N-X-182
ISBN 0704-7657

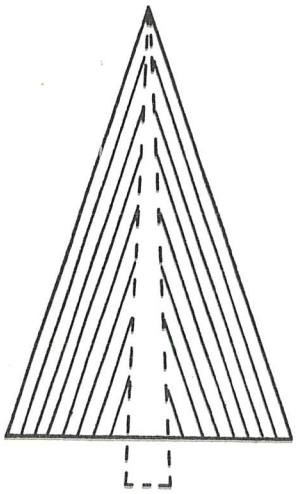
canusa

Canada
United States
Spruce Budworms
Program

A CONTRIBUTION OF THE
NEWFOUNDLAND FOREST
RESEARCH CENTRE

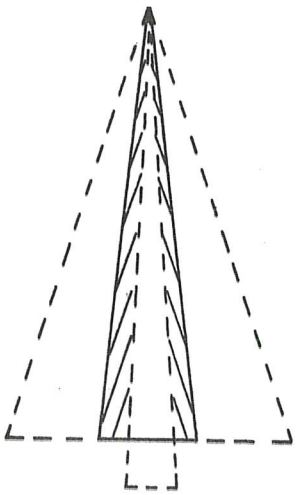
Distribution of Hibernating Spruce Budworm Larvae within Crowns of Balsam Fir Trees in Newfoundland

by
B.H. Moody and Imre S. Otvos



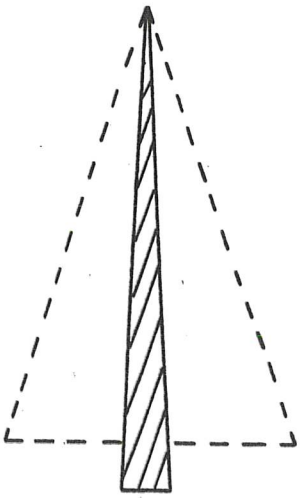
77%

on whorl branches



18%

on internodal branches



5%

on stem

Environment Canada
Forestry Service

Environnement Canada
Service des Forêts

ISSN 0704-7657

Environment
Canada

Forestry
Service

DISTRIBUTION OF HIBERNATING SPRUCE BUDWORM LARVAE WITHIN CROWNS OF BALSAM FIR TREES IN NEWFOUNDLAND

by B.H. Moody and Imre S. Otvos

NEWFOUNDLAND FOREST RESEARCH CENTRE
ST. JOHN'S, NEWFOUNDLAND
INFORMATION REPORT N-X-182

JANUARY 1980

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DISTRIBUTION OF HIBERNATING SPRUCE BUDWORM LARVAE WITHIN CROWNS OF BALSAM FIR TREES IN NEWFOUNDLAND

B.H. Moody and Imre S. Otvos

INTRODUCTION

The eastern spruce budworm, Choristoneura fumiferana (Clemens), females lay their eggs on the foliage of host trees in late July and early August in Newfoundland and hatching of larva (eclosion) is completed by early September (Crummey and Otvos 1980). The newly hatched, first instar larva spins a small silken capsule, called hibernaculum, in which the larva molts into second instar (L_2) and then hibernates. The hibernating second instar larvae can be found throughout the host trees: on twigs, branches and stems; at any location that offers some protection, such as inside staminate flower bracts and mined buds, beneath lichen mats and bud scales, and in the crevices of rough bark. Preference of the spruce budworm for empty staminate flower bracts of balsam fir, Abies balsamea (L.) Mill. as overwintering sites has been shown by Bess (1946) and Blais (1952). However, Jaynes and Speers (1949) and Miller (1958) found no definite evidence of a preferred hibernation site.

Second instar larval population estimates are used to forecast defoliation. The results of these samples can also be used to determine dispersal occurring when first instar larvae move to hibernation sites, and overwintering mortality. These factors are especially important

when a control (suppression) program is planned. Miller (1958) estimated that in New Brunswick the "stem" population of second instar larvae constitute only 1% of the total population in open grown stands of mature balsam fir trees, and 4% in dense, middle aged stands. McKnight (1969) estimated that in Colorado about 35% of the larvae of the western spruce budworm, C. occidentalis Freeman, hibernated on the stems of pole-size Douglas-fir trees, Pseudotsuga menziesii (Mirb.) Franco, and the remaining 65% hibernated on the branches in a six-year-old outbreak.

The distribution of second instar larvae within the tree in Newfoundland was not known and Bryant and Carter (1976) suggested that a high proportion of the larvae entered hibernacula near or on the stem of the trees.

In 1977 a study was conducted in eastern Newfoundland to determine intra-tree variation and the proportion of hibernating spruce budworm larvae (L_2) on the various parts of immature balsam fir trees.

METHODS

Study Areas

The distribution of second instar larvae was determined on five trees, randomly selected in immature balsam fir stands at two locations, Bunyan's Cove and Bellevue, in eastern Newfoundland.

