THE BIOLOGY OF THE BIRCH LEAF MINER, **FENUSA PUSILLA** (LEPELETIER) (HYMENOPTERA: TENTHREDINIDAE) IN NEWFOUNDLAND

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The Biology of the Birch Leaf Miner, *Fenusa pusilla* (Lepeletier) (Hymenoptera:Tenthredinidae) in Newfoundland

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ABSTRACT

The Birch Leaf Miner, Fenusa pusilla (Lepeletier), has been a pest of birch trees in North America since its introduction from Europe in the early 1920's. It was first reported in Newfoundland during 1959 on White Birch, Betula papyrifera Marsh. Since then damage by the leaf miner has been noted annually in the Province, particularly on roadside trees.

This study was initiated in 1972 to determine the number of generations of F. pusilla per year in Newfoundland, the number of larval instars per generation, and the distribution of the insect in birch according to crown position and leaf age.

In 1972 there were two complete generations and some individuals completed a third generation to the prepupal stage. There were five larval instars in each generation. All birch leaves were vulnerable to infestation in the first generation, whereas in later generations eggs and larvae were more abundant on young leaves of terminal shoots. Larval mortality was substantial. It decreased from the first to third generation in White Birch whereas in Mountain White Birch, Betula cordifolia (Reg.) Fern., larval mortality was extremely high throughout the season. Five larvae were capable of totally destroying the photosynthetic tissue of leaves up to 60mm. long.

Two parasitoid species of F. pusilla in Europe, Grypocentrus albipes (Ruthe) and Lathrolestes nigricollis (Thoms.) (both Hymenoptera: Ichneumonidae) were released onto Fenusa-infested birch in August 1972. Individuals of both species were recaptured in 1973.

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INTRODUCTION

The Birch Leaf Miner (Fenusa pusilla (Lepeletier)) is widely distributed throughout Europe where it is a common but not a serious pest in all birch-growing regions (Eichorn and Pschorn-Walcher, 1973). It was apparently introduced accidentally from Europe into North America in 1923 (Cheng and LeRoux, 1965). It was reported from Connecticut under the name F. pumila Klug (Britton, 1924), and has since spread through central and eastern United States and parts of Canada, where it is considered to be a pest of economic importance in forest and ornamental birch (Yoshimoto, 1973; Cheng and LeRoux, 1965). The insect was reported causing leaf damage to White Birch (Betula papyrifera Marsh) in Newfoundland by Carroll and Parrott (1959). Since then some damage to birch has been recorded annually in the Province (Canadian Forest Service, 1960-1973), but it is not considered to be of great economic importance (Newfoundland Forest Research Centre, 1973, 1974).

The Birch Leaf Miner can be distinguished from the species of sawflies whose larvae are known to mine in birch leaves by the presence of four black marks, one on the ventral surface of each of the thoracic and the first abdominal segments of second to fourth instar larvae (Cheng and LeRoux, 1965) (Plate I, p. 3). A key for distinguishing between the birch leaf-mining sawflies, Profenusa alumna (MacG.), F. pusilla (Lep.) and Heterarthrus nemoratus (Fall.) has been given by Lindquist (1959). The synonomy of F. pusilla has been listed by Cheng (1967). Accounts of the habits, life cycle, and hosts of F. pusilla have been given, in the New England States by Friend (1931), and in Quebec by Cheng (1967) and by

Guèvremont (1970). The adults are about 3mm. long, black, except for yellow-brown tibiae and tarsi (Plate II, p. 4). Mating occurs on the upper leaf surface of host trees (Plate III, p. 5). Eggs are laid into the palisade mesophyll, of buds or young leaves (Plate IV, p. 5) and the larvae remain in the same leaf throughout their development. Mines of early-instar larvae are kidney-shaped, whereas later-instar larvae tend to be gregarious and their mines may coalesce (Plates VI, p. 6; VII, p. 7). Full-grown larvae drop from leaves, form coccoons in the soil, and develop into prepupae, in which form they overwinter (Plate VIII, p. 8).

Cheng (1967) was concerned with the biology of F. pusilla in Blue Birch, Betula caerulea-grandis Blanchard, in the Morgan Arboretum of MacDonald College, Quebec. Guèvremont (1970) studied F. pusilla in Grey Birch, B. populifolia Marsh, in three habitats on Mt. Bellevue, Quebec.

This study was undertaken to determine the number of generations of F. pusilla per year in Newfoundland, the number of larval instars per generation, the distribution of the insect in birch according to crown position and leaf age, and the numbers of larvae capable of totally destroying leaves of different sizes. Host trees were White Birch and Mountain White Birch, B. cordifolia (Reg.) Fern. Simultaneously, responsibility was taken for first release into North America from Europe, of Priopoda nigricollis (Thoms.) (Hymenoptera:Ichneumonidae) and of Grypocentrus albipes (Ruthe) (Hym.:Ichneumonidae).

PLATE I. F. pusilla larvae, 3rd and 4th instars, showing the characteristic black marks on the ventral surface of the thoracic and first abdominal segments.

PLATE II. F. pusilla, male, on birch leaf.

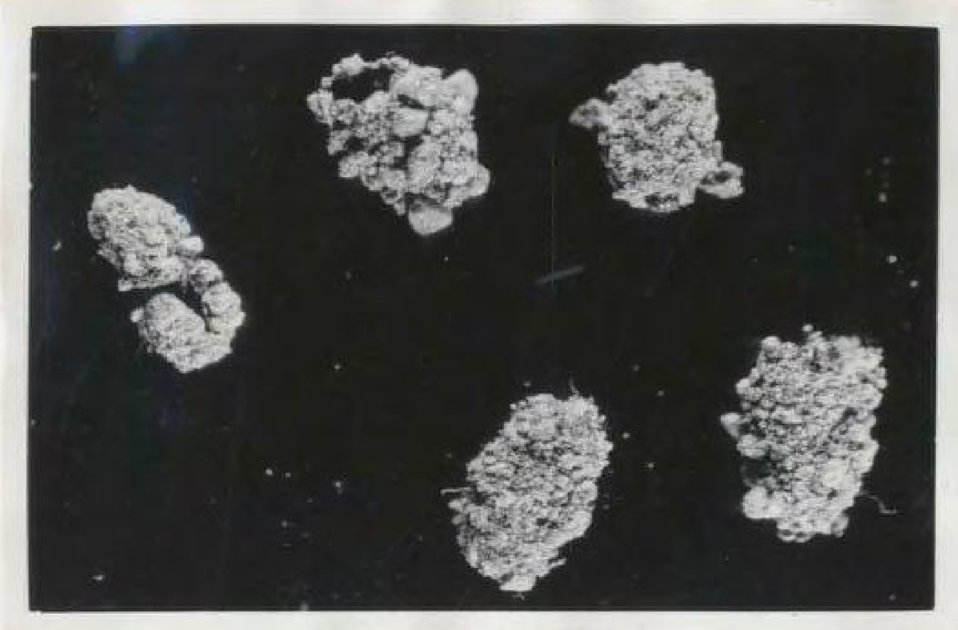
PLATE III. F. pusilla in copula on birch leaf.

PLATE IV. F. pusilla, ovipositing female.

PLATE V. Upper surface of birch leaf, showing grey blotches caused by developing eggs of <u>F. pusilla</u>.

PLATE VI. Upper surface of birch leaf, showing mines of <u>F. pusilla</u> larvae in the second and third instars.

PLATE VII. Birch leaf, showing mines and larvae of
F. pusilla in the third and fourth instars.



1mm.

PLATE VIII. Coccoons of F. pusilla.

MATERIALS AND METHODS

The development of F. pusilla larvae and the progress of destruction to infested leaves was determined by repeated observations of marked leaves on three trees, a White Birch at Wild Cove Point (Tree 1), a White Birch at Pasadena Field Station (Tree 2), and a Mountain White Birch (Betula cordifolia (Reg.) Fern.) in Pasadena Nursery (Tree 3). Leaf samples were collected repeatedly from the vicinity of these three trees (Sites 1-3). Occasional collections were made from Fenusa-infested birch at thirteen other places, mostly from alongside the Trans-Canada Highway, in central and western Newfoundland.

Description of Sampling Sites and Sample Trees

Wild Cove Point is a camp-site 1 mile east of Corner Brook, west Newfoundland. The site has a southerly aspect to the mouth of the Humber River. Tree 1 was one of several White Birch of similar height growing on the edge of a clearing cut in construction of the camp-site. The tree was fully exposed on the north side, and partly shaded by other birch on the south. Beneath the tree was exposed mineral soil.

Pasadena Field Station is about 20 miles north-east of Corner Brook. Tree 2 was growing in a field adjacent to the Station and was one of several White Birch of the same height, each one fully exposed on all sides (Plate IX, p. 10). Ground vegetation beneath the trees was dense.

Tree 3 was growing alone in a seed-bed in the Pasadena Forest Nursery, about 50 yards from Tree 2. It was the only Mountain White Birch of its size in the nursery. The seed-bed was kept weed-free (Plate X, p. 11).

PLATE IX. Tree 2, White Birch at Pasadena Field Station in July 1972.

PLATE X. Tree 3, Mountain White Birch in Pasadena Nursery, July 1972.

Within 20 feet of Tree 3 there was a bed containing Fenusa-infested White Birch, 4 years old.

Particulars of the locations of the sample sites, and heights of the sample trees are given in Table I, below.

TABLE I. Locations of sampling sites and heights of sample trees.

Tree	Species	Location	Lat.	Long.	Tree height (June 1972) metres
1	White Birch	Wild Cove Point	48°58'	57°53'	2.6
2	White Birch	Pasadena Field Station	49°01'	57°36'	2.3
3	Mountain White Birch	Pasadena Forest Nursery	49°01'	57°36'	1.0

Non-Destructive Sampling

Each of the three trees was sub-divided into five crown regions, as follows:

i = bottom crown, inner region;
shaded leaves adjacent to main stem.

ii = bottom crown, outer region;
exposed leaves.

iii = mid-crown, inner, shaded leaves.

iv = mid-crown, outer, exposed leaves.

v = leading shoot, exposed leaves.

For the two White Birch, 50 leaves per region were numbered in ink on the upper epidermis. In regions i and iii, leaves were numbered so that they were close to the main stem ('shaded leaves'). In the other three regions leaves were numbered from the tips of shoots downwards, so as to sample leaves which were fully exposed to light at the start of sampling ('exposed leaves'). Thirty leaves per region were marked similarly on the Mountain White Birch. Leaves were examined twice a week from mid-June to late August. Leaf age, presence of eggs and larvae, and an estimate of percent damage attributable to Fenusa in each leaf, were recorded on each occasion. Numbers of eggs and larvae were estimated with or without a hand lens. Egg presence was assumed when upper leaf surfaces showed grey blotches (Plate V, p. 6). Presence of larvae was judged by presence of larval mines (Plates VI and VII, pp. 6 and 7). The method allowed estimation of the developmental period of eggs and larvae in individual leaves ('Case histories'), and provided information on intra-crown distribution of Fenusa. It was assumed that marking with a pen would not adversely affect leaves or larval development. Leaves were not removed from Trees 1 and 2. Samples were taken from Tree 3.

Destructive Sampling

A destructive sampling method was also used. Leaves were picked from birch growing within 20 feet of each of Trees 1 and 2, used in non-destructive sampling. Since Tree 3 was the only one of its kind in the nursery samples were taken from it. Leaves showing presence of Fenusa eggs or larvae or both were picked indiscriminately from the upper crown regions of trees at the three sites (equivalent to crown regions iv and v of the non-destructive method). Infested leaves only were taken so that the maximum information on the biology of the leaf miner might be obtained.

A sample of 50 leaves per site was picked initially on each occasion. Analysis after the first few weeks showed that a 30-leaf sample was adequate to stabilize the variance. Therefore 30-leaf samples were taken after 20 July. All figures were converted to numbers per 50 leaves. Destructive leaf samples were collected twice a week from 19 June to 22 August and then once a week until leaf-fall. Sampling was completed on 18 October. Leaves were placed in polythene bags and either dissected soon after, or stored at $0^{o}C$ for later examination. Larvae and exuviae from these samples were preserved in KAAD (1 part yellow kerosene, 7 parts ethyl alcohol, 2 parts glacial acetic acid and 1 part Dioxane).

Before dissection all leaves were categorized and the percent damage attributable to Fenusa was estimated. Lengths of leaves showing total destruction were recorded separately and compared with the number of larvae that were responsible for this destruction. The number of eggs, live larvae in each instar, and dead larvae in each instar, were recorded for each leaf.

Leaves were categorized as follows:

B = Bud.

Y = Young leaf, not fully opened.

My = Young mature leaf, fully expanded and distinguished from mature leaves by having a 'young' leaf texture.

M = Mature leaf.

A comparison of the accuracy of estimating numbers of eggs and larvae in intact leaves in the field was made with counts when the same leaves were dissected under a binocular microscope. Other factors used when computing the number and duration of generations of the leaf miner were: estimates of abundance of adults throughout the summer; the period between final instar larvae entering the soil and emergence of adults; and the frequency of occurrence of leaves from which mature larvae had emerged. Branch samples collected from thirteen other places in the Province were compared with samples from the three main sites.

Accuracy of Field Counting

The accuracy of field-counting eggs and larvae was tested on 4 and 5 July, for 10-leaf samples on both occasions. The field count for each leaf (F) was compared with the number of eggs and larvae found on dissection of the leaf under a binocular microscope (M). For each leaf, a percent error was calculated as follows:

$$\% \text{ Error} = \frac{M-F}{M} \times 100$$

Index of Adult Abundance

An index of adult abundance (IAA) was determined by counting the number of adult *Fenusa* seen in a 1-minute search of upper surfaces of leaves of sample trees on each sampling date. Occurrence of mating was also noted.

