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J.A. Drouin and H.R. Wong

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ABSTRACT

Three species of birch leaf-mining sawflies, *Fenusa pusilla* (Lepeletier), *Profenusa thomsoni* (Konow), and *Heterarthrus nemoratus* (Fallen), have spread into Alberta from eastern North America, causing moderate-to-severe damage to birches. The relationships between these species feeding on the same host were studied during 1977-79. Adults of *F. pusilla* are the first to oviposit in young tender leaves, followed later in the season by *P. thomsoni* and *H. nemoratus*, both of which lay their eggs in more mature leaves. The upper crown is more heavily attacked by *F. pusilla* and *H. nemoratus*, while *P. thomsoni* appear to prefer the lower crown, and their relative abundance varies from year to year. *F. pusilla* occasionally produce a partial second generation. Three methods were used in testing 17 insecticides in 63 field efficacy tests. The soil drench technique is more effective than bark painting or foliar spray for controlling these insects.

RESUME

Trois espèces de tenthrèdes attaquant les feuilles du bouleau, *Fenusa pusilla* (Lepeletier), *Profenusa thomsoni* (Konow) et *Heterarthrus nemoratus* (Fallen), se sont répandues de l'est de l'Amérique du Nord jusqu'en Alberta, y infligeant des dommages modérés à graves aux bouleaux. Les relations entre les trois espèces qui se nourrissent aux dépens du même hôte ont été étudiées de 1977 à 1979. *F. pusilla* dépose ses oeufs en premier dans les jeunes feuilles tendres, puis, plus tard dans la saison, *P. thomsoni* et *H. nemoratus* pondent les leurs dans les feuilles plus matures. *F. pusilla* et *H. nemoratus* attaquent plus fortement la partie supérieure du houppier, tandis que *P. thomsoni* semble préférer la partie basse; l'abondance relative des trois espèces varie d'une année à l'autre. *F. pusilla* produit parfois une seconde génération partielle. Soixante-trois essais ont été effectués pour evaluer l'efficacité sur le terrain de 17 insecticides avec trois méthodes. La technique d'imbibiton du sol s'est révélée plus efficace que le badigeonnage de l'écorce et la pulvérisation sur le feuillage contre ces insectes.

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INTRODUCTION

The three species of birch leaf-mining sawflies causing serious damage to native and introduced birches in Canada were first described in Europe and apparently accidentally introduced into North America (Smith 1971). The birch leaf miner, *Fenusa pusilla* (Lepeletier), was first recorded in Connecticut in 1923 (Britton 1924). The leaf-mining sawfly, *Profenusa thomsoni* (Konow), was initially confused with the birch leaf miner, but infestations of this sawfly have occurred in Ontario since its recognition in 1948 (Martin 1960). The birch leaf-mining sawfly, *Heterarthrus nemoratus* (Fallen), was first reported from Pictou, Nova Scotia, in 1908 (Glasgow 1932). These three species of birch leaf miners can be identified by using Lindquist's (1959) key to the larvae and Smith's (1971) key to the larvae and adults. No collections of these sawflies were recorded for Saskatchewan or Alberta by Smith (1971) in his study of the subfamily Heterarthrinae, to which these three species belong, although unsightly brown birch leaves mined by the larvae of these sawflies were very evident in Alberta 12 years ago. The prevalence in recent years of continued moderate-to-severe damage to birches in urban plantings has caused some homeowners to remove birches from their property or to plant other tree species.

Because the three species may attack the same leaf, studies were undertaken to determine the relationship betweeen the species and methods to control them.

METHODS AND MATERIALS

The life history and seasonal occurrence of birch leaf-mining sawflies were studied at Looma and Winterburn. Two 45-cm branches were selected at random from both the upper and lower crowns of five trees in treated and control plots from late May to mid-September as outlined by Drouin and Kusch (1977, 1978, 1979). The leaves of these branches were examined, and the life histories, seasonal occurrence, and spatial distribution of the three species of sawflies were determined.

Insecticides were applied by three methods in two types of plots. Foliar sprays were used in 0.02 to 0.04 ha plots, and soil drenches and bark painting were used in plots containing five trees each, the trees averaging about 5 m high and 7.5 cm basal diameter. The foliar sprays were applied with a spreader/sticker (Atplus 526 at 0.5 mL/L) from early to mid-July at the rate of 9.1 L per plot and a concentration of 2.1 mL or g active ingredient (a.i.) per litre. Soil drenches were applied in late May at 4.6-5.6 mL or g a.i./cm basal diameter to four small, shallow holes dug around the base of the tree inside the drip line. The holes were filled with soil and watered until saturated to ensure uptake of the insecticide. The stems of birches 2.5-15.0 cm in diameter measured at 1.2 m above the ground were painted with a band of insecticide in May. For every 2.5 cm of tree diameter, a corresponding 2.5-cm wide band was painted around all stems. The stems were again painted at these widths in mid-June and mid-July.

Percentage control estimates were determined by applying Abbott's (1925) formula to data obtained from the branch sampling. Counts of living and dead larvae of all species were combined in the analysis.

