	-	- (12)	.80 (53)
II-3	- (5)	- (11)	- (14)	- (12)	- (42)
III-1	.77	-	.62	.56	.49
III-2	.71	-	-	-	.76
III-3	- (7)	- (11)	- (17)	-	.45 (50)
III-4	- (8)	- (5)	- (6)	- (5)	- (19)
IV-1	.82	-	-	-	.84
IV-2	.77	-	-	-	.78
IV-3	- (7)	- (11)	- (17)	.59 (14)	.64 (49)
IV-4	- (3)	- (4)	- (10)	- (6)	.79 (23)

*Non-significant correlation is represented by a dash. Number in parentheses is number of trees (n) that contained this crown stratum, when stratum not present in all trees.

Fig. 4. Proportion of cases in crown strata of white birch. Total per half crown = 50%, A. Pasadena, > 500 cases per foot crown; B. Pasadena, 201-500 cases per foot crown; C. Wild Cove Point, 201-500 cases per foot crown; D. Wild Cove Point, \leq 200 cases per foot crown.



the centre of the tree and decreases more slowly towards the bottom of the crown. The higher proportion at mid-crown than at the upper crown reflects the greater number of leaf clusters in those crown strata. The decrease in the casebearer numbers in the upper crown sectors of the "extreme" tree category again differed from the general pattern of other tree categories.

Number of cases per leaf cluster in crown strata

In all tree categories, number of cases per leaf cluster decreased gradually from the top of the tree towards the bottom, and from the outside of the tree towards the inside (Fig. 5). These differences among crown strata reflect changes in number of insects per unit of food supply. The exception to these trends occurred on the inside of the tree, shells 3 and 4, where the number of leaf clusters is small. Small numerical changes in leaf clusters in these strata can cause large, spurious changes in number of insects per leaf cluster.

The correlations of the number of cases per leaf cluster of crown strata to the average per tree were usually significant for all trees combined (Table 2). However, for individual tree categories, most strata were not correlated to the whole. Of those correlated, 10 occurred in shell 1, 6 in shell 2, and 2 in shell 3. Of the 10 significant correlations in the outer shell, 9 occurred in the upper 3 levels. Therefore only the number of cases per leaf cluster in the crown strata of the outer shell of the upper 3 levels were most consistently correlated to the average number of cases per leaf cluster per tree.

Relationship between mid-crown and the tree

The relationship between crown strata II-1 and III-1 combined and the whole was determined because (1) both crown strata contained high numbers,

Fig. 5. Number of cases per leaf cluster in crown strata of white birch. A. Pasadena > 500 cases per foot crown; B. Pasadena, 201-500 cases per foot crown; C. Wild Cove Point, 201-500 cases per foot crown; D. Wild Cove Point, \leq 200 cases per foot crown.