The Soil Period

The period between final instar larvae entering the soil and the emergence of adults (the 'soil period') was determined by collecting 50 larvae as they emerged from leaves and by placing them individually in containers filled with finely sieved soil. These were kept in the laboratory until the adults emerged.

Occasional Sampling from Other Areas

A total of 35 samples of *Fenusa*-infested birch foliage was collected by members of the Canadian Forestry Service from 13 places other than the three main collecting sites during 1972. These were casual collections and will be called 'branch samples' to distinguish them from destructive and non-destructive samples. Each branch sample consisted of part of the upper crown region of an infested birch (equivalent to crown regions iv and v of the non-destructive sampling). From each sample 10 shoots were cut, each shoot bearing a minimum of 10 leaves. The leaves of each shoot were numbered from 1 to 10, from the tip of the shoot downwards. Thus 100 leaves per sample were examined. Each leaf was categorized (B, Y, My or M) and the percent damage attributable to F. pusilla was estimated. The leaves were then dissected and the numbers of eggs and larvae counted under a binocular microscope. Through these procedures each leaf provided information comparable to each one from destructive sampling at the three main sites, although the method of leaf selection was different.

The Number of Larval Instars per Generation

The number of larval instars in the development period was determined by counting the number of exuviae in vacated leaf mines and by relating this number to the number of larvae known to have occupied the mines. Thus, if one larva had occupied a mine and 4 exuviae were found, it was concluded that there had been 5 larval instars. This information was obtained from the destructive leaf samples collected at the three main sampling sites.

The head-capsule widths of 100 KAAD-preserved larvae were measured using a Leitz-Weitzlar microscope at X160, with an eyepiece graticule that allowed measurement to the nearest 0.025mm. Of the 100 larvae measured, 20 were known to be in the first instar (absence of black marks on thorax and abdomen), 30 were estimated to be in the second or third instar, 30 were estimated to be in the third or fourth instar, and 20 were known to be in the final instar (non-feeding and lacking the black marks on thorax and abdomen).

An estimate of the duration of each larval instar was made from case histories of leaves marked on the three sample trees.

Larval Mortality

Estimates of larval mortality in the three trees were made in two ways. The first method was to count the number of living and dead larvae when leaves were dissected. The second method was by calculating the percentage mortality from the difference between total numbers of first instar larvae and full-grown larvae counted in the destructive leaf samples.

Intra-Crown Distribution of Eggs and Larvae

The distribution of oviposition sites in the three sample trees was determined from the non-destructive sampling data. Total numbers of eggs and larvae estimated in each crown region were ranked from 1 (greatest numbers) to 5 for each sample data. An average Rank Order, of numbers compared with crown regions, was calculated for each tree. The percentages of sampled leaves showing presence of one or more eggs or larvae in each crown region were also ranked from 1 to 5.

Distribution According to Leaf Age

Every infested leaf was categorized before dissection into one of the four leaf age-classes (B, Y, My, or M). From this information, and the number of eggs and larvae in each instar counted in every leaf, the percent showing eggs, early-instar larvae, late-instar larvae, and the percent from which full-grown larvae had emerged, was calculated for each leaf age-class. Data from branch sampling was also used in determining distribution.

Damage to Leaves

A number of leaves containing mines occupied by one larva only were drawn to scale on squared paper. The mines were traced and their areas calculated. The mine areas of 10 larvae in each instar were determined in this way.

Also, leaves which were completely destroyed by larvae were dissected and the numbers of individuals responsible for the destruction determined. This was done for 140 leaves, 10 in each of 14 leaf-length classes. Leaves were from 20 to 85mm. long and were categorized by 5mm. intervals. The numbers of larvae responsible for total destruction of each leaf-length class were then counted. All larvae were included, i.e. 10 larvae might mean 10 second-instar larvae were responsible for the destruction, or 10 fourth-instar larvae were responsible, or it might mean any combination of larval stages was responsible for the damage. A Regression Analysis was performed for the logarithm of numbers of larvae (x) over leaf length class (y).

RESULTS AND DISCUSSION

The Number of Generations per Year and their Duration

In the field, it was difficult to estimate the numbers of eggs and larvae in the marked leaves. Sometimes it was possible to hold a leaf up to the sun and count the larvae inside the leaf. When leaves were wet the upper epidermis above leaf mines was transparent and larvae in the leaf could be counted with ease. On most occasions only an estimate was possible.

The percent error in field counting eggs and larvae ranged from -80 to +60. This showed that estimates of numbers in marked leaves lacked precision. The results of two comparative tests to determine percent error are given in Table II, page 20.

Observation showed that the period from oviposition to eggs becoming apparent as minute grey blotches on upper leaf surfaces was about 8 days for both birch species.

Case histories for individual leaves showed that the period from eggs becoming apparent in leaves to emergence as full-grown larvae was from 14 to 33 (average 22) days in White Birch (Table III, p. 21). In the small number of leaves of Mountain White Birch in which larvae developed to emergence, the development period was 17 to 34 (average 21) days (Table III).

From Site 1 Destructive sampling data show two peaks of larval abundance, in June - early July, and in August (Table IV, p. 22; Fig. 1, p. 23). Thereafter, the numbers were less and there were no distinct

TABLE II. Comparison between field estimates (F) and microscope counts (M) of F. pusilla eggs and larvae in two samples each of 10 infested leaves, expressed as Percent Error.

Tree 2. 5 July			Tree 3. 4 July		
F	M	% Error	F	M	% Error
11	11	0	7	7	0
1	3	-66	26	21	+25
2	10	-80	32	25	+28
8	5	+60	17	11	+50
5	13	-56	15	12	+25
6	7	-14	18	17	+ 5
8	8	0	8	5	+60
4	4	0	6	4	+50
4	9	-55	11	17	-30
11	9	+22	8	11	-27

TABLE III. Case histories of individual leaves giving periods of development of *F. pusilla* first generation eggs and larvae in White Birch (Trees 1 & 2) and Mountain White Birch (Tree 3) in 1972. (Development period is from egg blotches becoming visible to emergence of full-grown larvae.)

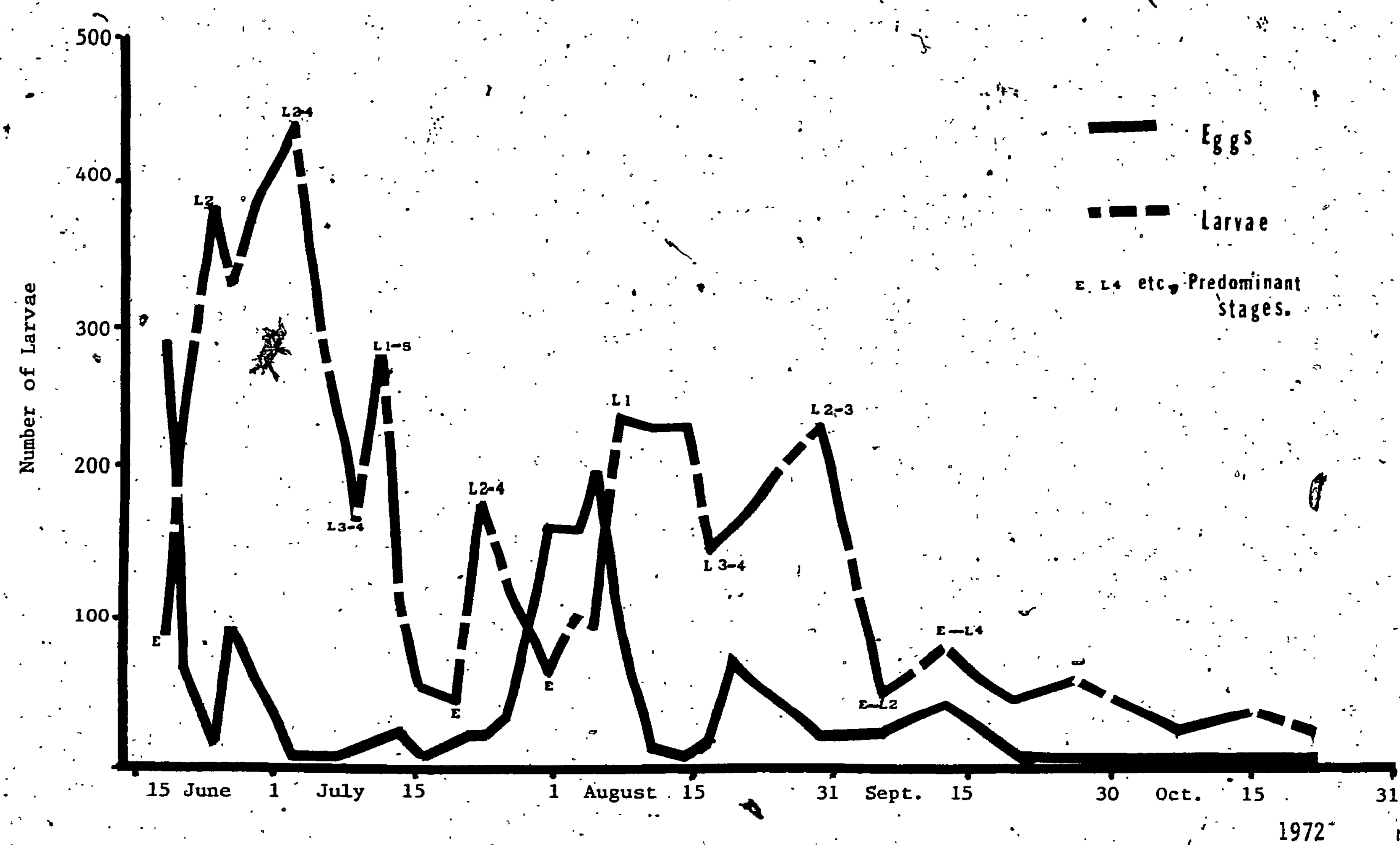
Tree	Date of Observing Egg Blotches	Development Period	Frequency
1	19- June	21	2
	19-	24	2
	21-	19	1
	13- July	26	1
		$\bar{x}$ = 22.5	N = 6
2	28- June	14	3
	28-	27	3
	12- July	33	1
		$\bar{x}$ = 22.3	N = 7
3	28- June	17	1
	28-	19	2
	28-	34	1
	4- July	21	2
	7-	20	2
		$\bar{x}$ = 21.4	N = 8

TABLE IV. Numbers of eggs and larvae of F. pusilla at Wild Cove Point per 50 infested leaves in 1972.

Date	Eggs*	Larval Instars 1	2	3	4	5	Total Larvae*	Total eggs and larvae
19- June	294	84	0	0	0	0	84	378
21-	67	165	115	0	0	0	280	347
24-	10	162	223	0	0	0	385	395
26-	89	183	144	0	0	0	327	416
29-	61	186	123	64	10	0	383	444
1- July	23	113	148	133	20	0	414	437
3-	0	58	143	113	120	0	434	434
6-	1	30	66	63	70	48	277	278
8-	1	47	92	55	12	32	238	239
10-	7	4	22	74	56	14	170	177
13-	11	100	77	75	22	7	281	292
15-	20	42	5	33	13	13	106	126
17-	0	3	10	15	20	4	52	52
21-	16	2	22	8	10	0	42	58
24-	18	40	73	32	32	8	185	203
27-	27	40	48	15	15	2	120	147
31-	165	40	15	2	5	0	62	225
3- Aug.	73	34	19	13	32	5	103	176
5-	100	42	13	8	27	0	90	190
8-	83	187	15	32	9	1	244	327
11-	5	98	90	40	2	2	232	237
15-	0	18	97	78	40	0	233	233
18-	13	15	12	65	47	7	146	159
21-	70	11	26	52	71	9	169	239
30-	15	61	77	61	36	0	235	250
6- Sept.	21	7	23	10	3	3	46	67
13-	34	10	17	28	25	0	80	114
20-	3	17	9	2	11	5	44	47
27-	0	26	18	9	4	0	57	57
4- Oct.	0	7	3	5	0	0	15	15
12-	0	16	9	3	1	0	29	29
18-	0	14	6	1	3	0	24	24

*See Figure 1, p. 23.

FIGURE I. Numbers of eggs and larvae of F. pusilla in White Birch at Wild Cove Point per 50 infested leaves in 1972.


Number of Larvae
500
400
300
200
100
15 June
1
July
15
1
August
15
31
Sept.
15
30
Oct.
15
31
1972
Eggs
Larvae
E, L4 etc. Predominant stages.
L2
L2-4
L3-4
L1-5
L2-4
E
E
L1
L3-4
L2-3
E—L2
E—L4
E

peaks. Data from Site 2 is similar, except that numbers of larvae were greater in August than at Site 1 (Table V, p. 25; Fig. 2, p. 26).

The Index of Adult Abundance (IAA) for the three trees (Table VI, p. 27) shows that adults were present from early June to September. For Trees 1 and 2 the Index showed three high periods: in late June, in late July and in mid-August. Adults were seen on Tree 3 from early June to late August in greater numbers than on the other two trees on most occasions. It seems likely that adults were attracted to this isolated Mountain White Birch from a bed of 4 year old White Birch, 30 feet away.

The percentage of Fenusa-damaged leaves showing presence of eggs and larvae in Tree 1 (Table VII, p. 28; Fig. 3, p. 29) indicated mid-July and mid-August as the times when large numbers of larvae emerged from leaves, by the sudden drop in percentage of leaves containing larvae. These two times were presumed to indicate near-completion of two generations.

Under laboratory conditions, the Soil Period was from 9 to 39 (average 20) days (Table VIII, p. 30). Under field conditions this period would probably be longer in early summer and shorter in late summer, when soils were warmer. The soil period would probably be influenced by the insulating effect of ground vegetation.