LIFE HISTORIES

The examination of thousands of birch leaves from early May to late August in the study plots showed that the life histories of the three birch leaf miners in Alberta were similar to those reported for *F. pusilla* (Cheng and Leroux 1965), *P. thomsoni* (Martin 1960), and *H. nemoratus* (Goebeil 1937) in eastern Canada. In Alberta, adults of *F. pusilla* (Fig. 1) are active from late May to early June. The number of eggs per leaf varies from 2 to 20 in slits near the midrib in the upper surface of young tender leaves (Fig. 2). The eggs hatch in 4-10 days (average 8) (Fig. 3). Young leaves growing near the top and periphery of the upper half of the tree crown (Fig. 4) are preferred. The larvae mine the leaf from the outer leaf margin toward the midrib (Fig. 5). The mature larvae (Fig. 6) emerge from the leaf in July and drop to the ground to pupate. Two weeks later the adults

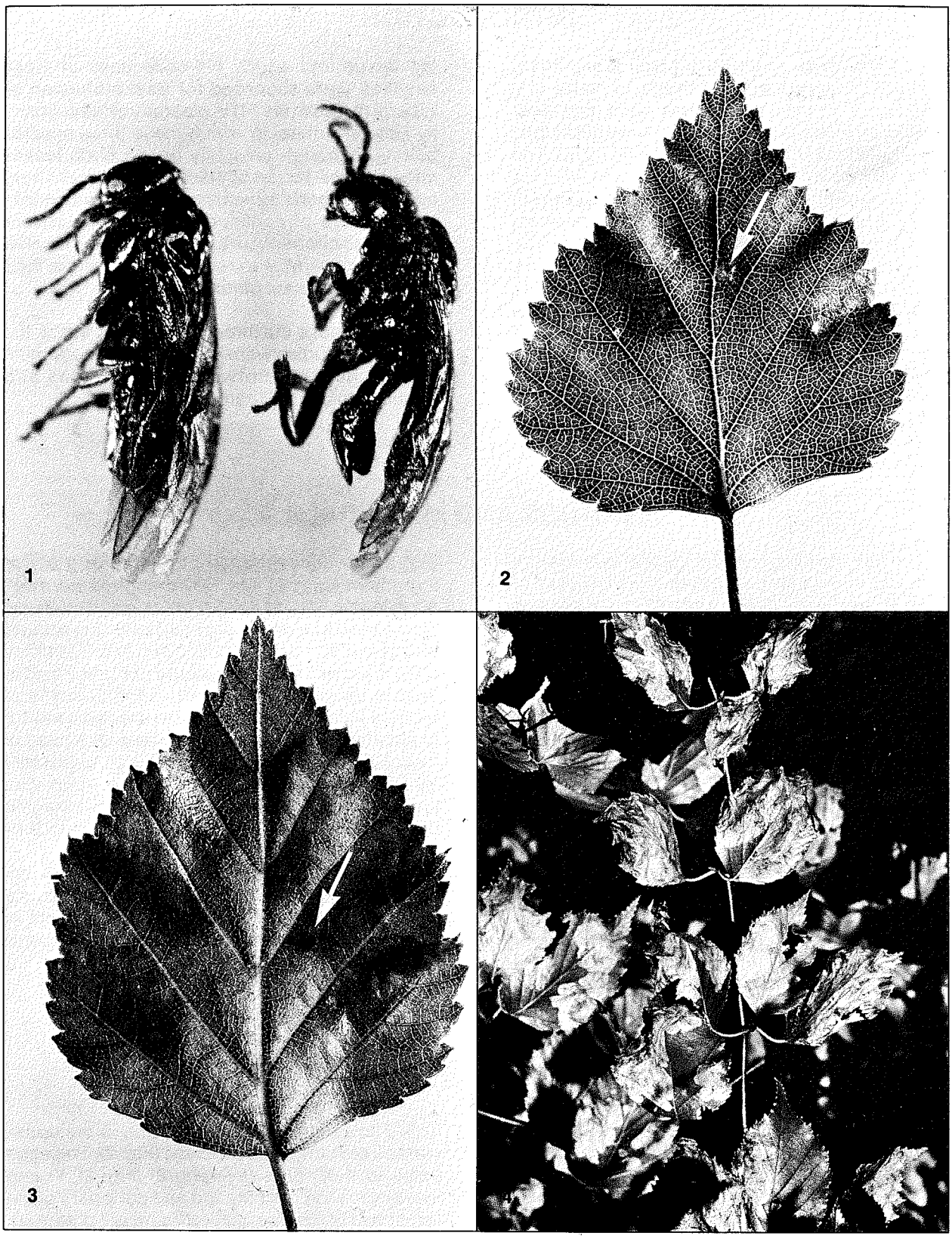

Figure 1. ***F. pusilla*** **female and male adults. Figure 2.** ***F. pusilla*** **eggs at upper central portion of the leaf. Figure 3.** ***F. pusilla*** **newly hatched eggs with some feeding damage. Figure 4.** ***F. pusilla*** **feeding damage in new leaves in upper crown.**

emerge. Larvae of the second generation are found in some years in late August to early September. In favorable years, a third generation has been found in eastern Canada (Daviault 1937), but not in Alberta. The birch leaf miner overwinters as a full-grown larva in a small earthen cell in the ground.