The stand at Bunyan's Cove was two-aged as a result of strip-cutting; and the younger age class (15 years) was sampled. The stand was on a hillside and the trees averaged 6 cm diameter at breast height

(DBH) and 4.5 m in height. In 1977 this stand had one year of severe (76-100%) defoliation and new egg-mass densities averaged 106 per 10 m^2 determined by using the method of Webb et al (1956).

The stand at Bellevue was even-aged and the trees averaged 5 cm DBH and 3.5 m in height. In 1977 the stand was severely defoliated for the second consecutive year, and new egg-mass densities in the fall, on adjacent plots, averaged 1606 per 10 m^2. Moderate-to-severe defoliation was forecasted to occur in 1978 in both stands.

Branching Characteristics of Balsam Fir Tree

A balsam fir tree has a central axis or stem supporting a narrow conical crown. The stem is composed of a series of internodes produced in successive seasons, alternating with nodes which are the junctions of adjoining internodes. The regularly occurring whorls of branches (nodal branches[1]), which originate from the stem nodes, and the irregularly occurring branches along the internodes (internodal branches) form the crown of the tree (Fig. 1). The crown on open grown trees is wide and extends nearly to the ground, while in dense stands crown shape is narrow and does not extend to the ground.

The use of the whole branch samples for population estimates of L_2 is a fairly standard practice. However, to assess, biologically and statistically, the results of the sampling it is necessary to know the proportional distribution of the hibernating larvae on the various parts of the host tree.

---

[1]Whorl of branches or branches in the text refers to nodal branches.