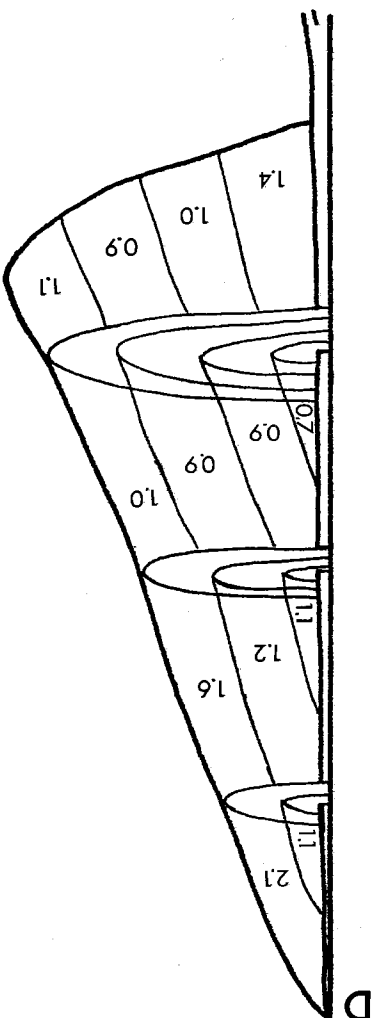
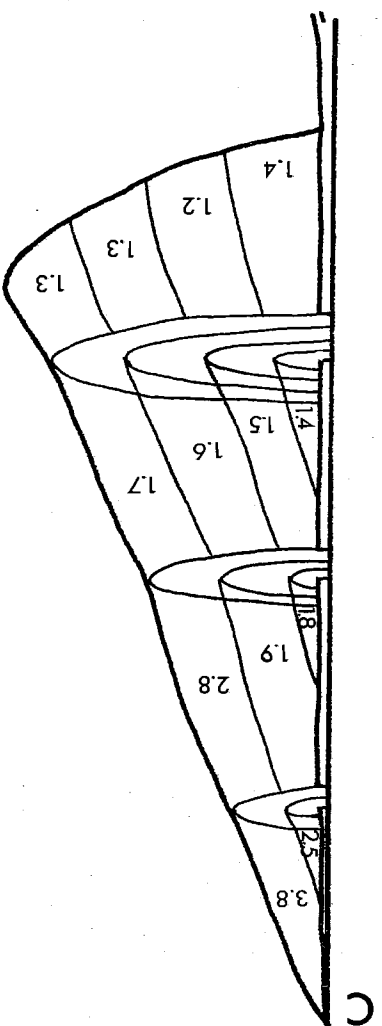
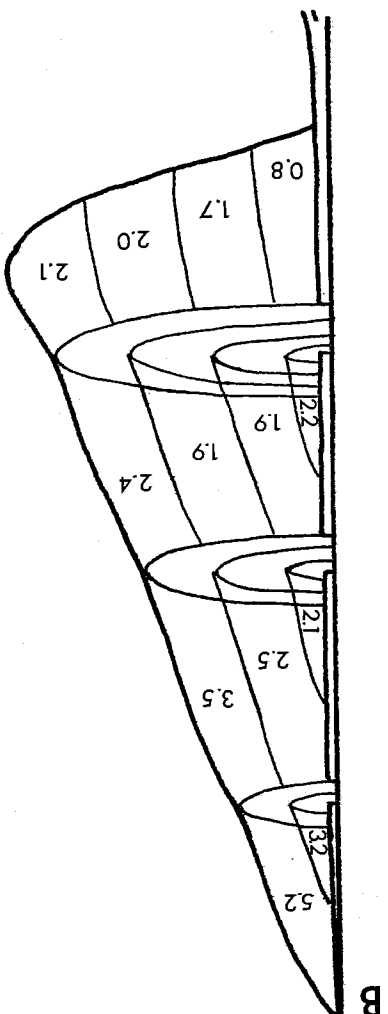
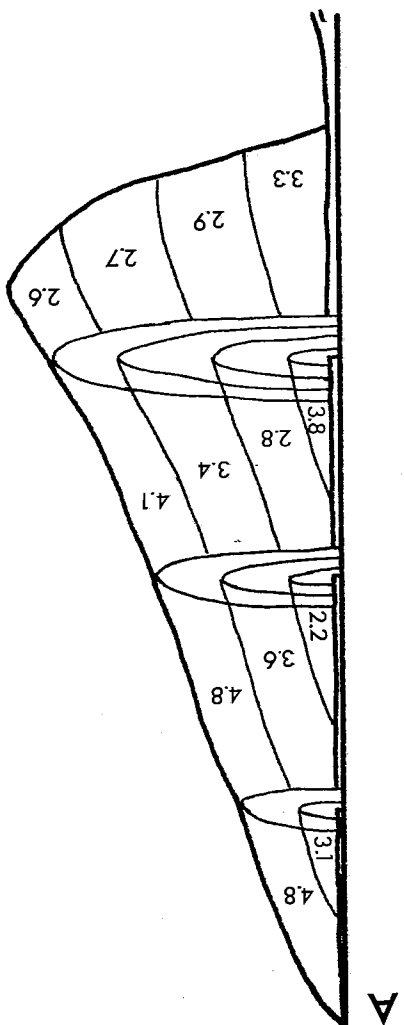


Table 2.- Significant ($P \leq .05$) coefficients of linear regression (r) of number of cases per leaf cluster in crown strata (X) and average cases per leaf cluster per tree (Y)*.

Crown stratum	Pasadena ≥ 500 cases per ft. crown (d.f. = 9)	Pasadena 201-500 cases per ft. crown (d.f. = 12)	Wild Cove Point 201-500 cases per ft. crown (d.f. = 16)	Wild Cove Point ≤ 200 cases per ft. crown (d.f. = 13)	All trees (d.f. = 56)
	<u>Extreme</u>	<u>High</u>	<u>High</u>	<u>Moderate</u>	
I-1	.97	.84	-	.86	.76
I-2	-	-	-	-	.61
I-3	-	-	-	-	.89
II-1	-	.61	.85	.88	.80
II-2	-	.69	.65	.65	.82
II-3	-	.86	-	-	.49
II-4	-	-	-	-	.73
III-1	.67	-	.85	.73	.80
III-2	-	-	.54	-	.70
III-3	-	-	.51	-	.49
III-4	-	-	-	-	.67
IV-1	-	-	.51	-	.59
IV-2	-	.78	.65	-	.77
IV-3	-	.66	-	-	-
IV-4	-	-	-	-	.56

* Non-significant correlation is represented by a dash. See Table 1 for reduced sample size for some strata.

and high proportions of cases, (2) both were well correlated to the whole for number of cases and for number of cases per leaf cluster, (3) both are easily accessible for future sampling and (4) the combined strata form a readily identifiable portion of the crown; i.e. mid crown.