Unlike *F. pusilla*, both *P. thomsoni* and *H. nemoratus* have only one generation a year; they are parthenogenetic, and females oviposit on mature leaves. Adults of *P. thomsoni* (Fig. 7) were abundant by early July. From 1 to over 100 eggs (average of 9 eggs) per leaf are oviposited in slits made by the female along veins in the basal and central area of the upper leaf surface (Fig. 8). Larvae (Fig. 9) mine the leaf toward the edge (Fig. 10), and the feeding areas coalesce with those made by other larvae of the same species to form a large patch containing two to seven larvae (Fig. 11). They do not merge with mines produced by larvae of *F. pusilla* or *H. nemoratus* (Fig. 12). Each mature larva emerges from the leaf from mid-August to early October to overwinter within an earthen cell beneath the soil surface.

Adults of *H. nemoratus* (Fig. 13) were present in the field from mid-May to late June. The female cuts three to five slits in the leaf margin and deposits a single egg in each (Fig. 14). The target-like feeding area for each larva turns dark brown. Larvae mine the leaf from the edge toward the midrib (Fig. 15). The mature larvae (Fig. 16) overwinter and pupate in the fallen leaves on the ground (Fig. 15).

SEASONAL LARVAL OCCURRENCE OF THE THREE SAWFLY SPECIES

Although all three species of sawflies can cause extensive damage to birch leaves, their numbers vary each year. The females of first *F. pusilla* and then *P. thomsoni* and *H. nemoratus* oviposit in the leaves of birch. *F. pusilla* oviposits mostly on young, tender leaves, while the other two species oviposit on mature leaves. In 1977 *P. thomsoni* was the most abundant species in the upper and lower crown (Fig. 17). In 1978 it was more abundant than the other two species only in the lower crown (Fig. 18), and it continued to decline in 1979 (Fig. 19). *F. pusilla* showed a gradual increase from 1977 to 1979, and the highest populations occurred in the upper and lower crowns. A partial second generation was apparent in 1977 in the lower crown (Fig. 17) but was absent in upper and lower crowns in 1978 (Fig. 18). In 1979, sampling for *F. pusilla* was conducted only from early July to early September to determine the presence of a second generation. In that year both crowns had a partial second generation (Fig. 19). Populations of *H. nemoratus* did not exceed those of either *F. pusilla* or *P. thomsoni* in the 3 years studied but showed a gradual increase, and it was the second most abundant species in 1978 and 1979.

A chi-square test of the percentage of mined leaves in samples from the upper and lower crowns for each species for each year showed highly significant differences (Table 1). Both *F. pusilla* and *H. nemoratus* had consistently higher attack rates in the upper crowns in all 3 years. Jones and Raske (1976) also noted that the highest percent of leaf attack by *F. pusilla* occurred at the upper crown. *P. thomsoni* attacked the lower crown heavily in 1977 and 1978 but not in 1979. This reversal of trend in 1979 may be the result of a much smaller sample size (Table 1). Martin (1960), however, indicated that the largest numbers of larvae of *P. thomsoni* were concentrated in the upper crown of the trees in Ontario.

The study results reported here agree with those obtained by Martin (1960) in that damage to birches growing in the shade and to those in the open was the same and was not restricted to one side of the crown in light-to-moderate infestations. Heavy damage to foliage was also recorded on water birch (*Betula occidentalis* Hook) by *F. pusilla* and *P. thomsoni* in 1977-79, but few *H. nemoratus* were noted. When the temperature and precipitation for the months of April to October are compared with the populations of the three species during 1977-79, only *F. pusilla* populations fluctuated slightly. Parasite populations were very low, and only 30 specimens were recorded during the 3-year study. Further studies are under consideration to determine parasite species and abundance.

CONTROL

Numerous insecticides have been tested in an effort to control birch leaf-mining sawflies (Table 2). The resulting data, obtained during three seasons, were reported earlier (Drouin and