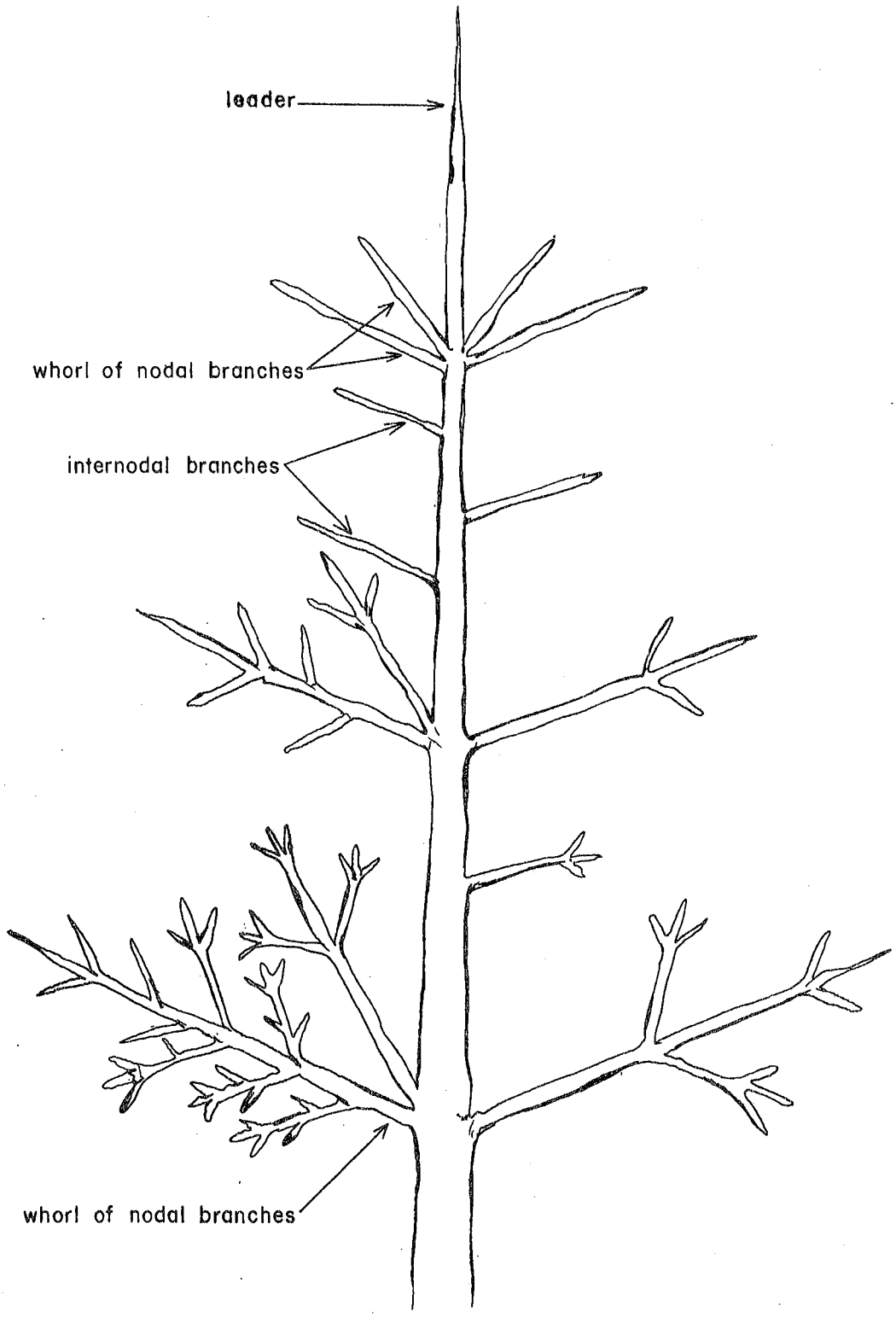


Figure 1. Branch types on the main stem of balsam fir.

Sampling of the Hibernating Larval Population

Five trees were felled in November 1977 in each of the two stands. The crown of each felled tree was divided into three equal portions: upper, middle and lower. From each crown level, 20 cm stem-sections containing one whorl of branches were taken in the following proportions: three sections from the upper third; two sections from the middle, and one section from the lower third (Fig. 2). This proportion of stem-sections was arbitrarily selected so as to have similar stem surface area and branch surface area from the three crown levels. Whole branches were cut, from each section, one inch from the stem. Each tree was measured so that for each crown level, the following could be calculated:

(a) whole branch surface area (total length of branch x width at half the total length)

(b) the 45 cm branch-tip surface area (similar to above using 45 cm as total length) for lower and middle levels

(c) surface area of internodal branches (loosely positioned to form a quadrangle of foliage, length x width)

(d) bark surface area of stem-sections (average diameter, based on measurements at two ends of the section, x π x length of section).

All samples: branches, internodal branches, and stem-sections were taken to the laboratory and the larvae extracted by the caustic