At Wild Cove Point the leaf miner apparently had 2 complete generations and a small portion of the population completed a third generation by reaching the prepupal (overwintering) stage. The first generation commenced on or about 7 June and terminated about 24 July, a duration of 47 days. This is supported by the estimates of 1 day between adult emergence and egg-laying, 8 days for egg development, 22 days for larval development, and 20 days for the soil period, a total of 51 days. Adults were first noted on 7 June, with peak emergence on 19-20 June (Table VI,

TABLE V. Numbers of eggs and larvae of F. pusilla at Site 2, Pasadena, per 50 infested leaves in 1972.

Date	Eggs	Larval Instars 1	2	3	4	5	Total Larvae	Total Eggs and Larvae
5- July	10	22	107	170	17	5	321	331
7-	12	23	109	120	46	12	310	322
11-	3	97	65	40	48	7	257	260
14-	32	59	102	94	36	1	292	324
19-	49	92	76	39	18	4	229	278
22-	8	58	103	47	10	0	218	227
25-	107	67	112	75	75	3	282	389
2- Aug.	0	50	55	37	28	7	177	178
4-	0	65	25	20	50	2	162	162
9-	27	48	13	33	28	3	125	152
14-	0	35	23	23	32	5	118	118
18-	10	52	130	102	40	0	324	334
20-	8	47	68	75	42	8	240	248
22-	2	50	75	141	84	0	350	352
30-	0	8	8	17	25	0	58	58
15- Sept.	--	--	--	--	--	--	--	--
21-	0	0	0	60	30	0	90	90
27-	0	28	22	17	5	0	72	72
4- Oct.	0	0	0	0	17	0	17	17
13-	0	0	0	42	25	0	67	67

FIGURE 2. Numbers of larvae of F. pusilla in White Birch at Pasadena per 50 infested leaves in 1972.

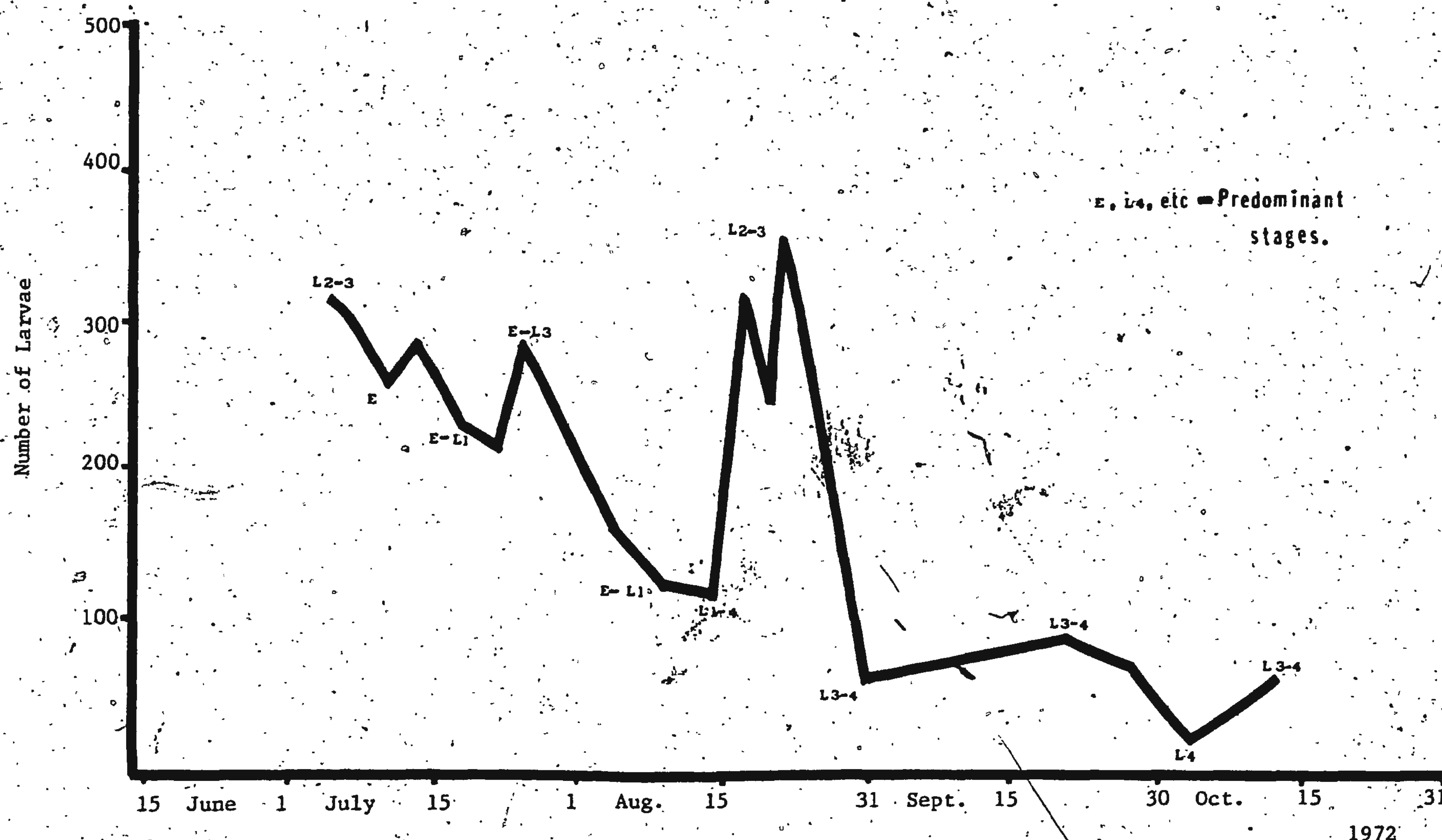

Number of Larvae
500
400
300
200
100
15
June
1
July
15
1
Aug.
15
31
Sept.
15
30
Oct.
15
31
1972
E, L4, etc = Predominant stages.
L2-3
E
E-L1
E-L3
E- L1
L2-3
L3-4
L3-4
L4
L3-4

TABLE VI. Abundance of F. pusilla (IAA) on three sample trees used in Non-Destructive sampling, 1972. Numbers are those counted in a 1-minute interval. M = mating was observed, 0 = no adults seen, -- + no data.

Date	Tree 1	Tree 2	Tree 3
7- June	3	20 M	33 M
17-	--	5	3
20-	50	15	20
26-	0	2	10
28-	--	20 M	4
30-	--	15	20 M
7- July	0	4 M	5 M
15-	0	2	0
25-	27 M	25	10
28-	2	0	30 M
31-	5	0	35 M
2- Aug.	--	20	5
8-	9	20	20 M
15-	15	14 M	15 M
17-	12	23	10
21-	7	5	5
30-	--	12	10
15- Sept.	4	0	0
21-	--	--	0
27-	0	1	5
4- Oct.	0	--	1
13-	--	0	0
18-	0	--	--

TABLE VII. % of leaves showing presence of F. pusilla eggs and larvae in 5 crown regions of Tree 1, Wild Cove Point, as obtained from Non-Destructive sampling in 1972.

Date	Crown Regions				
	i	ii	iii	iv	v
19- June	20	22	10	24	40
21-	20	22	12	32	30
24-	24	26	12	32	40
26-	28	28	12	32	40
29-	28	28	12	32	46
3- July	28	28	12	32	46
6-	28	34	16	32	52
10-	6	22	8	18	46
13-	0	18	4	16	24
17	0	8	4	14	22
24-	0	14	0	2	26
31-	0	22	2	6	26
8- Aug.	0	10	2	4	36
15-	0	4	2	0	6
21-	0	2	2	0	11

FIGURE 3. Percentages of leaves showing presence of eggs and larvae of F. pusilla in 5 crown regions (i to v) of White Birch (Tree 1) at Wild Cove Point in 1972.

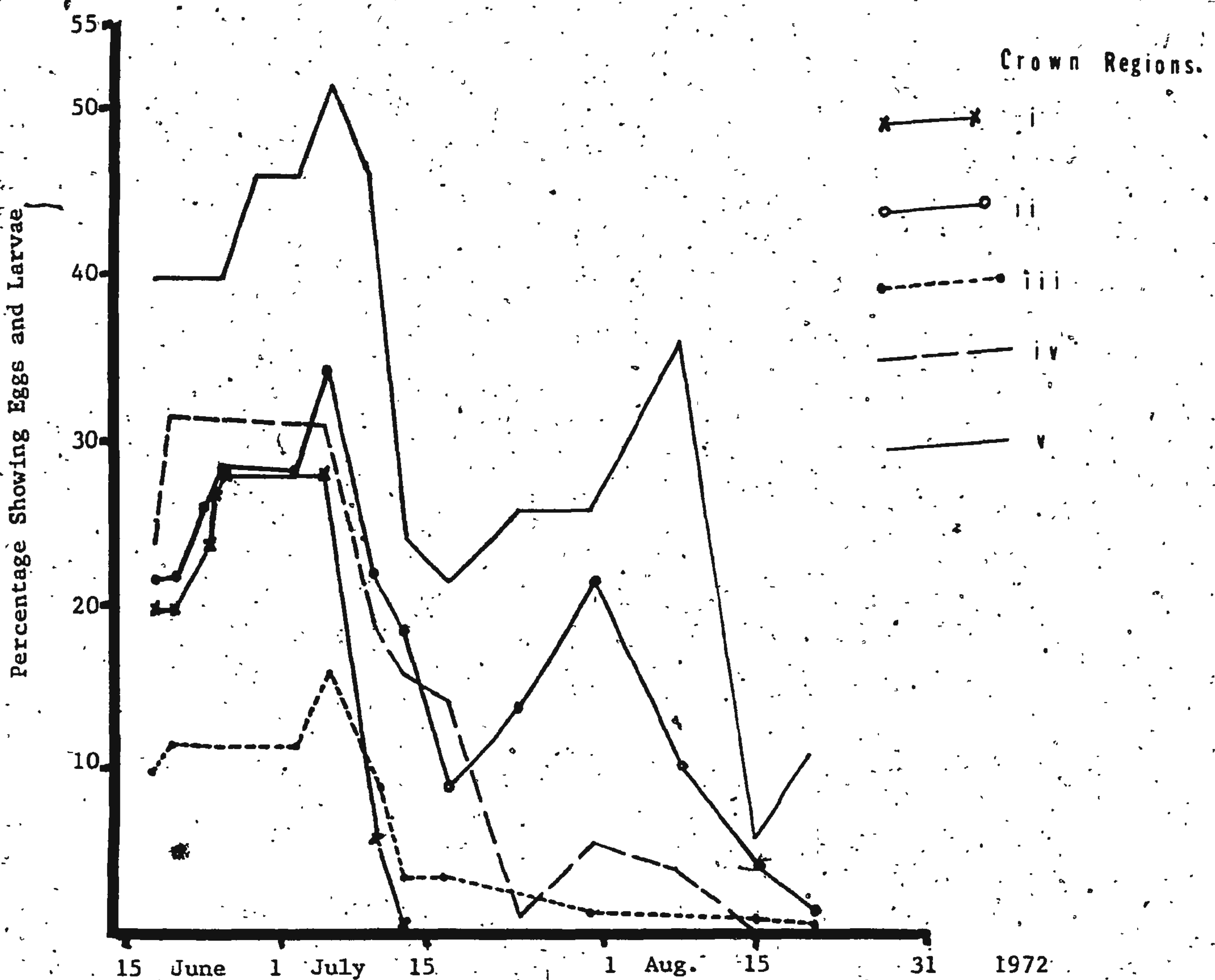

Percentage Showing Eggs and Larvae
55
50
40
30
20
10
15
June
1
July
15
1
Aug.
15
31
1972
Crown Regions.
i
ii
iii
iv
v

TABLE VIII. Number of days between emergence of F. pusilla larvae from leaves and their emergence from soil as adults (the "soil period") in 1972.

Days	Numbers
9	1
14	1
15	7
16	2
18	7
19	4
20	5
26	1
33	1
39	4

N = 33

$\bar{x}$ = 20.5 days

p. 27). Leaves from which mature larvae had emerged were observed first on 6 July. The period of greatest emergence was from 13 to 24 July. Thus it is likely that emergence of second-generation adults extended from about 24 July to mid-August. This conclusion is supported by the index of adult abundance which showed a virtual absence of adult _Fenusa_ at Wild Cove Point between 23 June and 21 July (Table VI, p. 27), and by the increase in the numbers of eggs after 27 July (Table IV, p. 22; Fig. 1, p. 23).

A second generation commenced on or about 24 July and terminated about 7 September, a duration of 45 days. Adults were suddenly abundant and seen mating on 24 July. This peak of adult abundance was followed by a peak in egg and larval abundance (Fig. 1). There was a substantial drop in incidence of larvae from 10 August.

There was considerable overlap between the first and second generations. This is supported by a case history of a leaf in which eggs were first seen on 13 July and from which larvae had emerged by 8 August. This most likely represented a precocious second generation from which third generation adults might have developed by late August, when the bulk of the population was still in the second generation. The peak of larval abundance on 13 July in Tree 1 (Fig. 1, p. 23) could also indicate a second generation; however this could also be explained by sampling error.

After 21 August adult _Fenusa_ were scarce at Wild Cove Point (Table VI, p. 27) and small numbers of eggs were found until 20 September. A few larvae in all instars were present until the last sampling date on 18 October. Most early-instar larvae found from late September onwards were dead, conceivably because of changes in the dietary content of fall leaves. Early-instar larvae cannot form soil cocoons (Cheng and LeRoux, 1965). Probably many of the fully-grown larvae that emerged prior to leaf fall (mid-October) entered the soil and formed overwintering coccoons. These individuals represented a third generation. It is also probable that some of the second-generation larvae that emerged from leaves from late August onwards overwintered as prepupae.