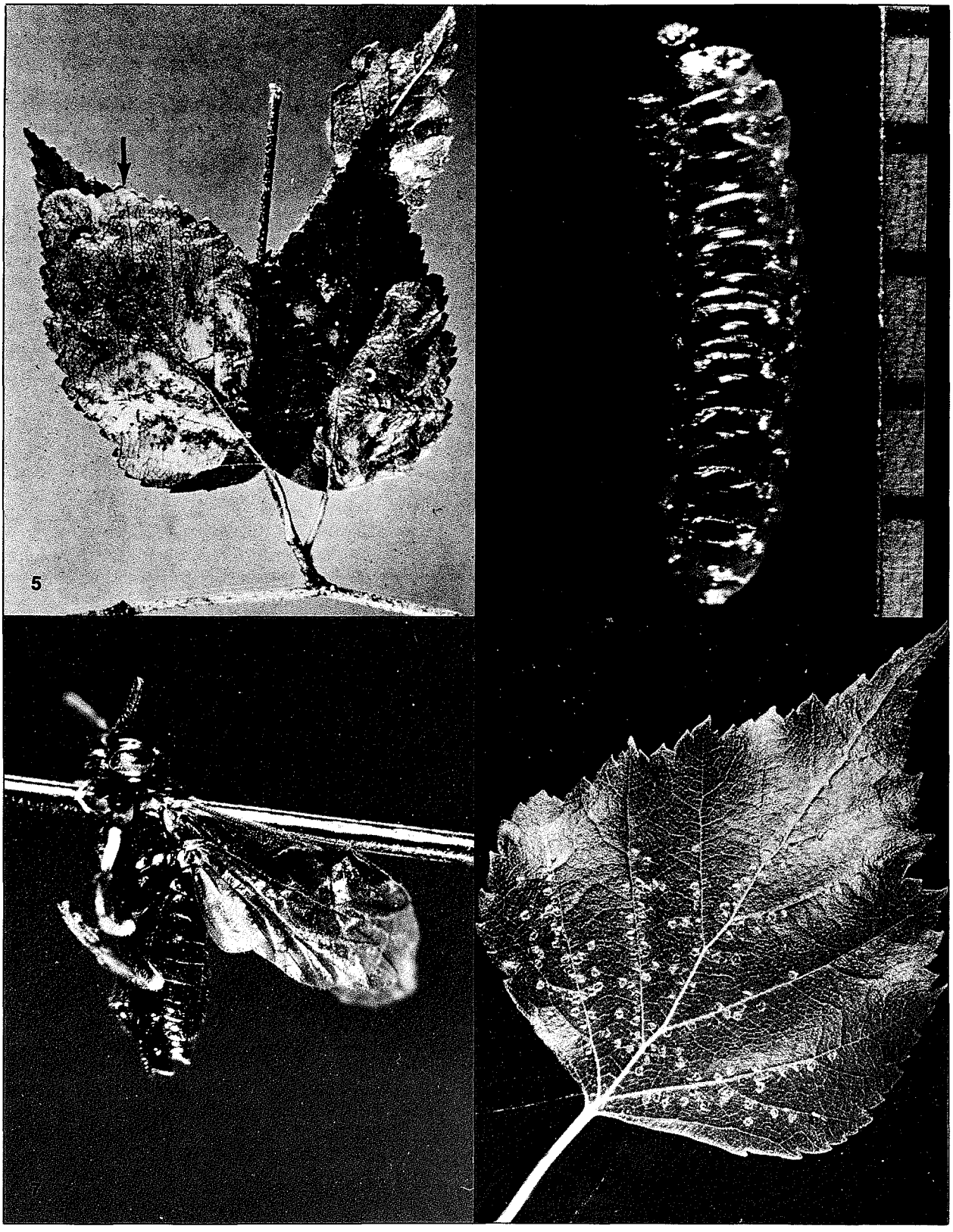

Figure 5. *F. pusilla* feeding damage from leaf margin toward midrib. Figure 6. *F. pusilla* mature larva. Figure 7. *P. thomsoni* female adult. Figure 8. *P. thomsoni* eggs in lower portion of the leaf.