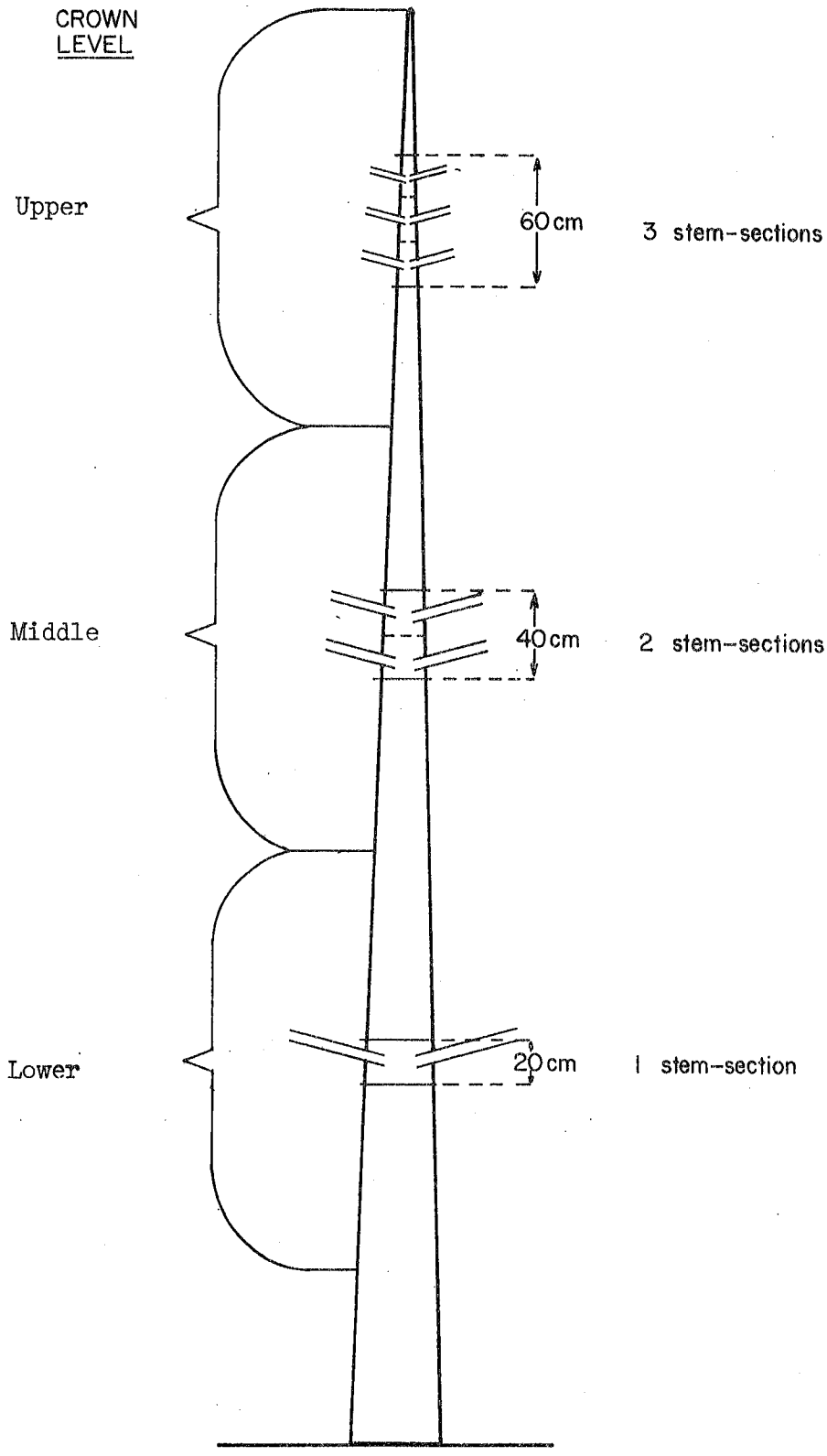


Figure 2. The proportional sampling method for hibernating spruce budworm larvae from the three crown levels of balsam fir.

soda solution washing technique (Miller et al. 1971). The number of hibernating larvae (L_2) were counted in each crown third from each of the sample trees.

Sampling for Vertical Distribution of Nodal Branches

The total number of branches on the trees sampled for hibernating larval population were not counted. However, these counts were made on five similar balsam fir trees ranging in height from 2.6 m to 5.2 m from each of the two locations and used to determine the distribution of branches among crown thirds and variation among trees. Total nodal branch area in each crown third was determined by applying the ratio of total number of nodal branches counted to number of nodal branches sampled.

RESULTS

Vertical Distribution of Nodal Branches

Crown length and vertical distribution of nodal branches on each balsam fir tree in the two study areas are shown in Table 1. The number of nodal branches did not differ significantly ($P = .05$) among crown levels. However, at the Bellevue plot, the number of nodal branches on the average was higher in the upper third than in the other crown levels.

The total nodal branch surface area was distributed in the upper, middle and lower crown in a 1:4:5 ratio at Bunyan's Cove and a 1:3:6 ratio on trees from Bellevue. When the data were combined and averaged for the two areas, the percentage distribution of branch surface

Table 1. Vertical distribution of nodal branches on balsam fir trees at Bunyan's Cove and Bellevue, Newfoundland.

Tree no.	D.b.h. (cm)	Diam. at stump (cm)	Total height (m)	Crown length (m)	No. of nodal branches by crown levels			
					Upper	Middle	Lower	Total
Bunyan's Cove								
1	6.0	7.2	3.8	2.8	18	10	17	45
2	5.2	7.2	4.6	4.6	14	16	13	43
3	5.9	8.0	5.2	3.9	19	22	16	57
4	5.5	6.5	4.5	3.7	15	17	15	47
5	7.0	7.6	4.6	4.3	18	18	20	56
Total	-	-	-	-	84	83	81	248
Average	5.9	7.3	4.5	3.87	17	17	16	49.6
S.D.	-	-	-	-	2.2	4.3	2.6	6.5
Bellevue								
1	4.5	6.7	2.6	2.2	26	24	22	72
2	4.8	6.0	3.0	3.0	27	19	22	68
3	5.0	6.3	3.9	3.9	26	17	20	63
4	6.0	7.0	4.0	4.0	22	17	10	49
5	5.8	7.0	4.1	4.1	25	22	26	73
Total	-	-	-	-	126	99	100	325
Average	5.22	6.6	3.52	3.43	25	20	20	65
S.D.	-	-	-	-	1.9	3	6	9.8

area from the upper, middle and lower crown levels were in an 11:35:54 proportion (Table 2) which approximates that for the surface of a right circular cone. For trees sampled in this study, all branches were removed and measured from the 20 cm stem sections which were arbitrarily selected in the proportion of 3:2:1 from the upper, middle and lower crown thirds, respectively. The percentage distribution of nodal branch surface based on these sample branches was similar to the percentage distribution of branch surface of the whole crown (Table 2).

The Proportion of Larvae on the Various Parts of the Tree

The number of nodal, internodal branches and bark surface area sampled in the three crown levels represented one-half of the upper crown level, one-third of the middle crown level, and one-sixth of the lower crown level. The average number of hibernating larvae in each crown third were extrapolated to a whole-tree basis.

The proportions of the total population of larvae on the tree for each crown third were averaged for five trees in each of the two study areas (Table 3) and the coefficient of variation ($CV = \frac{\text{standard deviation}}{\text{mean}}$) computed for each mean. The CV compares the variability independently of the units of measurement.

Of the average estimated total of 810 larvae per tree at Bunyan's Cove, 70% hibernated on the nodal branches, 21% on the internodal branches and 9% on the stem (Table 3, Fig. 3). More larvae (47%) hibernated

Table 2.- Percentage distribution of nodal branch surface area for sample nodal branches drawn from the crowns of young balsam fir trees.