The number of cases in the crown strata were correlated to the total in a tree in all tree categories except the "high" at Pasadena, and were correlated for all trees combined (Table 3). The number of cases per leaf cluster was correlated to the whole for all tree categories and for all trees combined. The correlation coefficients (r) were higher for the combined strata than for individual strata in both expressions of insect numbers.

Relationship between defoliation and number of cases

The intensity of defoliation was closely correlated to the number of cases per leaf cluster for each crown stratum and not correlated to the absolute numbers of cases per crown stratum. The percent defoliation in shell 1 for all trees (Fig. 6) was plotted on probability paper, and associated with its respective class of number of cases per leaf cluster, and then fitted with a hand-drawn line. About seven or more cases per leaf cluster were associated with 100 percent defoliation and three cases per leaf cluster with 50 percent.

The average percent defoliation at each crown level differed for each tree category (Fig. 7). The "extreme" category was 100 percent defoliated at the top three crown levels. In this category, crown level I was completely defoliated early in the spring when the leaves were less than half developed. In crown level II most leaves were prevented from complete development by early defoliation. Almost all leaves were able to develop completely in other parts of the crown in this category and in all parts of the crown in the other two tree categories.

Table 3.- Significant ($P \leq .05$) coefficients of linear regression (r) of number of cases in crown strata (II-1) + (III-1) (X) and number per tree (Y).

Crown strata (II-1) + (III-1)	Pasadena ≥ 500 cases per ft. crown (d.f. = 9)	Pasadena 201-500 cases per ft. crown (d.f. = 12)	Wild Cove Point 201-500 cases per ft. crown (d.f. = 16)	Wild Cove Point ≤ 200 cases per ft. crown (d.f. = 13)	All trees (d.f. = 56)
	<u>Extreme</u>	<u>High</u>	<u>High</u>	<u>Moderate</u>	
Number of cases	.91	-	.76	.87	.95
Number of cases per leaf cluster	.84	.81	.94	.92	.81

The "high" tree categories, both at Pasadena and at Wild Cove Point, were more severely defoliated in the top of the tree than at the bottom. The "moderate" category had only slight defoliation and it only varied between 10% and 15% among crown levels.

DISCUSSION

While counting the number of cases, it was repeatedly observed, at all insect population densities, that more feeding areas occurred on the leaves than could be caused by the number of insect cases present in the sample; even if they had all been occupied by living casebearer larvae. Furthermore, an overabundance of insect numbers, in relation to the feeding sites, was not observed in any other crown stratum. Thus at all insect population densities, a proportion of the insects that had contributed to defoliation in spring was absent in early June



Fig. 6. Relationship between number of birch casebearer cases per leaf cluster and percent defoliation (probability scale) of white birch. All tree categories and areas combined.