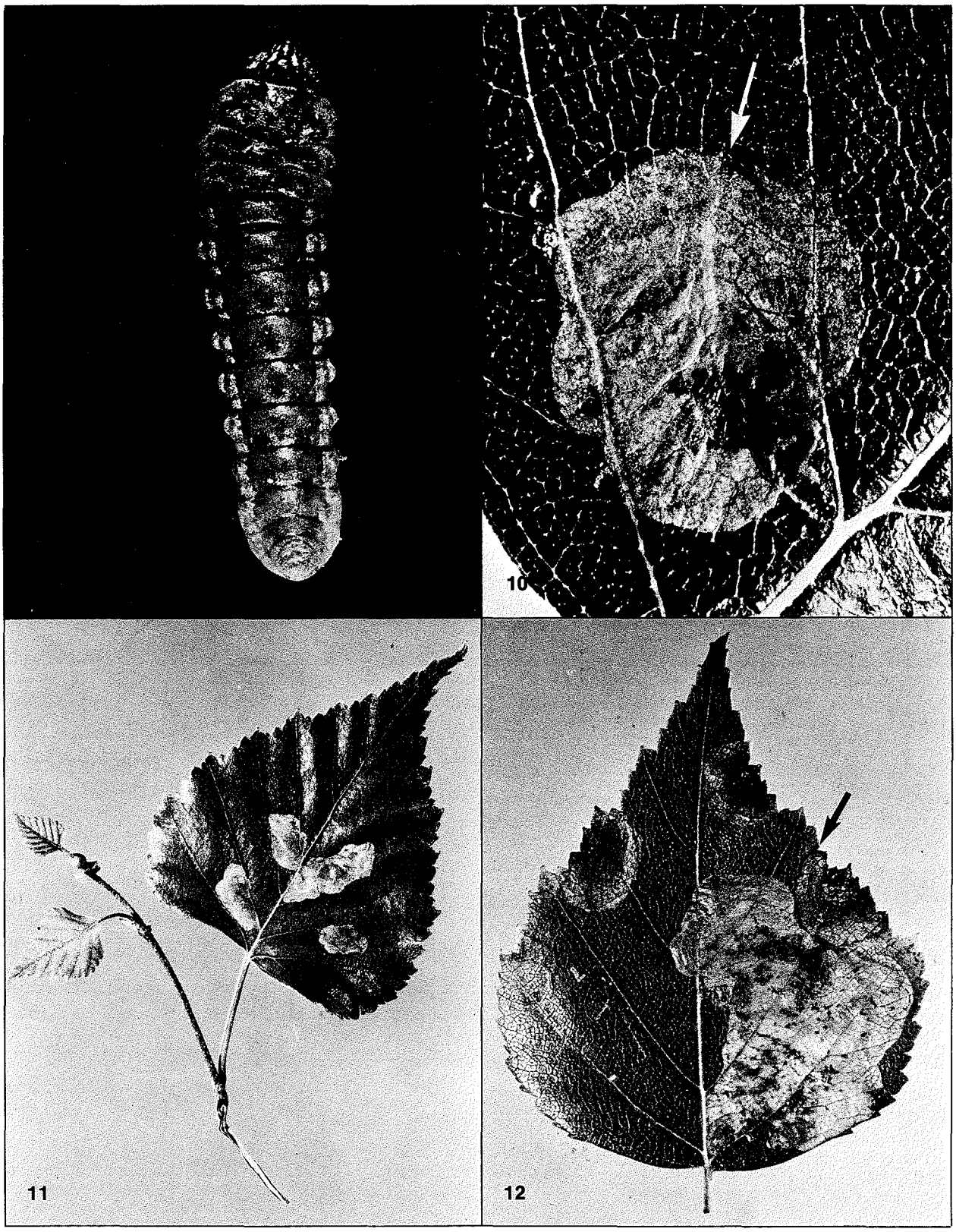

Figure 9. ***P. thomsoni*** **mature larva. Figure 10.** ***P. thomsoni*** **mine toward the edge. Figure 11.** ***P. thomsoni*** **feeding areas coalesce. Figure 12.** ***P. thomsoni*** **and** ***H. nemoratus*** **feeding damage—note the separation between the two species.**

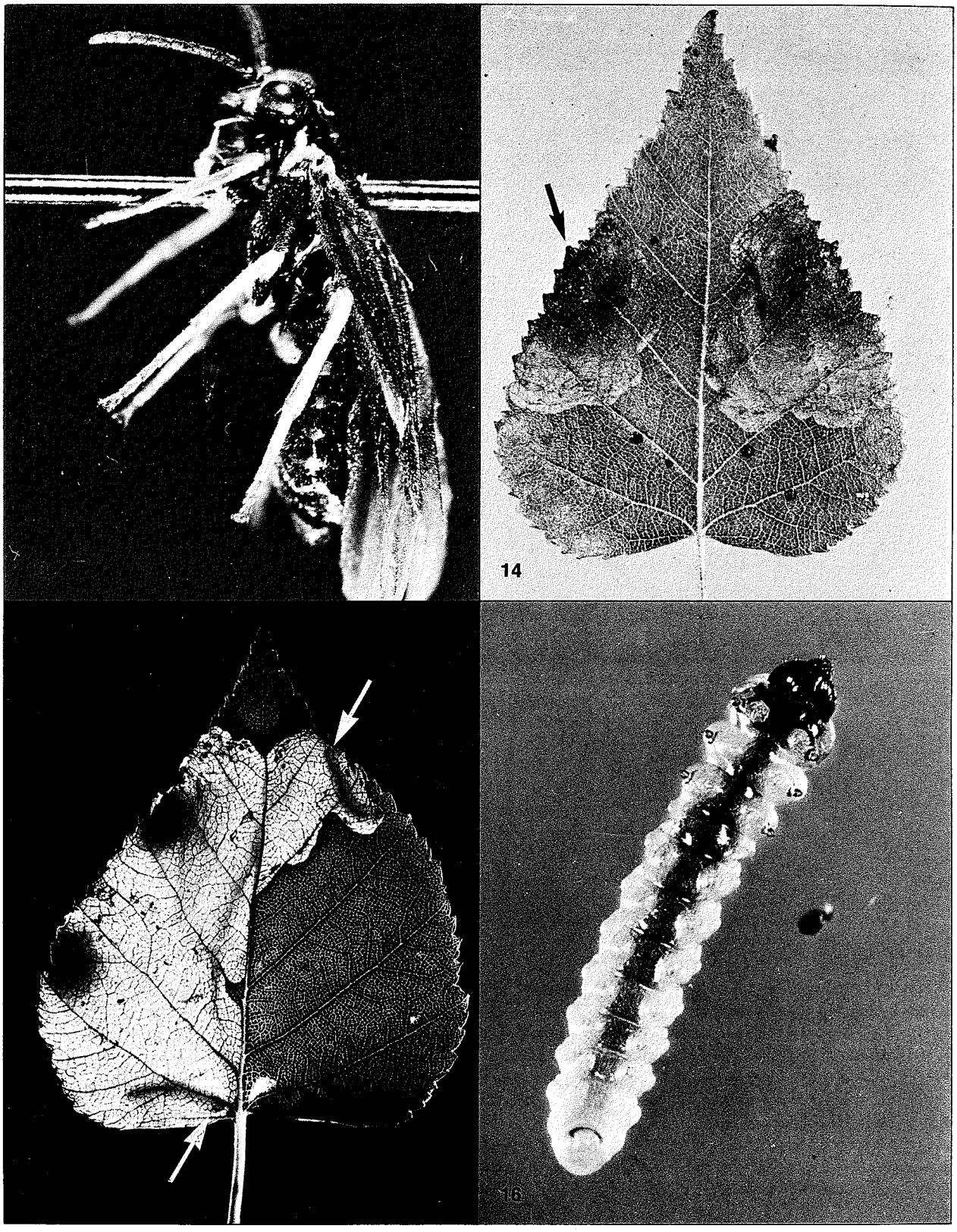

Figure 13. ***H. nemoratus*** **adult. Figure 14.** ***H. nemoratus*** **egg at the edge of the leaf. Figure 15.** ***H. nemoratus*** **mine the leaf from the edge toward the midrib. Figure 16.** ***H. nemoratus*** **mature larva.**