Plot	No. of sample units	Crown level		
		Upper	Middle	Lower
Bunyan's Cove	107	11	39	50
Bellevue	110	11	31	58
All	217	11	35	54

Table 3. The average number of hibernating spruce budworm larvae on the various parts in the tree crown by crown levels of balsam fir trees (n = 5).

Location	Crown level	Average number of hibernating larvae on						
		Stem		Internodal branches		Nodal branches		
		No.	%	No.	%	No.	%	Total
Bunyan's Cove	Upper	13	11	28	23	78	66	119
	Middle	40	7	115	21	388	72	543
	Lower	20	14	26	18	102	68	148
	All	73	9	169	21	568	70	810
Bellevue	Upper	31	4	204	26	537	70	772
	Middle	36	3	159	14	956	83	1151
	Lower	44	4	102	10	876	86	1022
	All	111	4	465	16	2369	80	2945
Average for the two areas	Upper	22	5	116	26	307	69	445
	Middle	38	5	137	16	672	79	847
	Lower	32	6	64	10	489	84	585
	All	92	5	317	17	1468	78	1877

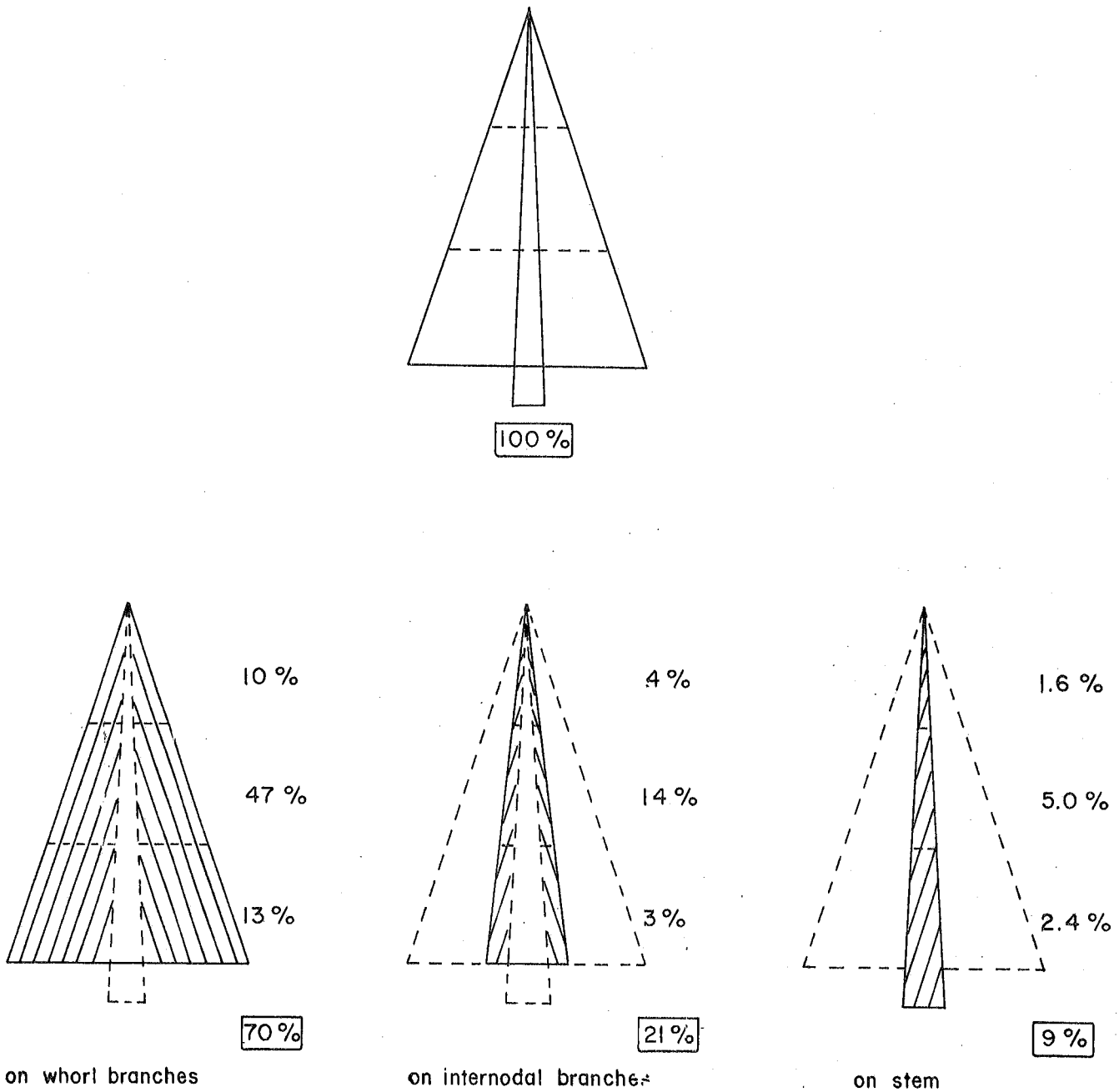


Figure 3. Vertical distribution of hibernating spruce budworm larvae on balsam fir trees at Bunyans Cove.

on nodal branches of the middle crown level, than in any other level (Fig. 3). The coefficient of variation was lowest (0.62) for the upper crown nodal branches and highest (1.13) for the lower crown level estimate.