At Pasadena, Fenusa in Tree 2 also had two complete and a partial third generation. Adults were abundant from 7 June more or less continuously until 30 August, only a brief absence being recorded from 3 to 11 July (Table VI, p. 27), and it seems likely that there was a more protracted first generation than at Wild Cove Point. Delayed emergence of adults might have resulted from the soil remaining cool due to the insulation afforded by the thick herbaceous ground cover. Leaves from which larvae had emerged were first seen on 5 July, i.e. within one day of that recorded at Wild Cove. Numbers of larvae did not decrease appreciably until 9 August and there was a further substantial decrease on 30 August (Fig. 2, p. 26). It is concluded that between 7 June and 30 August (84 days) most insects completed 2 generations, the first from 7 June to 15 July (38 days), the second from about 15 July to 30 August (46 days). As at Wild Cove Point, there was overlap between the two generations.

After 30 August, adults, eggs and early-instar larvae were scarce, although five late-instar larvae were found up to and including 13 October. It seems likely that some second-generation and some third-generation prepupae overwintered.

A composite graph for comparison between Trees 1 and 2 is given in Figure 4, p. 33.

Although the Mountain White Birch (Tree 3) in Pasadena Nursery was more heavily infested with Fenusa than the other two trees, relatively few larvae developed beyond the second instar (Table IX, p. 34). Adults were

FIGURE 4. Numbers of larvae of F. pusilla in White Birch at Wild Cove Point (Tree 1) and Pasadena (Tree 2) per 50 infested leaves in 1972.

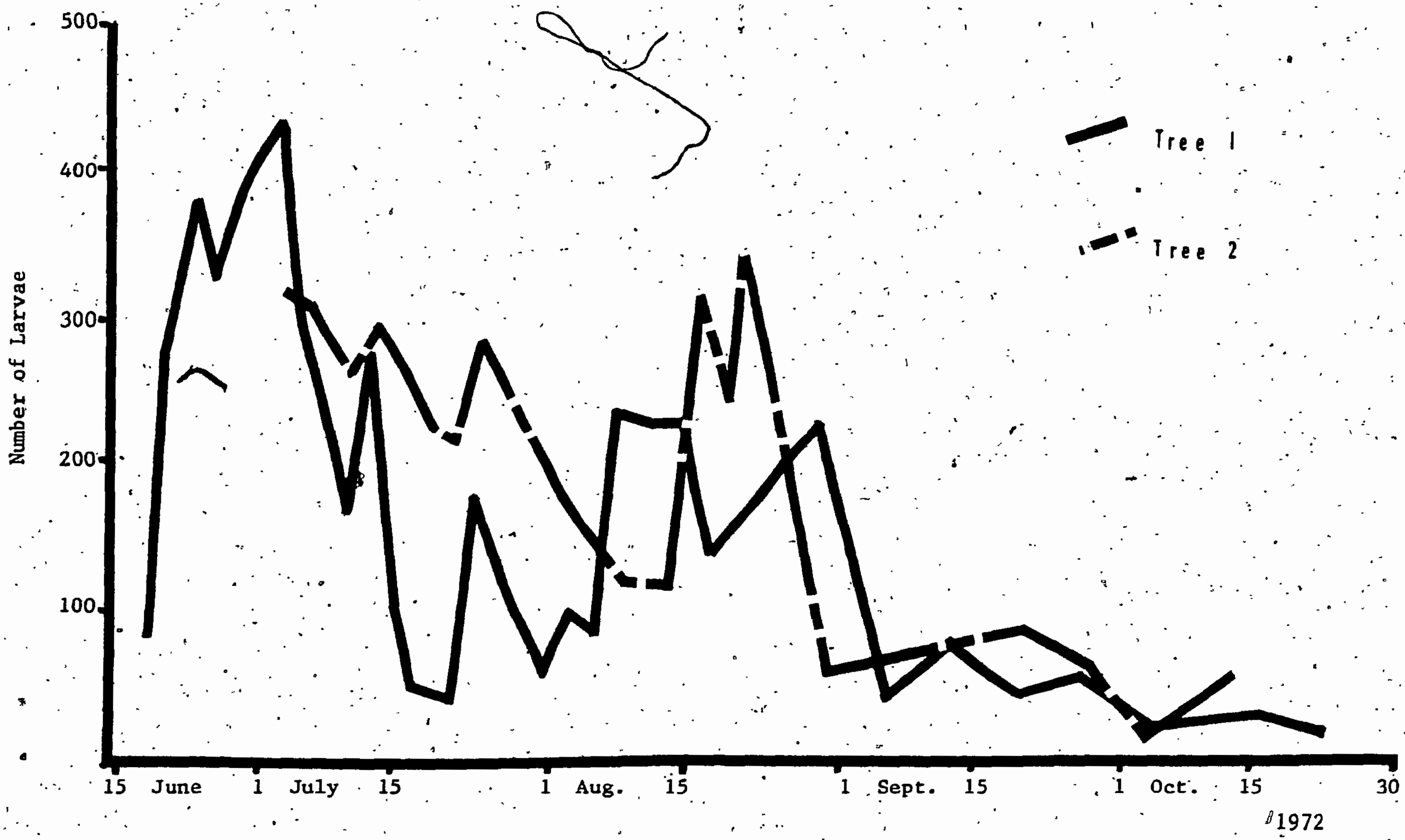
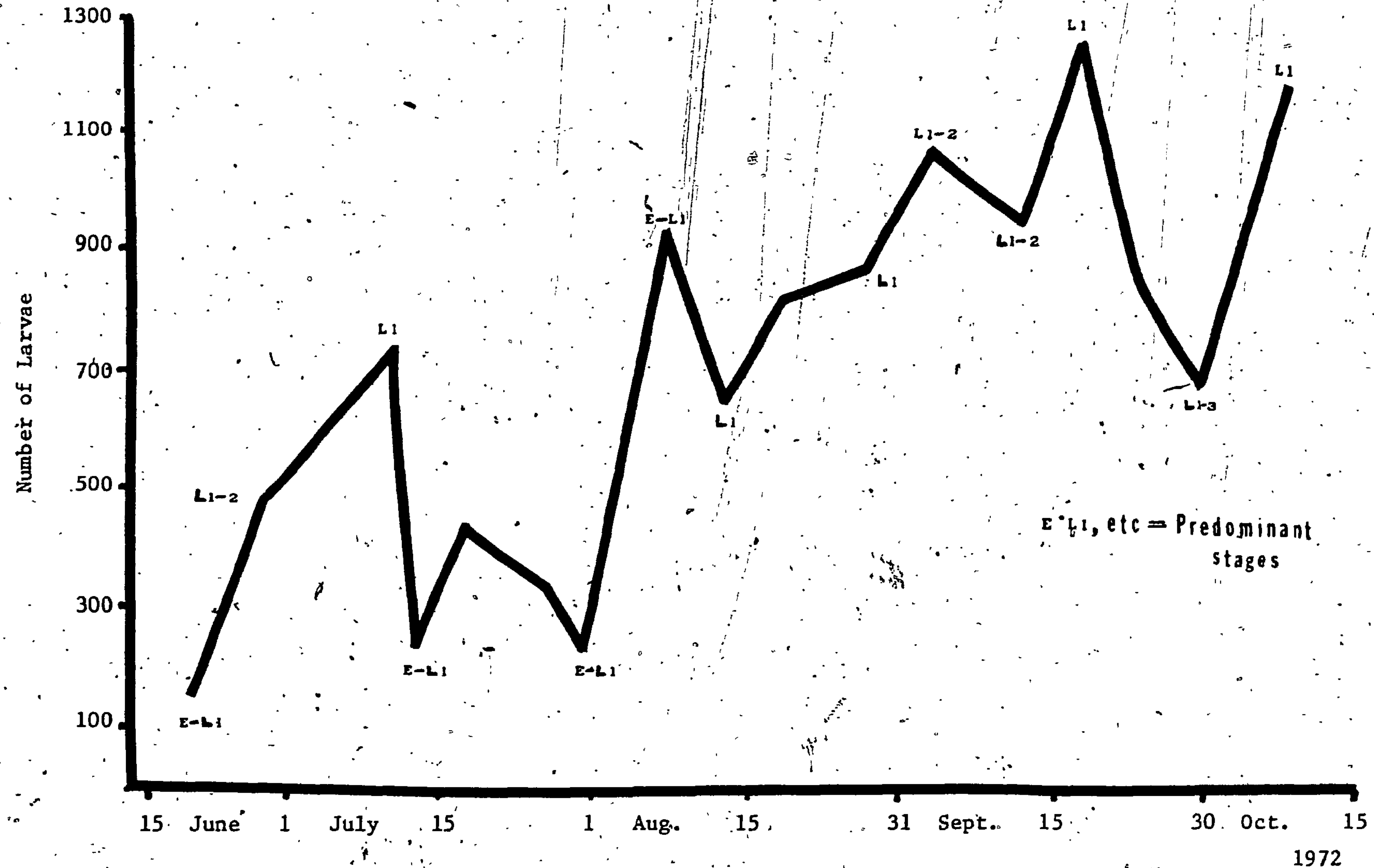

Tree 1
Tree 2
500
400
300
200
100
Number of Larvae
15
June
1
July
15
1
Aug.
15
1
Sept.
15
1
Oct.
15
30
1972

TABLE IX. Numbers of eggs and larvae of F. pusilla in Tree 3, Pasadena Nursery, per 50 infested trees in 1972.

Date	Eggs	Larval Instars					Total Larvae*	Total Eggs and Larvae
		1	2	3	4	5		
19- June	375	134	0	0	0	0	134	509
28-	20	240	210	20	0	0	470	490
7- July	0	250	125	10	0	0	385	385
11-	0	500	25	20	20	0	565	565
14-	70	240	5	0	5	0	250	320
19-	110	340	85	5	0	0	430	540
28-	350	245	60	15	10	0	330	680
1- Aug.	515	195	30	0	5	0	230	745
9-	285	900	20	0	0	0	920	1205
15-	15	555	70	5	5	0	635	650
22-	5	770	150	10	0	0	930	935
30-	70	810	55	0	0	0	865	935
6- Sept.	40	885	175	10	0	0	1060	1100
15-	0	825	105	15	0	0	945	945
21-	0	1065	140	35	5	0	1245	1245
17-	0	430	305	110	25	0	870	870
4- Oct.	0	515	85	40	20	0	660	660
13-	0	1115	60	0	0	0	1175	1175

* See Figure 5.

FIGURE 5. Numbers of larvae of F. pusilla in Mountain White Birch (Tree 3) at Pasadena per 50 infested leaves, in 1972.


Number of Larvae
1300
1100
900
700
500
300
100
15
June
1
July
15
1
Aug.
15
31
Sept.
15
30
Oct.
15
1972
E-L1
L1-2
L1
E-L1
E-L1
E-L1
L1
L1
L1-2
L1-2
L1
L1-3
L1
E-L1, etc = Predominant stages

abundant from 7 June to late August (Table VI, p. 27) and were obviously more plentiful than on the other two sample trees. Since few larvae reached maturity on Tree 3 it is concluded that many of these adults came from other White Birch in the vicinity. A group of 4 year White Birch in a nearby seed-bed in the nursery was heavily infested with Fenusa. Many of the leaves on these nearby birch trees showed that larvae successfully emerged in contrast with the Mountain White Birch from which few larvae emerged. The graph showing numbers of live larvae in Tree 3 (Fig. 5, p. 35) is quite different from those for Trees 1 and 2 (Figures 1 and 2, pp. 23 and 26). One peak in early July represents the first generation. From early August the number of larvae increased substantially but very few of these were more advanced than the second instar.

Leaves from which mature larvae had emerged were first seen on 11 July and were found only in crown region i.

It is concluded that, in Tree 3, the first generation commenced on or about 7 June and terminated about 31 July for some individuals: many failed to reach the prepupal stage. Some second generation adults from these prepupae plus adults from surrounding trees were responsible for the increase in numbers of eggs from 1 August (Table IX, p. 34). Thereafter the number of eggs and early-instar larvae increased markedly in most leaves, and the numbers of larvae remained high until 13 October. Late-instar larvae were found occasionally to early October. It seems that some individuals completed two generations in Tree 3, but the high level of infestation despite low numbers of mature larvae indicates that invasion from surrounding trees was responsible for maintaining the population. The high mortality will be discussed later.