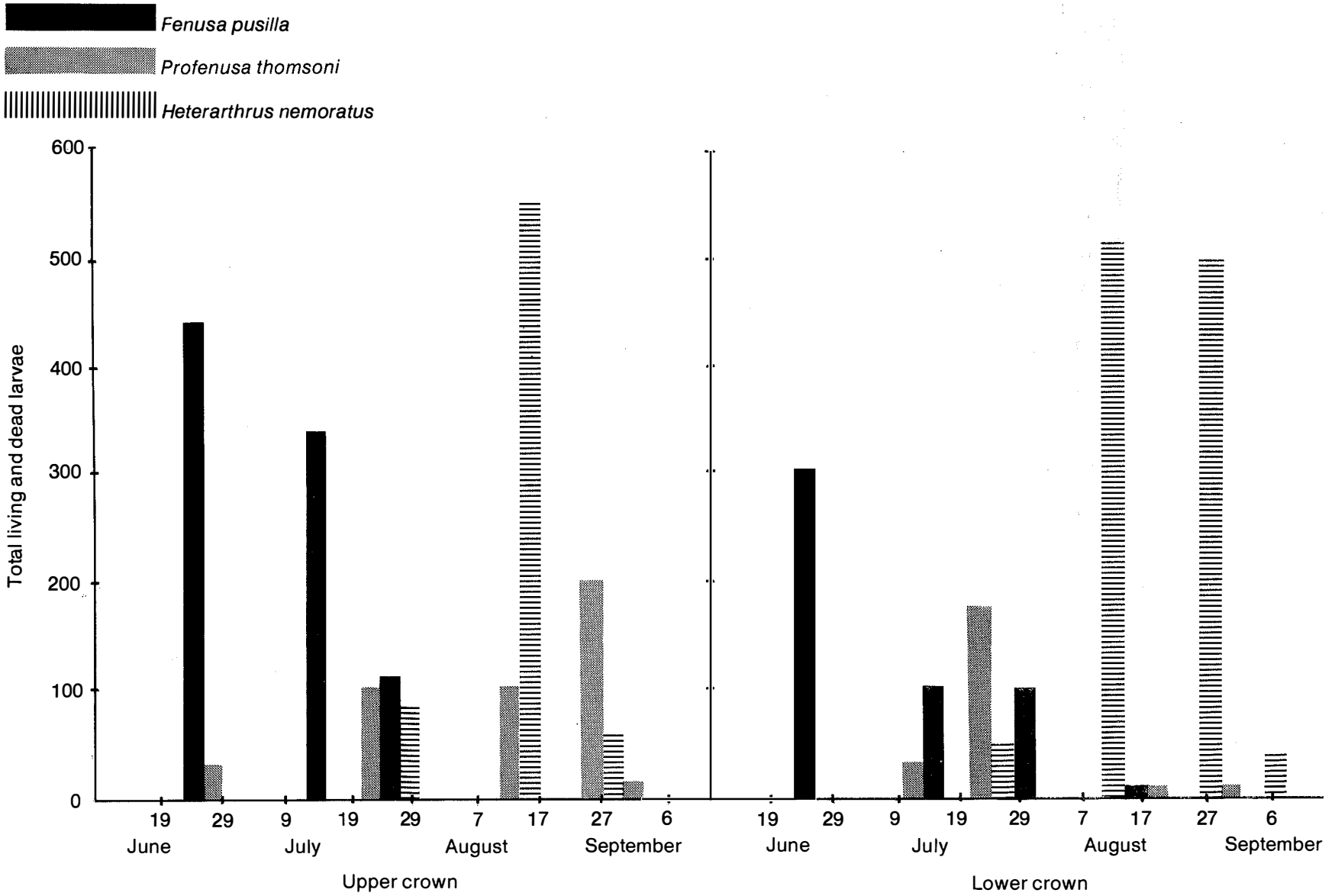

Figure 17. Relative abundance in 1977 of three species of birch leaf-mining sawflies in upper and lower crowns of white birch from 10 branch samples of five trees.