At Bellevue, of the average total of 2945 larvae per tree, 80% hibernated on the nodal branches, 16% on the internodal branches and 4% on the bole (Fig. 4). Again, more larvae (32%) hibernated on nodal branches of the middle crown level than in any other level and the coefficient of variation was lowest (0.57) for this estimate. When the data from the two study areas were pooled, of the average total of 1877 larvae per tree, about 78% hibernated on the nodal branches, 17% on the internodal branches and 5% on the main stem.

At Bunyan's Cove, the proportion of larvae hibernating on the stem of the middle third of the crown was about twice the proportion of larvae on the lower stem and about three times the number of larvae hibernating on the upper stem third (Fig. 3). The coefficient of variation was lowest (0.57) for the upper crown section and highest for the lower crown section. But, the horizontal (stem to branch) distribution of hibernating larvae indicated that the lowest percent of larvae (7%) was on the stem for the middle crown level (Table 3). This is probably a reflection of the higher larval counts throughout this crown level.

At Bellevue, the proportion of larvae hibernating on the stem of the middle crown level was about the same as that of the upper (the lowest estimate) and lower crown levels. The coefficient of variation

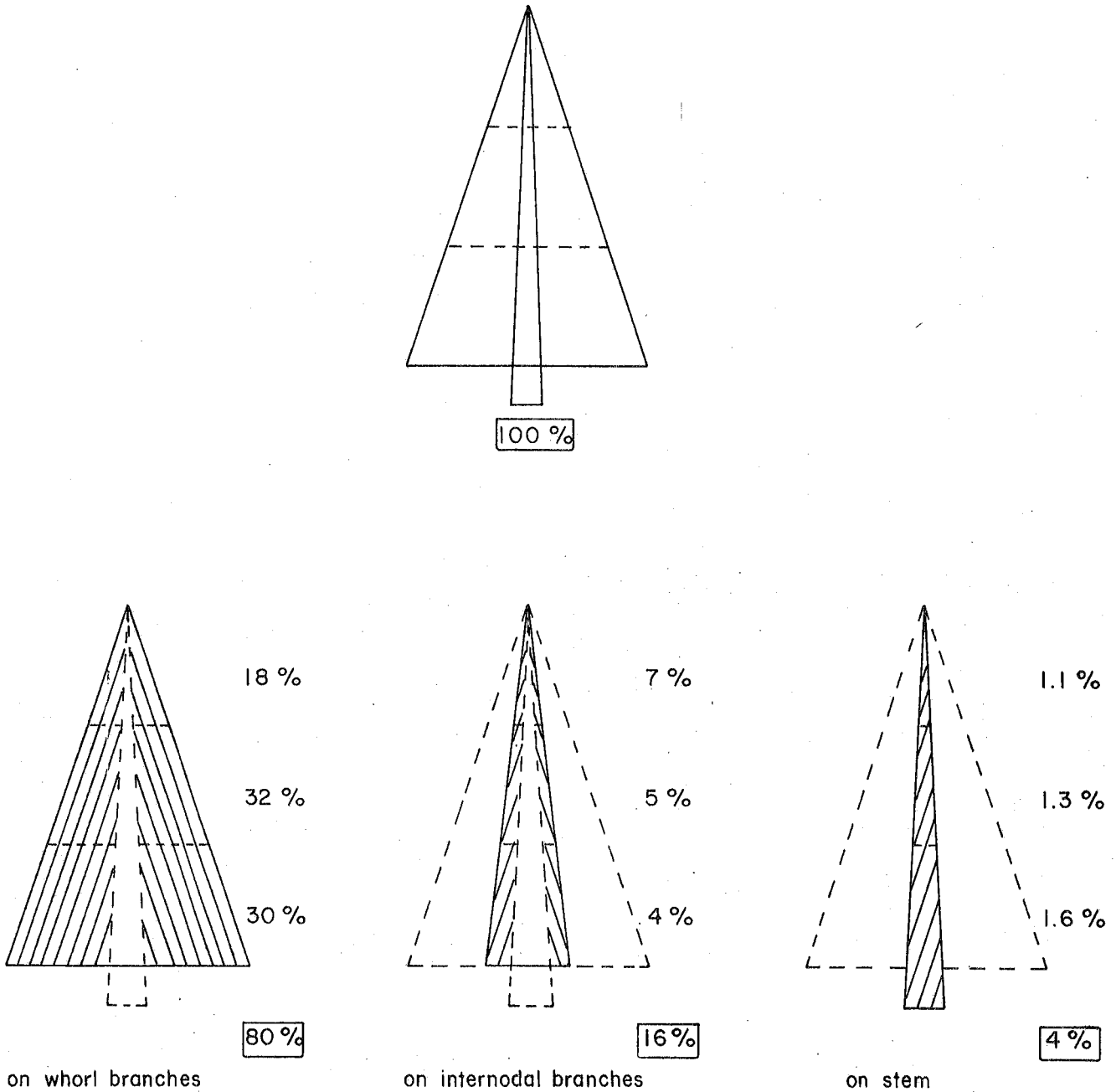


Figure 4. Vertical distribution of hibernating spruce budworm larvae on balsam fir trees at Bellevue.

was lowest (0.43) for the middle crown level. On a whole tree basis, the proportion of larvae on the stem of the middle crown level was the lowest (3%).

The concentration of larvae in the middle crown level especially on the whorl branches, could be the result of greater budworm defoliation and smaller branch size in the upper crown level, and dispersal of the first instar larvae from the upper level. Also, live branches of the lower and middle crown levels may provide more hibernation sites under bark scales and lichens than the upper level branches, but this was not considered significant.

Hibernating Spruce Budworm Larval Populations

Differences among crown thirds — Table 4 shows the differences in the average numbers of hibernating larvae on the branch and stem of balsam fir in the two study areas. When the whole branch was used, larval numbers were, on the average, lowest in the upper crown third in both study areas (Table 4). However, at Bunyan's Cove the larvae per branch in the upper and lower third were significantly less than estimates in the middle crown level.

When the density of the larvae was compared based on the whole branch area (expressed as 10 m^2), on the average, larval density was lowest in the lower crown level and higher in the upper and middle crown levels (Table 4).