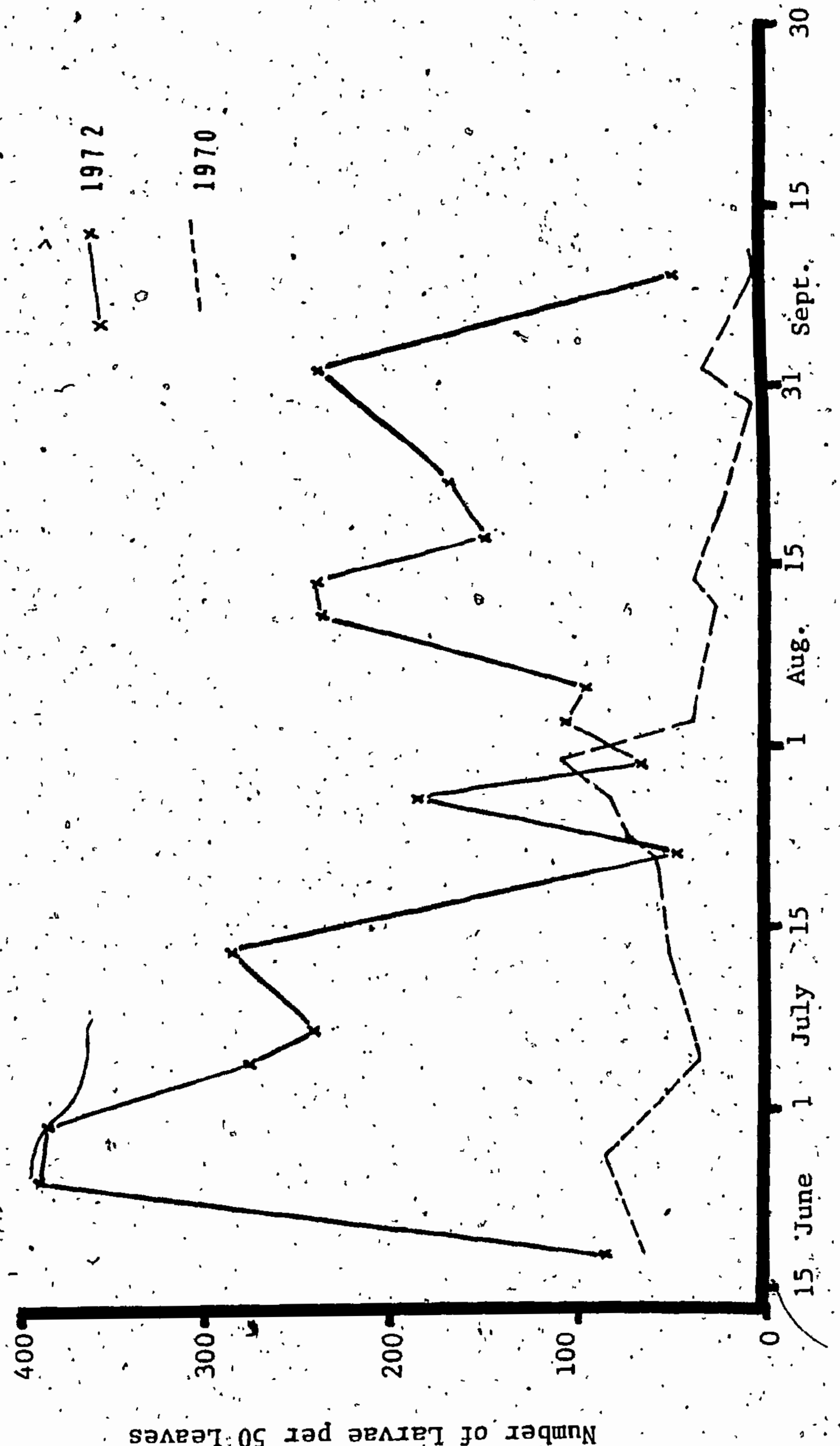
Guèvremont (1970) showed that there were 3 complete generations of

F. pusilla and a partial fourth generation (to the prepupa) on Grey Birch on Mt. Bellevue, Quebec. Adult emergence was first noted on 18 May, three weeks earlier than was noted in Newfoundland in 1972. On Mt. Bellevue, the first generation was from 18 May to 14 July (57 days); the second was from 21 July to 18 August (29 days), while the third generation was from 21 August to 16 September (26 days). The timespans of the second two generations are considerably shorter than those in Newfoundland. Guèvremont noted that there was much overlap between generations after the first generation, and that the duration of the life cycle varied according to habitat.

For comparison, Figure 6 (p. 38) is adapted from Guèvremont (1970; Figure 9, p. 39). It shows the numbers of larvae found by Guèvremont in Grey Birch in a forest margin habitat. Numbers of larvae found at Wild Cove Point have been added. Numbers at Wild Cove were appreciably higher than those of Guèvremont. The samples from Wild Cove were infested leaves, whereas Guèvremont collected leaves at random regardless of the presence of eggs or larvae; the host trees were different, as was the climate and the year of study. The comparison is valid only to the extent of showing that fluctuations in numbers of larvae were of a similar order of magnitude in the two places on some occasions, such as an appreciable decrease in numbers in early September.

Cheng (1967) found that there were 3 complete and a partial fourth generation (to prepupa) of F. pusilla on Blue Birch seedlings in the MacDonald College Arboretum, on the west end of Montreal Island, Quebec, in 1964. He observed first generation adults from early May to 10 June, with peak emergence from 9 to 20 May; second generation adults were evident from 16 June to 14 July; third generation adults from 18 July to 13 August;

FIGURE 6. Numbers of larvae of *F. pusilla* in Grey Birch in a forest margin habitat on Mt. Bellevue, Quebec, according to Guèvremont (1970; Fig. 9, p. 39) compared with numbers of larvae found in White Birch at Wild Cove Point (1972).


1972
1970
June
July
Aug.
Sept.
15
1
15
1
15
31
15
30
0
100
200
300
400
Number of Larvae per 50 Leaves

and fourth generation adults from 19 August to 15 September. He determined the end of each of these generations by sieving soil samples and counting the number of full and empty cocoons. The first generation terminated on or about 30 June, the second generation on 24 July, third on 13 August, and the fourth on 7 September. Cheng confirmed that overwintering was in the prepupal stage, not as a pupa, as previously reported by Britton (1926).

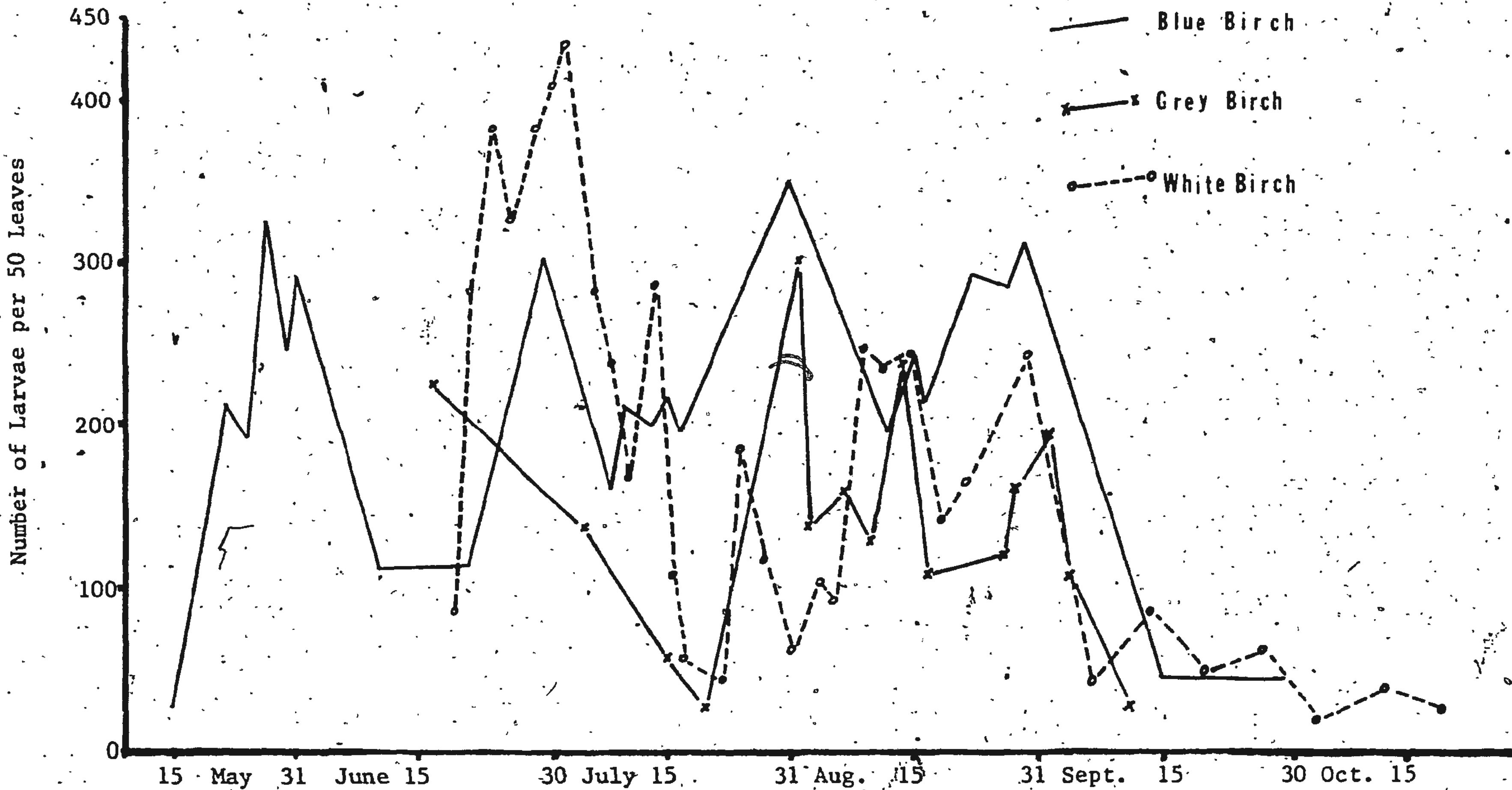
A composite graph showing numbers of larvae according to Guèvremont (1970, Fig. 9), Cheng (1965, Fig. 7), and the author (Wild Cove Point, Tree 1) is given for comparison (Figure 7, p. 40). It shows that a first generation in MacDonald Arboretum was completed before commencement of a first generation at Wild Cove Point and that numbers of larvae decreased sharply in all three places in early September. In view of the climatic differences between the three places other similarities may be nothing more than fortuitous, although further work might be justified to see to what extent climatic differences affect the number and duration of life cycles of the leaf miner.

Elsewhere in North America, three and sometimes a full, or partial, fourth generation have been reported (Britton, 1926; Friend, 1931; Cheng and LeRoux, 1965). Cheng and LeRoux also reported that the number of generations tends to decrease with increasing host age; older trees produce fewer young leaves after the first leaf flush.

In Europe F. pusilla has two generations per year in Eastern Austria and the German Rhine Valley ($\leq$ 100m.a.s.l.) whereas at higher elevations, such as in the Black Forest ($\geq$ 1200m.a.s.l.) only one generation occurs. Information on the number of generations at lower elevations is lacking (Eichorn and Pschorn-Walcher, 1973).

In Newfoundland, where adult emergence of F. pusilla is nearly one

FIGURE 7. Numbers of larvae of F. pusilla per 50 leaves in Blue Birch (Cheng, 1965), in Grey Birch (grassland habitat; Guèvremont 1970) and in White Birch (Tree 1, Wild Cove Point, 1972).


Blue Birch
Grey Birch
White Birch
Number of Larvae per 50 Leaves
450
400
300
200
100
0
15 May 31 June 15 30 July 15 31 Aug. 15 31 Sept. 15 30 Oct. 15

month later than in mainland Canada, it is not surprising that there was one generation less per year. What is perhaps more important than the number of generations is the fact that from early June to September in any year in Newfoundland in the areas studies, F. pusilla larvae are likely to be present in birch leaves. From 1971 to 1974 first emergence of adults has been noted in the first two weeks of June. This consistency suggests that there may be similar consistency in the number of generations and their duration.

The Number of Larval Instars per Generation and the Duration of each Instar

Counts of exuviae and larvae occupying mines showed that there were 5 larval instars in all leaves and in all generations.

First-instar larvae were distinguished by size, by the absence of the 4 black marks on the ventral surface of the thoracic and first abdominal segment, and by the kidney-shape and small size of their usually individual leaf mines. Instars 2 to 4 have the black marks (Plate I, p. 3). Mines of second-instar larvae were usually individual, more round than kidney-shaped, and larger than first-instar mines (Plate VI, p. 6). First- and second-instar larvae did not eat through main leaf veins. It was usually impossible to distinguish third- from fourth-instar larvae by size alone. Exuvial counts indicated that third-instar larvae were frequently as large as, or larger than, some fourth instars. Third- and fourth-instar larvae ate through main leaf veins, so that when there were several larvae in one leaf, their mines often coalesced (Plate VII, p. 7). Commonly, several larvae in instars 2 to 4 were seen eating leaf tissue, parallel to each other, with their mouth parts proximal to the leaf margin. Because of the frass it was not always possible to find all exuviae in mined leaves. Thus data collected for some larvae could not be used in analysis.

The fifth-instar larvae lacked the 4 black marks which characterized instars 2 to 4, and had distinctly hypognathous mouthparts, in contrast with the prognathous mouthparts of the first four instars. The absence of gut contents and measurement of leaf mine areas showed that the fifth-instar larvae did not feed: their low incidence in leaves (e.g. Table IV, p. 22) indicated that they vacated leaves shortly after the fourth larval moult. My measurements of the five larval instars and the form of their mines are in complete accord with those of Cheng (1967).

Interest in the use of head capsule measurements of sawfly larvae for determining the number and duration of instars has been shown by Taylor (1930, 1931), Miles (1931), Ghent (1956) and Cheng (1967). Whereas Taylor (1931) concluded that application of Dyar's Rule to sawflies should be restricted to corroboration of the number of instars observed, Ghent found that data on the Jack Pine Sawfly, <u>Neodiprion pratti banksianae</u> Roh. and <u>F. pusilla</u>, indicated that the growth of the head capsules of these species was linear rather than exponential and that there was predictive value in head capsule measurements.