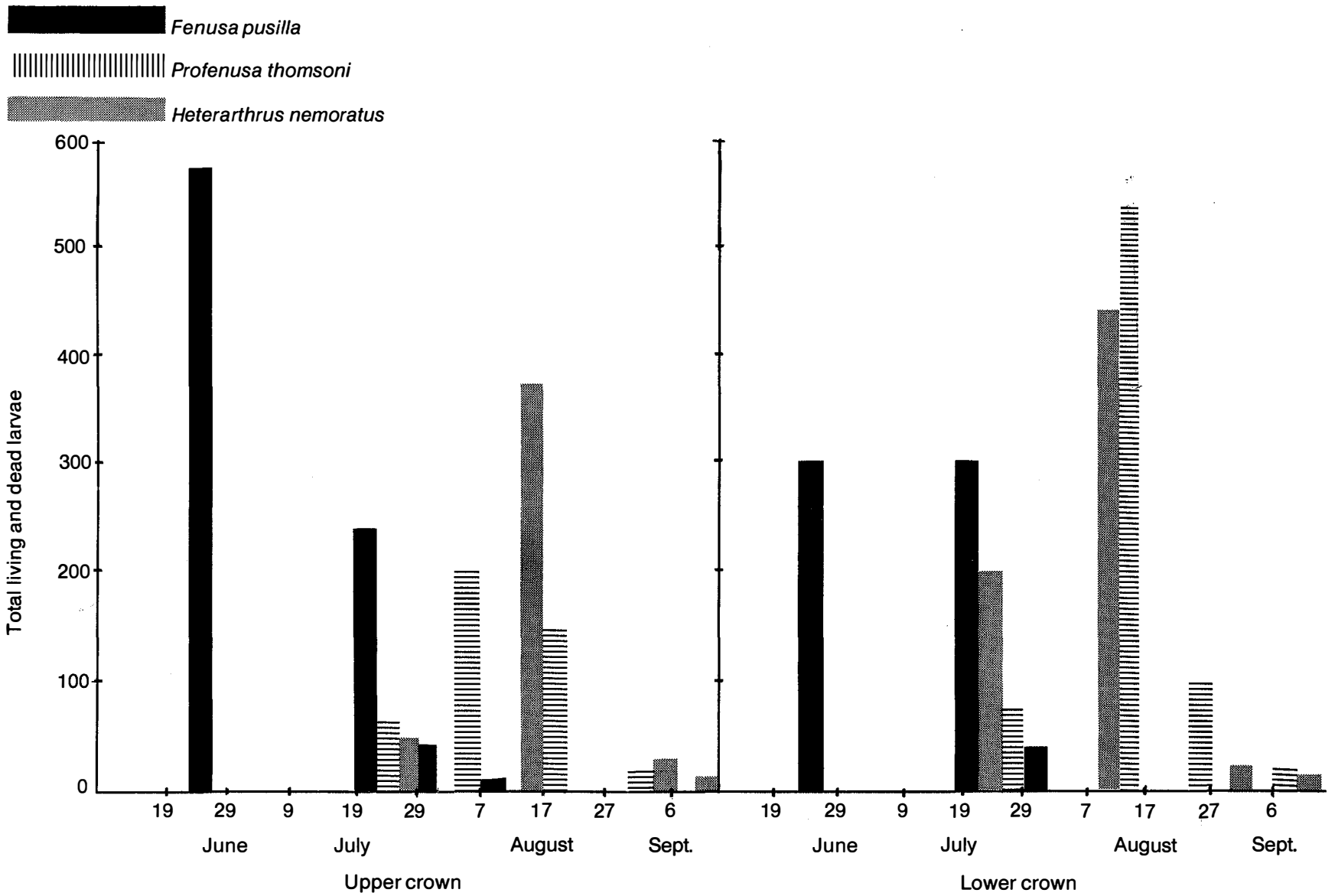

Figure 18. Relative abundance in 1978 of three species of birch leaf-mining sawflies in upper and lower crowns of white birch from 10 branch samples of five trees.