The slightly lower larval numbers per branch area in the upper level compared to that of the middle crown level at Bunyan's Cove, may be the result of the relatively small size of the branches in the upper crown level thus providing fewer hibernating sites.

Table 4. The average number of hibernating spruce budworm larvae by sample units and crown levels.

Location	Sample unit	Counts by crown levels			Whole tree, $\bar{x}$
		Upper	Middle	Lower	
	Foliage				
	Per branch				
Bunyan's Cove		5	23	6	11
Bellevue		21	48	44	38
	All, $\bar{x}$	13	35	25	24
	Per branch surface area* ($10\ m^2$)				
Bunyan's Cove		914	1206	212	777
Bellevue		4067	3428	1697	3064
	All, $\bar{x}$	2490	2317	954	1920
	Stem				
	Per stem-section (20 cm in length)				
Bunyan's Cove		2.2	6.7	3.4	4.1
Bellevue		5.2	6.0	7.4	6.2
	All, $\bar{x}$	3.7	6.3	5.4	5.1
	Per unit area of bark ($10\ m^2$)				
Bunyan's Cove		1108	1398	706	1071
Bellevue		3875	2214	2474	2854
	All, $\bar{x}$	2491	1806	1590	1962

*This is not an accurate measure of foliage surface but merely a correction factor that permits the direct comparison of insect populations on branches of different sizes (Morris 1955).

The larval distribution per stem-section between crown levels was similar to that of larvae per branch for both study areas. When expressed as counts per unit area of bark, the results were similar to that of the branch area (Table 4). That is, at Bunyan's Cove the number of larvae per unit area of stem was higher for the middle crown level and at Bellevue it was highest in the upper crown level. When the results from the study areas were combined, the number of larvae per unit area was highest in the upper, average in the middle and lowest in the lower crown levels.

Efficiency of sampling in the different crown thirds — Coefficients of variation for either the whole branch or branch area, in both study areas, were consistently lower for the upper (0.39 and 0.87 respectively, at Bunyan's Cove and 0.91 and 0.51 at Bellevue) and the middle (0.62 and 0.75 at Bunyan's Cove and 0.57 and 0.59 at Bellevue) crown levels than for the lower crown level (1.13 and 1.11 at Bunyan's Cove and 0.89 and 0.71 at Bellevue). The variability was lower when the larvae were expressed on a whole branch basis.

Differences between 45 cm branch-tip and whole branch samples — The lengths of the branches on the upper crown level were 45 cm or less and only the middle and lower level branches were considered. Hibernating larval populations as well as the percent distribution of these larvae on the 45 cm tip and the remainder of the branch by crown level and study areas are shown in Table 5. When the data from study areas were combined and averaged, 36% of the total larvae per whole branch hibernated on the 45 cm branch tip.