● - means, ○ - observations

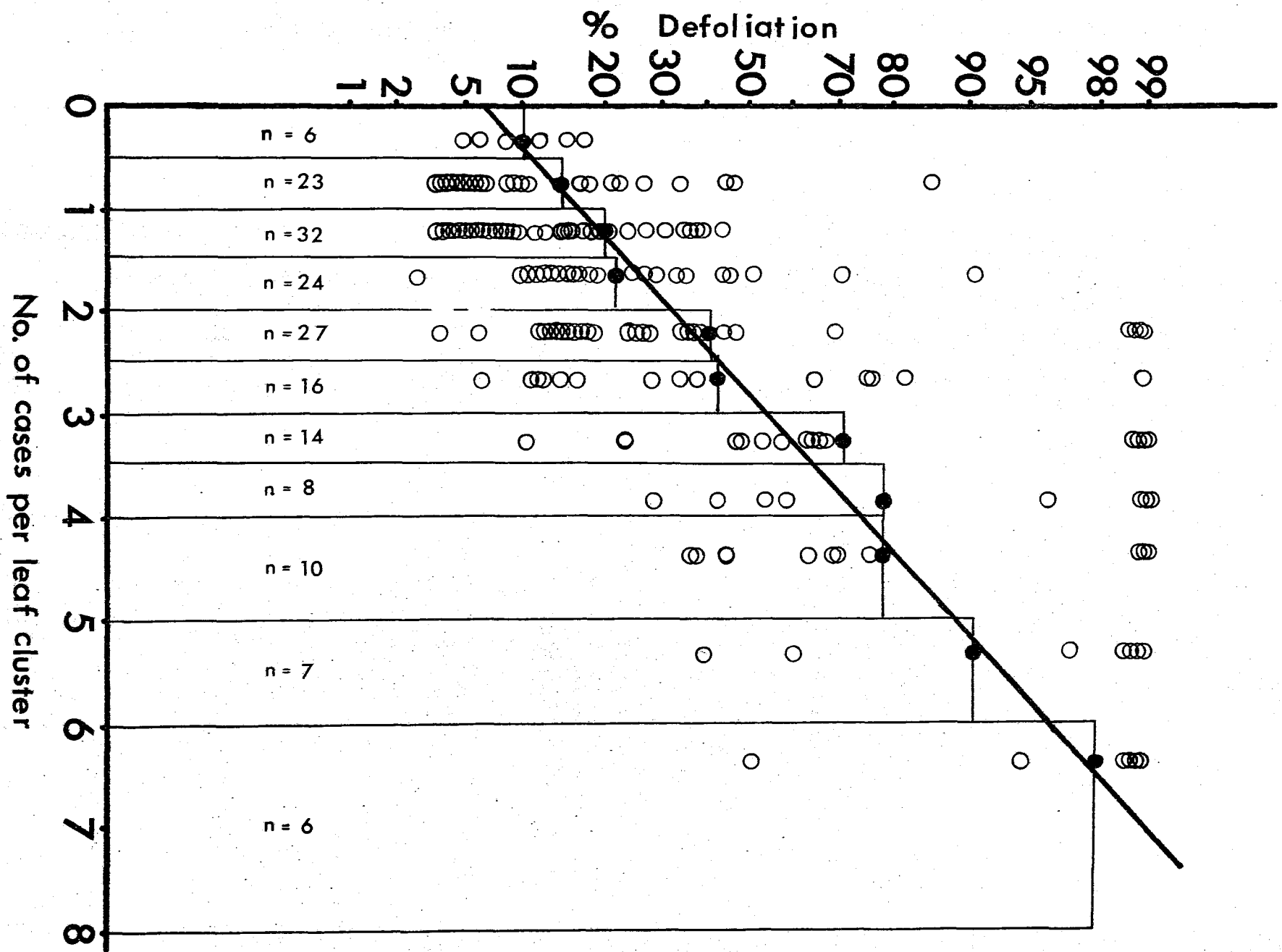
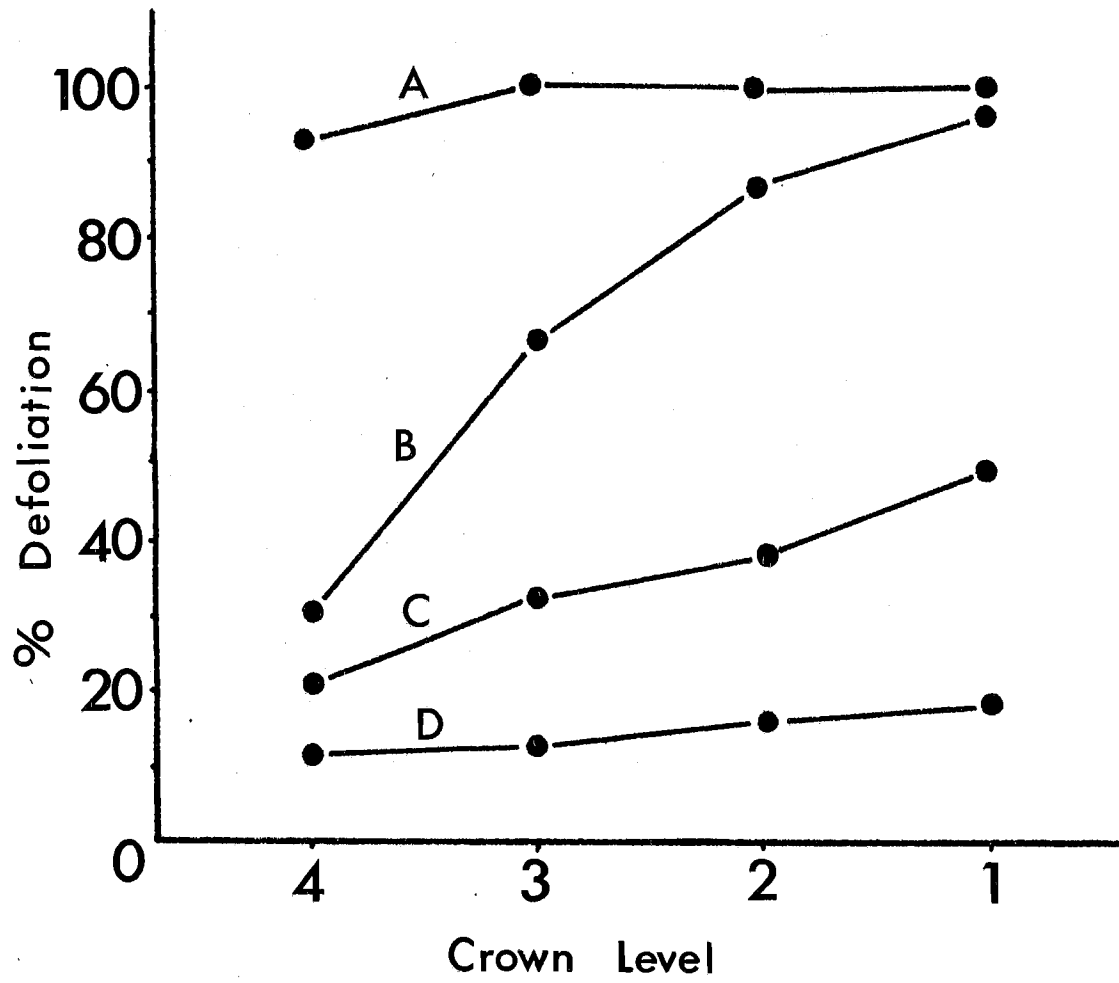