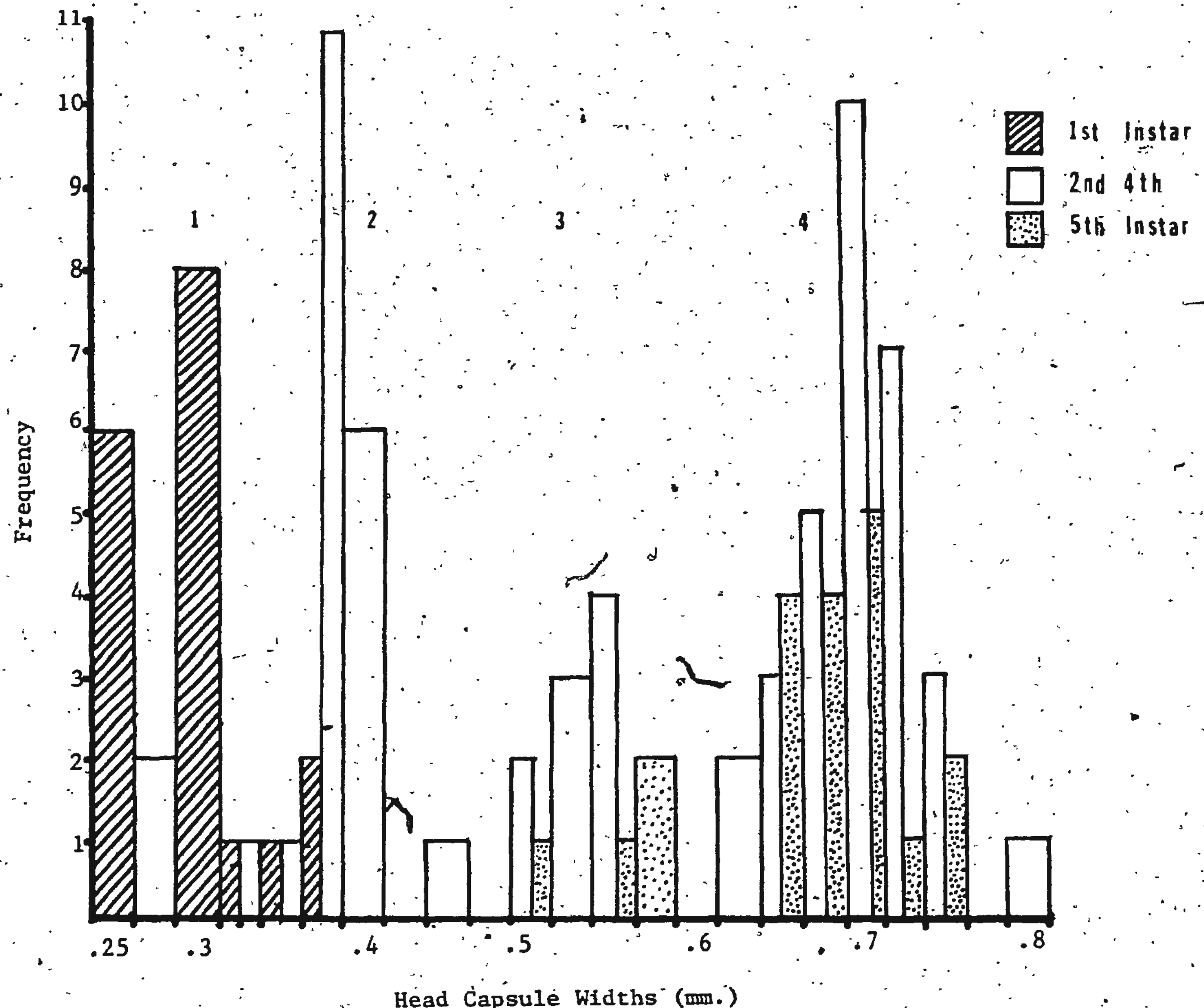
In this study the head capsule widths of <u>F. pusilla</u> confirm 5 larval instars per generation (Fig. 8, p. 43). First-instar larvae had widths from 0.250 to 0.375 (average 0.300) mm. Of the 30 larvae thought to be in the second or third instar, the majority (20) were second instar. Head widths of these 20 larvae were from 0.325 to 0.450 (average 0.380) mm. Of the 30 larvae thought to be in the third or fourth instar, the majority (29) were fourth instar. The head widths of the 9 third-instar larvae were from 0.500 to 0.550 (average 0.530) mm. The head widths of the 29 fourth-instar larvae were from 0.625 to 0.800 (average 0.705) mm.

FIGURE 8. Head capsule widths of 100 larvae of _F. pusilla_.

Each interval on the horizontal axis is 0.025 mm.

Scale is from 0.250 to 0.800 mm.

1, 2, 3, 4 represent the nodal widths for the first 4 larval instars


1st Instar
2nd 4th
5th Instar
1
2
3
4
Frequency
11
10
9
8
7
6
5
4
3
2
1
.25
.3
.4
.5
.6
.7
.8
Head Capsule Widths (mm.)

The head capsule widths of the 20 known fifth-instar larvae were 0.500 to 0.750 (average 0.660) mm.

No attempt was made to predict what instar a larva was in from these data of head widths. The purpose was to see if data from head widths agreed with the observation of five instars: they did.

Average head capsule widths from Ghent (1956), Guèvremont (1970), and this study are given in Table X, below. Guèvremont found that head widths of larvae from leaves growing in open ("Prairie") habitats were significantly larger than those in forest. Further study is required.

TABLE X. Average head capsule widths (mm.) of F. pusilla larvae, according to Ghent (1956), Guèvremont (1970) and the present study.

Instar	Ghent	Guevremont	Newfoundland 1972
I	0.293	0.29	0.300
II	0.416	0.42	0.380
III	0.552	0.56	0.530
IV	0.680	0.71	0.705
V	--	--	0.660

Observation of marked leaves on the sample trees allowed estimations to be made of the duration of each larval stage. These estimates, and estimates of the duration of the other stages in the insect's life cycle, are given in Table XI, p. 45.

Larval Mortality

As F. pusilla eggs develop the surrounding leaf tissue becomes grey in colour and the upper leaf epidermis swells to a blister-like protrusion.

TABLE XI. Estimates of the duration of stages in the life cycle of F. pusilla in 1972.

	Range (days)	Average (days)
Adults, pre-ovipositing	--	1
From egg being laid to its becoming apparent as a leaf blotch	--	8
From egg blotch to egg hatching	2-4	3
1st instar larva	2-6	3
2nd instar larva	3-7	4
3rd instar larva	3-7	5
4th instar	3-8	6
5th instar	--	1
Soil Period	9-39	20
		Total = 51 days

If the eggs fail to hatch, or the resulting first-instar larvae die, the discolouration changes to brown, and the protrusions collapse. On this basis, external examination of leaves showed that large numbers of eggs and first-instar larvae died, particularly in Mountain White Birch.

In leaves dissected soon after collection, dead larvae were brown and frequently shrivelled, whereas live larvae were pale-coloured and swollen. When leaves were dissected after cold-storage it was usually possible to distinguish live from dead larvae in the same way. However, in some instances, all larvae in stored leaves were found to be brown and shrivelled on dissection, and it was not possible to tell how many of these were dead at the time of collecting the samples. In future mortality studies it follows that leaves should be dissected fresh.

Leaf samples collected from the three sites at the end of July, i.e. at the end of the first generation, showed that at Sites 1 and 3, between 50% and 60% of the larvae were dead, whereas at Site 2, 17% were dead. The majority of dead larvae at all three sites were in the first or second instar. It is probable that these larvae starved in competition with late-instar larvae.

Scrutiny of Tables IV (p. 22), V (p. 25) and IX (p. 34) shows that there was considerable decrease in numbers of larvae from the first to the fourth instar. The numbers of eggs were less than numbers of larvae because the sampling method had been deliberately biased in favour of larvae. Therefore, representative counts of numbers of eggs were not obtained. But observations, mentioned previously, showed that the numbers of eggs were greater than numbers of larvae. Numbers of fifth-instar larvae were considerably less than numbers of fourth-instar larvae because the former spent only a short time in the leaves.

The numbers of first-instar and fourth-instar larvae were totalled for each site for three time periods, each period spanning the estimated duration of each generation, i.e. from early June to late July; late July to early September; and early September to mid-October. The difference between numbers of first- and fourth-instar larvae was expressed as a percent decrease (Table XII, below). The table shows that at Site 1 decrease was 50% or greater. In Tree 3, mortality was consistently nearly 100%. An apparent paradox still exists in that numbers of first- and second-instar larvae increased in the Mountain White Birch throughout the season (Table IX, p. 34; Fig. 5, p. 35). These were alive at the time of dissection but would not have survived, since early-instar larvae cannot form soil cocoons.

TABLE XII. Percent decrease in numbers of F. pusilla larvae (%) from first (1st) to fourth (4th) instar for the three sampling sites as calculated from destructive sample tables, in 1972.

Generation	Time	Site 1			Site 2			Tree 3		
		1st	4th	%	1st	4th	%	1st	4th	%
1	7-June to 24-July	1219	385	69	418	200	53	1949	35	98
2	25-July to 6-Sept.	553	287	49	355	329	10	4115	10	99.8
3	7-Sept. to 18-Oct.	90	44	51	--	--	--	3950	50	98.7

Non-destructive sampling showed that in Trees 1 and 2 larvae developed to emergence stage in all crown regions, whereas in Tree 3 larvae emerged only from shaded leaves.

Cheng and LeRoux (1965, 1966) reported that considerable mortality of eggs was associated with hardening of leaf tissue. Egg hatching was proportional to the amount of tender foliage present and decreased throughout the growing season. A large proportion of first- and second-instar larvae died owing to desiccation of the foliage. Late-instar larvae were not so vulnerable to leaf desiccation. They found that mortality was greater in 9 year old than in 3-5 year old Blue Birch, and that larval mortality was higher in the fall than in spring.

Guèvremont (1970) found that mortality of larvae was greater in younger (4 ft.) than in older (10 ft.) Grey Birch in an open habitat, but that mortality was higher in older trees in closed forest.

It appears that larval mortality of F. pusilla varies according to host species, host age, locality and the season. A method for determining leaf toughness in insect feeding studies has been described by Cherrett (1968). The method could be used to test possible differences between penetrability by F. pusilla ovipositors of shaded and exposed leaves, and between leaves of different birch species. In addition, leaf toughness may be correlated with egg and larval survival. Cheng (1967) has noted that some species of birch are more susceptible to the leaf miner than others: White Birch, Grey Birch and Blue Birch are among the more susceptible species.

Intra-Crown Distribution of Eggs and Larvae

Intra-crown distribution of eggs and larvae in the three sample trees is given in Table XIII, p. 49. Non-destructive sample tables, from which these rank orders were obtained, are given for the three trees in Appendices I, II and III (pp. 72, 73, 74, respectively).

TABLE XIII. Intra-crown distribution (regions i-v), of *F. pusilla* eggs and larvae for three sample trees, as determined by Rank Order Correlation (1-5), from Non-Destructive Sample Tables in 1972.

	Tree 1	Tree 2	Tree 3
i. Shaded leaves, lower crown	4	5	5
ii. Exposed leaves, lower crown	2	3	3
iii. Shaded leaves, mid-crown	5	2	4
iv. Exposed leaves, mid-crown	3	4	2
v. Exposed leaves, leading shoot	1	1	1

The leading shoot was consistently the region with greatest egg and larval numbers. In Trees 1 and 3 lowest numbers were recorded in shaded leaves. Tree 2 was open-crowned, so that leaves in "inner" crown regions were not completely shaded. This may explain the apparent paradox, that numbers of eggs and larvae were greater in region iii than in regions ii and iv in Tree 2.

Percent infestation of foliage in each crown region was also calculated for the three sample trees. A leaf was considered to be infested if it showed one or more eggs or larvae. Data are presented in Table XIV, p. 50, for two sampling dates only for each of the three trees. The first date was the peak infestation recorded in the first generation; the second date was the peak infestation recorded in the second generation. The figures in Table XIV show that in White Birch an average of 30% of the leaves marked for Non-Destructive Sampling were infested at the height of

TABLE XIV. Percentage of leaves showing presence of one or more eggs or larvae of F. pusilla in five crown regions (i-5) for three sample trees on two dates, coinciding with peak infestation in the first and second generations in 1972.

Crown Region	Tree 1		Tree 2		Tree 3	
	6-July	22-August	25-July	14-August	4-July	22-August
i	28	0	14	5	100	30
ii	34	2	28	13	75	80
iii	16	2	26	22	90	60
iv	32	0	18	18	100	95
v	52	11	54	45	95	100
Means	32	3	30	21	92	73

the first generation. The amount of infestation was less in the sampled leaves in both trees in the second generation, markedly so in Tree 1 at Wild Cove Point. This does not necessarily indicate an actual decline in the degree of infestation in the trees, because the leaves were marked early in the first generation. The marked leaves aged; the focus of second generation infestation was younger leaves.

In contrast with the two White Birch, almost all of the marked leaves on the Mountain White Birch were infested at the height of the first generation. There was an overall decrease in percent infestation of the aging marked leaves in the second generation but in that generation infestation was notably higher in the exposed than in the shaded leaves.

Rank order correlation of percentage of leaves showing infestation with the five crown regions is summarized for the three sample trees in Table XV, p. 51.

TABLE XV. Average rank values (1-5) of the percentage of marked leaves in 5 crown regions (i-v) of three sample trees which were infested with F. pusilla in 1972.

Crown Region		Tree 1	Tree 2	Tree 3
i.	Shaded leaves	4	4	5
ii.	Exposed leaves	2	3	3
iii.	Shaded leaves	5	2	4
iv.	Exposed leaves	2	5	1
v.	Leader	1	1	2

These rank values were the averages obtained from ranking the percentages of marked leaves that were infested in each of the 5 crown regions on each sampling date. Thus the rank values for Tree 1 were derived from Table VII, p. 28. For Trees 2 and 3 the tables from which average rank values were derived are given in Appendices IV and V (pp. 75 and 76, respectively).

Average rank values show that the leading shoot was the region of highest percent infestation of leaves, and also the region of highest egg and larval numbers. Shaded leaves in the inner regions of the crown were generally less heavily infested. Data for crown region iii (mid-crown, shaded leaves) in Tree 2 showed that more leaves in this region were infested, and so agreement is shown between numbers of eggs and larvae, and the percentage of leaves that were infested.

Distribution According to Leaf Age

The percentages of infested leaves in each age-class showing eggs, first- or second-instar larvae, third- to fifth-instar larvae, and from which larvae had emerged, are given in Table XVI, below. Percentage totals exceed 100 in some cases because leaves frequently contained both early- and late-instar larvae, etc.