Table 5. Distribution of hibernating spruce budworm larvae per 45 cm branch-tip, remainder of branch and whole branch.

Location	Crown level	45 cm branch tip $\bar{x}$	S.D.	Remainder of branch $\bar{x}$	S.D.	Total branch	n*
Bunyan's Cove	Middle	6.3 29%	5.7	15.3 71%	10.9	21.6	33
	Lower	2.2 32%	3.1	4.8 68%	5.1	7.0	19
Bellevue	Middle	20.7 39%	13.5	33 61%	20.1	53.7	28
	Lower	14.8 38%	12.2	24.2 62%	25.0	39.0	20
All		11 36%		19.3 64%		30.3	100

*Only branches that could be divided into 45 cm tip and remainder.

DISCUSSION

This study indicated that, on the average, a very low proportion (5%) of the second instar spruce budworm larvae hibernated on the main stem of immature balsam fir trees. Miller (1958) showed that the stem (trunk) population was less than 1% of the total population in open, mature stands and approximately 4% in dense, middle-aged stands. However, in his study, samples of trunk bark were "confined to the middle of the clear portion, and the middle of the crown portion of the trunk". Also, his branch samples included a small ring of bark from the tree trunk at the base of the branch.

The results of this study show that the middle crown level is the most suitable universe for sampling hibernating spruce budworm larvae in Newfoundland. Similar results have been reported for New Brunswick (Miller 1958). A consistently high proportion of the total population of larvae on the tree hibernated in the middle crown level. Also, the number of larvae per whole branch had the lowest variability. Internodal branches had only 18% of the hibernating larvae. The number of larvae hibernating on the stem and internodal branches totalled 23%, and represented a portion of the population that would not normally be sampled.

The internodal branches are too small and variable and difficult to reach; and it is impractical to sample these branches. On the average, the 45 cm branch-tip has only 36% of the total larvae hibernating on the whole branch. Therefore, whole mid-crown branches should be sampled to estimate populations of hibernating spruce budworm larvae. If estimate of larval density on a per-hectare basis, is desired, knowledge of the branch surface area is required. This may be obtained either by measuring all sample branches, or by measuring a small number of branches to obtain mean branch size per plot and using these data to compute larval density per hectare.

ACKNOWLEDGEMENTS

We would like to thank our colleagues of this Centre for reviewing the report; and we are pleased to acknowledge the excellent technical assistance of J. Carter and D.S. Durling. We also thank D.M. Stone for preparing the illustrations and Mrs. D. Didham for typing the manuscript.

REFERENCES

Bess, H.A. 1946. Staminate flowers and spruce budworm abundance. Dominion Dept. Agr., Forest Insect Invest. Bi-monthly Progr. Rept. 2(2):3-4.

Blais, J.R. 1952. The relationship of the spruce budworm (Choristoneura fumiferana (Clem.)) to the flowering condition of balsam fir (Abies balsamea (L.) Mill.)). Can. J. Zool. 30:1-29.

Bryant, D.G. and J. Carter. 1976. Population levels of commercially important softwood defoliators: spruce budworm. Envir. Canada, Can. For. Serv., Nfld. For. Res. Centre, File Report - Study 15-1 (76-77A). 11 pp.

Crummey, H.R. and I.S. Otvos. 1980. Biology and habits of the eastern spruce budworm, Choristoneura fumiferana (Lepidoptera: Tortricidae) in Newfoundland. Envir. Canada, Can. For. Serv., Nfld. For. Res. Centre, Inf. Rept. N-X-181. 33 pp.

Jaynes, H.A. and C.G. Speers. 1949. Biological and ecological studies of the spruce budworm. J. Econ. Ent. 42:221-225.

McKnight, M.E. 1969. Distribution of hibernating larvae of the western budworm, Choristoneura occidentalis on Douglas-fir in Colorado. J. Econ. Ent. 62:139-142.

Miller, C.A. 1958. The measurement of spruce budworm populations and mortality during the first and second larval instars. Can. J. Zool. 36:409-422.

Miller, C.A., E.G. Kettela and G.A. McDougall. 1971. A sampling technique for overwintering spruce budworm and its applicability to population surveys. Dept. Fish. & Forest., Can. For. Serv., Maritimes For. Res. Centre, Fredericton, N.B. Inf. Rept. M-X-25, 11 pp.

Morris, R.F. 1955. The development of sampling techniques for forest insect defoliators, with particular reference to the spruce budworm. Can. J. Zool. 33:225-294.

Webb, F.E., D.C. Cameron and D.R. MacDonald. 1956. Studies of aerial spraying against the spruce budworm in New Brunswick. V. Techniques for large-scale egg and defoliation ground surveys 1953-55. Canada Dept. Agric. For. Biol. Lab. Interim Rep. 1955-8. Fredericton, New Brunswick.