Fig. 7. Percent defoliation of white birch at crown levels.
A. Pasadena, > 500 cases per foot crown; B. Pasadena,
201-500 cases per foot crown; C. Wild Cove Point, 201-
500 cases per foot crown; D. Wild Cove Point, \leq 200
cases per foot crown.



and at the top of the tree. This indicates that larvae tended to crawl towards the tip of the branches and also upward. Therefore the insects are not distributed randomly on their food supply, but their distribution is influenced by larval behavior.

There are several advantages in using the leaf cluster as the basic sampling unit. This unit relates insect numbers to the amount of food in the various crown strata. Also it is more meaningful to relate defoliation to numbers per food-unit than to absolute numbers per space-unit. Lastly, number of cases per leaf cluster eliminates variation in crown-strata volume and variation in the number of branches in crown strata. Thus the number of cases per leaf cluster is an expression of insect population that facilitates comparison between trees, between stands and between years and an expression that is directly related to percent defoliation.

Generally more crown strata are correlated to the whole when insect density is expressed as number of cases per leaf cluster than as number of cases. In addition the regression coefficients are higher in the former, indicating a closer relationship. Regression coefficients for individual crown strata, strata I-1, II-1, and III-1, were generally higher than for other strata, but not as high as for strata II-1 and III-1 combined.

CONCLUSIONS

Cases of feeding birch casebearer larvae are distributed on small-sized white birch trees in a pattern, which is partially caused by the distribution of leaf clusters, i.e. the food supply, and partially by insect behavior.

The number of cases per leaf cluster seems to be the most biologically meaningful sampling unit. A sampling system for late-instar larvae on the foliage is theoretically possible. The number of cases per leaf cluster of crown level I-1, II-1, III-1 and II-1 plus III-1 are correlated with the insect population of the whole tree. Of these, II-1 and III-1 combined probably is the most practical because its high correlation would reduce sample size and because the sampling system can be designed to sample from mid-crown; a crown area rather easily defined and located.

However there are several disadvantages to sampling the late instar larvae. (1) Each year the collection of samples must be precisely timed to the seasonal development of the insects because the number of cases on a tree is constantly changing. New cases are cut and empty cases drop off the tree towards the end of the feeding period. Therefore any sampling system would be applicable for a short period only. (2) Observations indicated that not all of the insect population was present during the sampling period. Therefore distribution studies should be initiated for other periods in the life history of the casebearer, periods in which a given stage in the life cycle is stable within the sampling unit and over a longer period.

ACKNOWLEDGEMENTS

Thanks are due to G.L. Warren who made significant contributions during the planning stages of this study. I wish to thank D.G. Bryant for advice in analysing the data, D.K. Lane and W.F. Butt for their assistance in the field, and R.C. Clark for his help in the preparation of the manuscript.

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