TABLE XVI. Percentages of leaves showing eggs (E), 1st or 2nd instar larvae, 3rd to 5th instar larvae, and from which full-grown larvae had emerged, in four age-classes of leaves, in 1972.

Age-Class	E	1-2	3-5	Emerged
Bud	100	0	0	0
Young	48	55	9	0
Young-Mature	28	58	31	7
Mature	11	24	57	34

The results in Table XVI show a correlation of leaf age with larval development. Eggs were most often laid in buds or young leaves, but a few eggs were also laid in older leaves. Observation showed that *Fenusa* females occasionally oviposited in mature leaves when uninfested buds and young leaves were available nearby. Observation also indicated that egg and larval mortality was greater in mature than in young leaves. Early-instar larvae were predominant in young and young-mature leaves, whereas late-instar larvae were found mainly in young-mature and in mature leaves.

Branch Samples

The data of branch samples from 13 localities other than the three sampling sites are summarized in Table XVII, p. 53. The pattern of development of larvae in leaves, from the tips of shoots (Leaf 1) to the tenth leaf down the shoot (10), clearly shows that eggs and early-instar larvae were predominant in leaves nearest the tip, whereas vacated leaves were

TABLE XVII. Percent of leaves infested with eggs and larvae of F. pusilla as obtained from branch sampling in 1972. (B = bud, Y = young leaf, My = young-mature leaf, M = mature leaf).

	Leaf Numbers from Tips of Shoots Down to Tenth Leaf									
	1	2	3	4	5	6	7	8	9	10
Leaf Category	B	B	Y	Y	My	My	My	M	M	M
Containing 1 or more eggs	14	12	11	8	6	5	4	4	2	0
Containing 1 or more 1st to 2nd instar larvae	6	8	15	28	32	32	25	15	7	6
Containing 1 or more 3rd to 5th instar larvae	2	4	8	12	20	27	23	16	8	5
Leaves from which larvae had emerged	1	5	7	12	17	22	24	22	18	10
Number of leaves sampled	267	278	286	285	276	280	258	237	207	143

usually the fifth or more down.

Damage to Leaves

Most leaves were not completely destroyed and photosynthesis would continue in the undamaged parts. In totally damaged leaves only the upper and lower epidermis remained.

Eggs were observed to be quite clustered in inter-leaf distribution. Frequently, leaves close to each other, and apparently of the same texture, varied considerably in the number of eggs they contained. Thus, totally destroyed leaves were commonly adjacent to slightly damaged and completely undamaged leaves. No trees were seen in which damage was so severe as to suggest that appreciable reduction in tree growth or death would result.

Eggs were usually laid near the main leaf veins and only rarely near the leaf margins. Frequently, females appeared to oviposit on one leaf as many as 20 times. Several females were seen to oviposit on one leaf. In the two White Birch the average number of eggs per leaf decreased with the season, whereas it increased in the Mountain White Birch. There was considerable variation in the number of eggs per leaf, suggesting that the leaf miner is not particularly efficient in distributing its eggs to maximize on food resources. The average numbers of larvae in Trees 1 and 2 were 3 per infested leaf, and 15 per leaf in Tree 3 (Table XVIII, p. 55).

The amount of food eaten as determined from the surface area of 10 larval mines in each instar showed large variation in second- to fourth-instar mines (Table XX, p. 56). Size and variation of mine areas in Grey Birch according to Guèvremont (1970) are presented along with my data for comparison.

TABLE XVIII. Average numbers of F. pusilla larvae per infested leaf in three sample trees (Trees 1-3) in 1972.

	Tree 1	Tree 2	Tree 3
28- June	6.5	--	9.0
10- July	3.5	5.2	14.6
17-	1.0	4.6	8.6
24-	3.7	5.7	6.5
31-	1.2	3.6	4.6
7- Aug.	4.0	2.5	18.4
14-	4.7	2.4	12.7
21-	5.3	7.0	16.6
28-	4.7	1.2	17.3
6- Sept.	0.9	--	21.4
13-	1.7	1.8	18.9
20-	--	--	24.9
27-	2.0	1.4	17.4
4- Oct.	--	0.3	13.2
13-	2.0	1.3	23.5
18-	1.5	--	--
$\bar{x}$	3.0	3.0	15.2

TABLE XIX. Average size and range of mine areas (mm^2) of <u>F. pusilla</u> larvae in White Birch and in Grey Birch (the latter from Guèvremont, 1970).

Instar	White Birch		Grey Birch	
	Range	Mean	Range	Mean
1	0.9 - 2.2	1.3	1.0 - 6.0	2.0
2	5.8 - 60.0	14.0	3.0 - 23.0	8.0
3	24.7 - 75.0	30.3	12.0 - 56.0	26.0
4	55.0 - 126.	90.5	27.0 - 213.	--
5	No increase in size after 4th instar			

In the case of the White Birch, 10 individual mines were measured that were occupied by a single larva in each of the 5 instars. The minimum and maximum areas of the second- to fourth-instar larvae are greater than those found by Guèvremont, except in the fourth-instar maximum. The means show reasonably good agreement. Differences could be attributable to different host species.

The estimated average number of larvae responsible for total destruction of leaves of different sizes is given in Table XX (p. 57). The number of larvae is the total of all instars. Regression analysis of the individual observations showed a significant correlation between leaf size and the average number of larvae responsible for total leaf destruction ($P = 0.05$, $r = 0.746$, $F = 173.471$ (Appendix VI, p. 77). The range of individual observations was great. This was expected in view of the considerable range in mine areas.

Cheng (1967) reported that 1 to 2 larvae per leaf resulted in no serious damage, but 5 to 10 larvae per leaf led to almost total destruction

TABLE XX. Total number of larvae of F. pusilla responsible for complete destruction of photosynthetic leaf tissue of White Birch according to leaf size (10 leaves per size-class, 5 mm. intervals).

Leaf Blade Length (mm.)	Approx. Area mm^2	Average Number of larvae	Range
16-20	108	2.0	1-4
21-25	162	3.3	1-6
26-30	216	3.9	2-7
31-35	303	5.4	1-12
36-40	468	6.6	3-14
41-45	612	4.8	3-12
46-50	756	6.3	4-11
51-55	986	6.9	4-20
56-60	1080	7.8	5-12
61-65	1440	8.0	4-12
66-70	1584	9.7	5-14
71-75	1944	10.4	4-17
76-80	2520	11.8	5-20
81-85	2700	14.4	10-23

of spring foliage. Such high population levels of the spring generation usually produced enough offspring to do appreciable damage to terminal leaves produced in the second leaf flush. Cheng also found that trees were not killed by heavy infestation.

In this study no attempt was made to assess the effect of F. pusilla infestation on tree growth. Frequently, Birch Casebearer[1] and leaf miner infestation occurred on the same trees. In such cases damage by casebearer was more severe than that by leaf miner. Future studies on the effect of both of these insects on tree growth would be justified.

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[1]Birch Casebearer, Coleophora fuscedinella (Zeller) (Lepidoptera:Coleophoridae).

RELEASE OF TWO EUROPEAN ICHNEUMONIDS AGAINST THE BIRCH LEAF MINER

Introduction

The Commonwealth Institute of Biological Control at Delemont, Switzerland, has been studying the parasite complex of F. pusilla and the biology of the parasitoids in Europe since 1968 (Eichorn and Pschorn-Walcher, 1973). Of the 17 species of parasitoids that have been observed and evaluated for possible introduction into Canada, Lathrolestes (= Priopoda) nigricollis (Thomson)[1] and Grypocentrus albipes (Ruthe) (both Hymenoptera: Ichneumonidae) were selected for introduction into Newfoundland in 1972. This decision was made by the Canadian Forestry Service, but the author was responsible for methods of release and initial observation of the two insects after their release.

Materials and Methods

In June and early July 1972 an estimated 7,000 host pupal cases of F. pusilla were collected in northern Germany and the German Rhine Valley. These were shipped from Delemont to Belleville, Ontario, Canada Department of Agriculture, for quarantine and rearing of parasitoids. Following emergence, three shipments of L. nigricollis (99 ♂ and 114 ♀), and one shipment of G. albipes (4 ♂ and 9 ♀) were sent by air freight to Deer Lake, Newfoundland, in cardboard cylinders surrounded by ice-packs. Live adults were released in August on the dates shown in Table XXI (p. 63).

The insects were released onto caged White Birch trees on the

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[1] Hereafter referred to as L. nigricollis.

property of the Canadian Forestry Field Station at Pasadena. This facilitated observation of parasitoid behaviour and confined the small numbers released. Four cages were used, three for L. nigricollis (numbered L_1, L_2, and L_3) and one for G. albipes (G_1). Cages were 4 ft. x 4 ft. and 7.5 ft. high. The sides and top were covered with 20-strand-per-inch fine nylon screening (Plate XI, p. 61). Ground vegetation within cages was cut at ground level and removed, and the ground covered with about 3 inches of sifted soil to provide a suitable substrate for larval pupation.

Two trapping methods were used to collect host pupae. One method consisted of placing plastic dishes 6.5 inches in diameter, filled with sifted soil, on the floor of the cages beneath foliage infested with F. pusilla larvae. The other method consisted of suspending plastic bags containing sifted soil beneath infested leaves. In the second case slits were cut in the bags to reduce condensation within them. Trap contents were collected in October 1972, at which time the screening was removed from the cages. The screening was replaced in May 1973 so that any emerging parasitoids could be collected.[2]

Prior to releases, an estimate was made of the numbers of larvae of F. pusilla in the leaves of the caged trees. The aim was to ensure a minimum of 20 host larvae per female parasitoid. So far as possible all of the few native Ichneumonids inside the cages were removed.

Precise numbers of L. nigricollis released into cages are not known. The top of the container was removed inside a cage and the number of adults of each sex that flew out was estimated. This method of release was used

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[2]One of the L. nigricollis-release trees was almost completely defoliated by the Birch Casebearer in 1973 and was therefore not rescreened.

PLATE XI. Two White Birch infested with F. pusilla, caged for parasitoid release experiments. Foreground shows Cage L_1, background cage L_2 used for L. nigricollis release, August 1972.

because there were more insects in one container than were required for one cage, and I did not want to risk killing some of these costly individuals by anesthetizing or handling them.

Results and Discussion

Two releases were made into Cage L_1, on 10 and 16 August. One release was made into Cage L_2 on 10 August. Releases into Cage L_3 were made on 16 and 23 August. The one release of G. albipes into Cage G_1 was made on 10 August (Table XXI, p. 63).

Mating, host searching, and oviposition were observed for L. nigricollis but not for G. albipes. Adults of both species were found alive and active up to 12 days after their release. No parasitoid eggs were found on F. pusilla larvae two days after L. nigricollis females were seen apparently ovipositing on them.

A total of 50 F. pusilla cocoons were obtained in October 1972 from the trap contents of the L. nigricollis cages, and 13 cocoons from the trap contents of the G. albipes cage. Dissection of the cocoons yielded two parasitoid larvae and one pupa from the L. nigricollis cage but none from the G. albipes cage. The shape and sculpturing of the thoracic sclerites of the pupa could not be distinguished from the larvae. Consequently, all three individuals were presumed to be L. nigricollis.

Parasitoid adults were first observed on 27 June 1973. By 29 June a total of 10 L. nigricollis and 10 G. albipes were seen. Three of each species were collected and their identification verified by J. R. Barron.[3] No additional parasitoids were seen until 11 July when about 40 G. albipes

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[3]Biosystematics Research Institute, Ottawa.

TABLE XXI. Number of L. nigricollis and G. albipes released at Pasadena, Newfoundland, in August 1972.

Date shipped from Belleville	Date arrived in Nfld.	Date released	Time released	Temp. at release time (°F)	No. parasites received ♂	♀	Total	Dead	No. parasites released ♂	♀	Total	Cage no. (L)	Estimated no. of host eggs and larvae on caged tree
							L. nigricollis						
Aug. 8	Aug. 9	Aug. 10	12:30 PM	65	51	56	107	21	20	20	40	L_1	700
									31	36	67	L_2	600
Aug. 14	Aug. 15	Aug. 16	10:30 AM	55	38	36	74	5	18	16	34	L_1	700
									20	20	40	L_3	400
Aug. 21	Aug. 22	Aug. 23	10:15 AM	60	10	22	32	0	10	22	32	L_3	400
Total					99	114	213	26	99	114	213		
							G. albipes						
Aug. 8	Aug. 9	Aug. 10	12:30 PM	65	5	9	14	1	4	9	13	G_1	350

were observed. All insects seen were males. At the time of the 1972 release it was observed that males of both species tended to be on the screens where they were readily visible, but females remained among the foliage where they were almost impossible to find.

Small numbers of L. nigricollis and of G. albipes were released onto the same trees as those used in the 1972 release on 30 August 1973 by A. G. Raske.[4] At this time, leaf sampling did not show presence of any larvae of F. pusilla.

Further work on the release of L. nigricollis and G. albipes is to be undertaken by Guèvremont in Quebec. At present the status of the two introduced species in Newfoundland is uncertain.

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[4]Newfoundland Forest Research Centre.

SUMMARY

This study has shown that in 1972 there were 2 complete generations of F. pusilla and that some individuals completed a third generation to the prepupal (overwintering) stage. There was considerable overlap between generations. One generation averaged 51 days in duration but some individuals could have completed their life cycle in as little as 35 days.

Counts of exuviae in mines compared with the number of larvae known to have occupied the mines, and measurements of larval head capsule widths, indicated 5 larval instars per generation.

Observation of marked leaves in five crown regions in three sample trees showed that exposed leaves in the upper crowns of both White and Mountain White Birch were consistently more often infested with F. pusilla than shaded leaves in the mid and lower parts of the crowns.

A small Mountain White Birch in a forest nursery was much more severely infested with early-instar larvae than two larger White Birch growing under more natural conditions, but larvae in the Mountain White Birch seldom became full-grown. The difference in infestation may indicate a difference in vulnerability between the 2 species; or it may indicate that small birch growing on exposed mineral soils are more attractive to ovipositing females than larger trees under more natural conditions, or it may be a combination of these factors.

Larval mortality was about 50% in White Birch in the first generation and was less for the second and probably also for the third generation. Larval mortality in the Mountain White Birch was near 100%. Whereas infestation levels in this tree were higher in exposed leaves, larvae completed development only in shaded leaves. In both birch species eggs and early-instar larvae suffered the greatest mortality. In White Birch many early-instar larvae apparently died due to starvation in competition with more advanced larvae. In Mountain White Birch it appeared that something in the leaves inhibited development of the eggs and larvae, so that very few individuals reached the late-instar stage. Further work on host preference and leaf palatibility is recommended.

Oviposition occurred in all crown regions during the first generation because all regions contained young leaves. After the first generation oviposition was concentrated on buds and young leaves at the tips of exposed shoots. The number of eggs laid per infested leaf averaged 3 in White Birch and 15 in Mountain White Birch. The maximum number of eggs and larvae found in any one leaf was 47. There was considerable variation in the number of eggs and larvae per leaf, suggesting that the leaf miner is not particularly efficient in utilizing its host.

There was close correlation between leaf size and the numbers of larvae responsible for total leaf destruction. Two larvae were capable of destroying leaves 16-20 mm. long, whereas 14 larvae were needed to destroy leaves 81-85 mm. long.

Two parasitoids, Lathrolestes nigricollis (Thomson) and Grypocentrus albipes (Ruthe) were introduced from Europe in 1972. Three shipments of L. nigricollis (99 males and 114 females), and one shipment of G. albipes (4 males and 13 females) were released in August 1972 into caged White Birch infested with F. pusilla, at Pasadena Field Station, western Newfoundland.

Mating, host searching and oviposition were observed for L. nigricollis only, but adults of both species were seen up to at least 12 days after release. About 50 adults, progeny of these releases,were positively identified in 1973, but it would be premature to say that the 2 species are established.

REFERENCES

REFERENCES

Britton, W. E. 1924. A European leaf-miner of birch. Jour. Econ. Ent., 17:601.

Canadian Forest Service. 1960-73. Annual reports of the Forest Insect and Disease Survey. Department Environment, Ottawa.

Carroll, W. J., and W. C. Parrott. 1959. Province of Newfoundland, IN Annual Report of Forest Insect and Disease Survey, Canada Dept. Agric., Div. Forest Biol., pp. 9-14.

Cheng, H. H. 1967. Population Dynamics of the Birch Leaf Miner, Fenusa pusilla (Lep.) on Blue Birch, Betula caerulea grandis Blanchard, in Quebec. Ph.D. thesis, McGill University.

Cheng, H. H., and E. J. LeRoux. 1965. Life history and habits of the Birch Leaf Miner, Fenusa pusilla (Lepeletier) (Hymenoptera:Tenthredinidae), on Blue Birch, Betula caerulea grandis Blanchard, Morgan Arboretum, Quebec. Ann. Soc. Ent. Quebec, 10(3):173-188.

________. 1966. Preliminary life tables and notes on mortality factors of the Birch Leaf Miner, Fenusa pusilla (Lepeletier) (Hym.: Tenthr.) on Blue Birch, Betula caerulea grandis Blanchard, in Quebec. Ann. Soc. Ent. Quebec, 11(1):81-104.

________. 1970. Major factors in survival of the immature stages of Fenusa pusilla in South Western Quebec. Can. Ent., 102(8):995-1002.

Cherrett, J. M. 1968. A simple penetrometer for measuring leaf toughness in insect feeding studies. Jour. Econ. Ent., 61(6):1736-1738.

Eichorn, O., and H. Pschorn-Walcher. 1969. Annual Project Statement, Commonwealth Inst. Biol. Control, European Station, Delémont, Switzerland: Birch Leaf-mining Sawfly (Fenusa pusilla). Unpublished report.

________. 1971. Annual Project Statement, CIBC. Birch Leaf-mining Sawfly-work in Europe in 1971 (10 pp.) Unpublished report.

________. 1973. The parasites of the Birch Leaf-mining Sawfly (Fenusa pusilla Lep.) in Central Europe. Report from CIBC, Delémont. Unpublished report.

Friend, R. B. 1931. Life history and control of the Birch Leaf-mining Sawfly, Fenusa pumila Klug. Jour. Econ. Ent., 24:171-177.

Ghent, A. W. 1956. Linear increment in width of the head capsule of two species of sawflies. Can. Ent., 88(1):17-23.

Guèvremont, H. 1970. Bionomie de Fenusa pusilla (lep.) dans trois Biotopes: Frairie, Lisière du Bois, et Bois, en tenant compte de la grandeur des Arbres et de la strate foliaire. M.Sc. thesis, Université de Sherbrooke, Quebec. 199 pp.

Lindquist, O. H. 1959. A key to the larvae of Leaf-mining sawflies on birch in Ontario with notes on their biology. Can. Ent., 91(10):625-627.

Miles, H. W. 1931. Growth in the larvae of Tenthredinidae. J. Expt. Biol., 8(4):355-364.

Newfoundland Forest Research Centre. 1973. Biological agents released in Newfoundland for the control of Forest Insect pests. Newfoundland Forest Research Centre. Information Report N-X-96.

Taylor, R. L. 1930. A simple statistical method for determining the approximate duration of instars of leaf mining larvae. Jour. Econ. Ent., 23:587-595.

________. 1931. On 'Dyar's Rule' and its application to sawfly larvae. Ann. Ent. Soc. Amer., 24:451-466.

Yoshimoto, C. M. 1973. Review of North American Chrysocharis (Eulophidae: Chalcidoidea) north of Mexico, especially species attacking birch casebearer (Lepidoptera:Coleophoridae) and birch leaf-miner (Hym.: Tenthred.). Can. Ent., 105(10):1309-1349.

APPENDICES

APPENDIX I. Field estimated numbers of eggs (E) and larvae (L) of F. pusilla in 50 marked leaves in each of 5 crown regions (i-v) in Tree 1 at Wild Cove Point in 1972 (Non-Destructive Sample Table).

Date	Crown Regions															Total for all regions per 250 leaves		
	i			ii			iii			iv			v					
	E	L	E+L	E	L	E+L	E	L	E+L	E	L	E+L	E	L	E+L	E	L	E+L
19- June	67	0	67	83	0	83	18	0	18	44	0	44	144	0	144	356	0	356
21-	48	22	70	45	33	78	18	7	25	30	15	45	123	25	148	264	120	366
24-	2	70	72	26	58	84	18	13	31	10	37	47	115	91	206	171	269	440
26-	7	72	79	3	72	75	10	17	27	5	38	43	114	104	218	139	303	442
28-	12	65	77	10	70	80	0	18	18	8	37	45	122	97	219	152	287	439
3- July	6	70	76	3	74	77	1	33	34	5	29	34	7	100	107	22	306	328
6-	4	40	44	0	65	65	0	25	25	2	28	30	7	97	101	13	252	265
10-	0	12	12	0	34	34	0	10	10	2	12	14	3	91	94	5	159	164
13-	0	5	5	3	18	21	0	11	11	0	10	10	8	62	70	11	106	117
17-	0	0	0	0	12	12	0	7	7	0	9	9	0	49	49	0	77	77
21-	0	0	0	2	7	9	0	3	3	2	8	10	2	32	34	5	50	56
24-	0	0	0	6	7	13	0	1	1	4	6	10	10	26	36	20	40	60
28-	0	0	0	17	2	19	2	0	2	8	4	12	12	16	28	39	22	61
31-	0	0	0	50	9	59	2	3	5	7	8	15	36	25	61	95	45	140
4- Aug.	0	0	0	38	7	45	2	1	3	7	2	9	22	40	62	69	50	119
8-	0	0	0	23	17	40	2	0	2	5	5	10	18	52	70	48	74	122
12-	0	0	0	14	12	26	0	0	0	3	4	7	17	27	44	34	43	77
15-	0	0	0	0	17	17	0	0	0	0	4	14	10	40	50	10	61	71
17-	0	0	0	0	14	14	0	0	0	0	3	3	10	31	41	10	48	58
21-	0	0	0	0	12	12	0	0	0	7	3	10	9	27	36	16	42	58

APPENDIX II. Field estimated numbers of eggs (E) and larvae (L) of <u>F. pusilla</u> in 50 marked leaves in each of 5 crown regions (i-v) in Tree 2 at Pasadena Field Station in 1972 (Non-Destructive Sample Table).

Date	Crown Regions															Total for all regions per 250 leaves		
	i			ii			iii			iv			v					
	E	L	E+L	E	L	E+L	E	L	E+L	E	L	E+L	E	L	E+L	E	L	E+L
20- June	24	0	24	13	1	14	19	0	19	14	2	16	37	14	51	107	17	124
28-	6	20	26	7	20	27	7	24	31	2	13	15	42	145	187	64	222	286
5- July	0	26	26	0	27	27	42	31	73	1	12	13	37	187	224	80	283	363
7-	3	22	25	0	26	26	15	63	78	0	8	8	28	186	214	46	305	351
12-	5	20	25	16	15	31	9	43	52	15	1	16	24	93	117	69	172	241
18-	11	14	25	23	27	50	14	41	55	12	12	24	25	63	88	85	157	242
25-	9	23	32	19	42	61	9	58	67	5	21	26	12	100	112	54	244	298
2- Aug.	0	18	18	0	20	20	8	30	38	24	10	34	20	84	104	52	162	214
14-	0	6	6	0	21	21	0	58	58	0	70	70	0	75	75	0	230	230
22-	0	10	10	0	25	25	0	28	28	0	50	50	0	61	61	0	176	176

APPENDIX III. Field estimated numbers of eggs (E) and larvae (L) of <u>F. pusilia</u> in 50 marked leaves in each of 5 crown regions (i-v) in Tree 3 (Mountain White Birch) at Pasadena Forest Nursery in 1972 (Non-Destructive Sample Table).

Date	Crown Regions															Total for all regions per 250 leaves		
	i			ii			iii			iv			v					
	E	L	E+L	E	L	E+L	E	L	E+L	E	L	E+L	E	L	E+L	E	L	E+L
7- June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-	15	0	15	20	0	20	22	0	22	32	3	35	35	9	40	124	8	132
28-	0	70	70	57	225	282	10	215	225	100	265	365	405	502	907	572	1277	1849
4- July	0	75	75	62	236	298	17	145	162	165	272	437	42	582	624	286	1310	1596
7-	0	80	80	95	232	237	7	185	192	47	277	324	75	750	825	224	1524	1748
11-	0	50	50	0	22	22	0	80	80	0	87	87	52	80	132	52	319	371
28-	10	0	10	182	122	304	35	75	110	100	117	217	137	22	159	464	336	800
1- Aug.	32	0	32	252	220	427	67	62	129	162	237	399	625	65	490	938	584	1522
9-	0	37	37	202	380	582	60	137	197	295	617	912	612	567	1179	1169	1738	2907
22-	62	137	199	185	425	610	77	202	279	212	757	999	685	640	1325	1251	2161	3412

APPENDIX IV. The percentages of marked leaves in 5 crown regions (i-v) of Tree 2 that were infested with F. pusilla in 1972.

Date	Crown Regions				
	i	ii	iii	iv	v
28- June	12	10	10	8	32
5- July	14	14	16	4	42
7-	18	12	16	4	42
12-	10	12	18	2	32
25-	14	28	26	18	54
2- Aug.	10	11	27	4	46
14-	5	13	22	18	45
22	4	7	20	17	31
*Average Rank Value	4	3	2	5	1

*See Table XV, p. 51.

APPENDIX V. The percentages of marked leaves in 5 crown regions (i-v) of Tree 3 that were infested with <u>F. pusilla</u> in 1972.

Date	Crown Regions				
	i	ii	iii	iv	v
7- June	0	0	0	0	0
18-	9	6	7	11	12
20-	17	23	14	53	41
24-	55	60	65	65	55
28-	70	80	90	80	100
4- July	100	75	90	100	95
7-	70	100	90	95	100
11-	55	95	90	100	100
28-	5	70	40	80	60
1- Aug.	10	70	45	90	80
9-	10	75	45	95	95
22-	30	80	60	95	100
*Average Rank Value	5	3	4	1	2

*See Table XV, p. 51.

APPENDIX VI. Numbers of larvae (all instars) of F. pusilla causing total destruction of the photosynthetic tissue of 10 birch leaves in each of 14 different length classes (Data used for regression analysis, p. 56)

Leaf length classes (mm)	Numbers of larvae in leaf no.									
	1	2	3	4	5	6	7	8	9	10
16-20	1	1	1	1	2	2	2	3	3	4
21-25	1	2	2	3	3	3	4	4	5	6
26-30	2	2	3	3	3	4	4	5	6	7
31-35	1	3	3	3	3	4	6	8	11	12
36-40	3	3	5	5	5	5	7	8	11	14
41-45	3	3	3	3	3	4	4	5	8	12
46-50	4	4	5	5	5	5	6	8	10	11
51-55	4	4	4	5	5	5	6	8	8	20
56-60	5	5	5	6	6	7	10	11	11	12
61-65	4	6	6	7	7	8	9	9	12	12
66-70	5	6	7	9	10	11	11	12	12	14
71-75	4	5	7	9	10	11	12	14	15	17
76-80	5	8	9	10	10	12	13	14	17	20
81-85	9	10	12	12	12	15	16	17	18	23

Number of leaf classes = 14, N = 140, r = 0.746, F = 173.471**,

b = 49.902.

(See page 54, and Table XIX, page 56.)