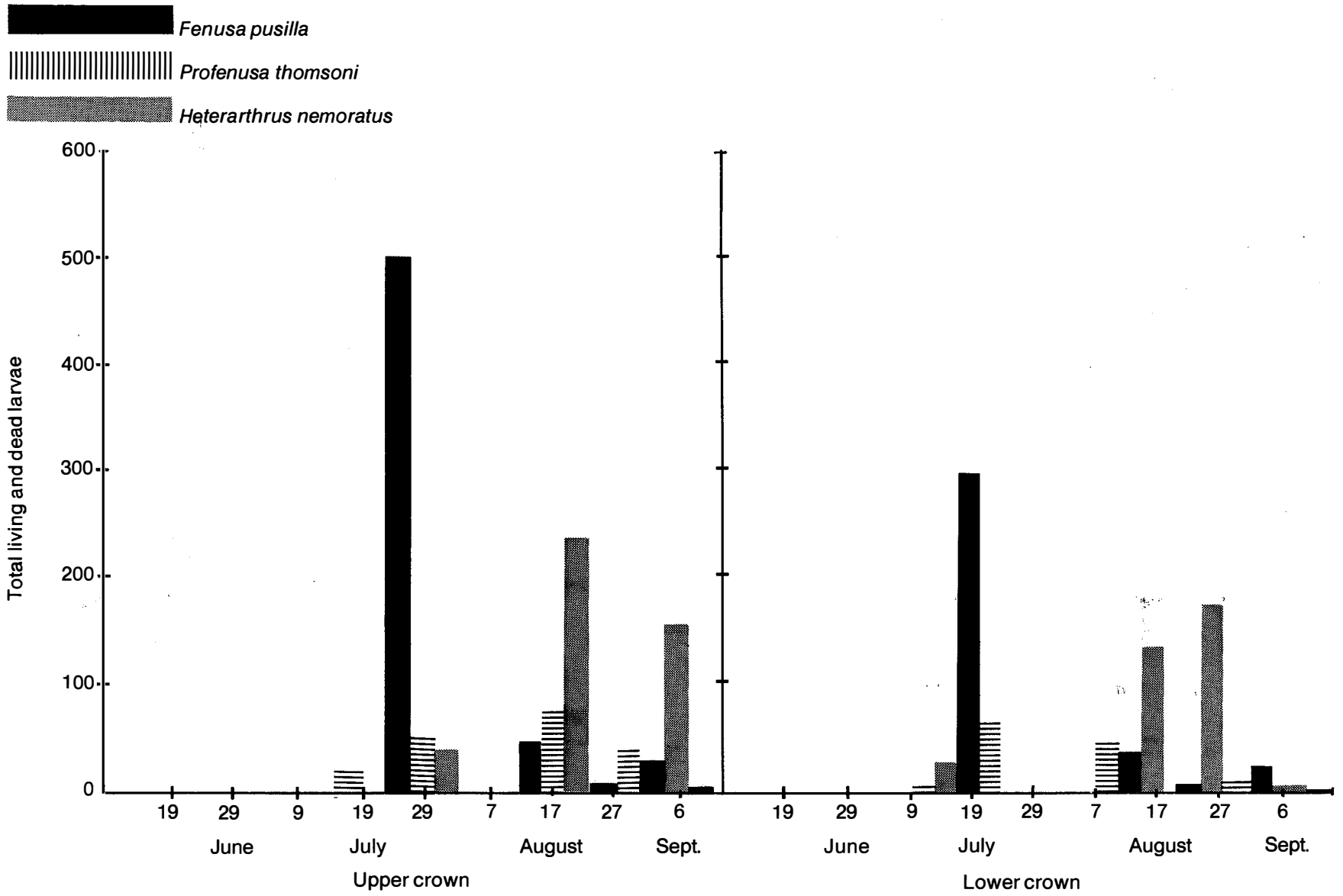

Figure 19. Relative abundance in 1979 of three species of birch leaf-mining sawflies in upper and lower crowns of white birch from 10 branch samples of five trees.

Table 1. Incidence and location of infestation for three species of birch leaf miners, 1977-79

	1977		1978		1979	
	Upper crown	Lower crown	Upper crown	Lower crown	Upper crown	Lower crown
Total leaves examined	21 876	22 188	22 240	24 472	8 393	10 440
Infested *F. pusilla* leaves						
No. leaves examined	3 263	2 526	5 028	2 434	1 047	596
Percent of total	14.9	11.4	22.6	10.0	12.5	5.7
Chi-square	120.4**		1 391.7**		267.5**	
Infested *P. thomsoni* leaves						
No. leaves examined	1 743	2 757	1 484	2 668	248	199
Percent of total	8.0	12.4	6.7	10.9	3.0	1.9
Chi-square	238.7**		257.4**		22.1**	
Infested *H. nemoratus* leaves						
No. leaves examined	661	502	4 743	2 145	890	683
Percent of total	3.0	2.3	21.3	8.8	10.6	6.5
Chi-square	24.7**		1 462.4**		100.3**	
Infested total leaves						
No. leaves examined	5 246	4 686	8 306	6 070	3 570	1 774
Percent of total	24.0	21.0	37.4	24.8	42.5	17.0
Chi-square	51.6**		860.5**		1 493.6**	

**Statistically significant at the 0.005 level.

Table 2. Insecticidal field tests on birch leaf-mining sawflies during 1977-79 near Edmonton, Alberta

Insecticide	Type of application[a]	Dosage (mL/L or g/L)	% leaves attacked			% control		
			1977	1978	1979	1977	1978	1979
Acephate	MB	1.5	28	27	-	89	94	-
Acephate	SD	5.6	11	0	25	34	100	100
Aldicarb	SD	4.5	11	0	-	100	100	-
Carbofuran	SD	4.5	13	21	-	100	100	-
Carbaryl	MB	1.5	17	39	-	90	68	-
Diazinon	MB	1.5	56	16	23	90	30	80
Diazinon	SD	5.6	25	49	-	0	18	-
Dimethoate	SD	5.6	26	0	-	100	100	-
Dimethoate	BP	-	19	0	-	100	100	-
Dimethoate	MB	1.5	23	3	-	90	95	-
Fenvalerate	MB	0.2	13	13	24	2	84	82
Fosthietan	SD	5.6	4	0	-	100	100	-
Fosthietan	BP	-	-	33	-	97	47	-
Fosthietan	MB	1.5	-	40	-	-	87	-
Malathion	MB	1.5	23	-	-	90	81	-
Methidathion	MB	1.5	29	53	-	90	88	-
Methidathion	SD	5.1	19	24	-	51	0	-
Oxydemeton-methyl	BP	-	35	-	-	100	100	-
Oxydemeton-methyl	MB	1.5	27	-	-	89	-	-
Oxydemeton-methyl	SD	5.6	11	-	-	61	-	-
Oxydemeton-methyl + trichlorfon	BP	-	-	0	-	-	100	-
Oxydemeton-methyl + trichlorfon	MB	1.5	-	15	34	-	54	100
Oxydemeton-methyl + trichlorfon	SD	5.1	-	21	30	-	96	100
Oxamyl	SD	5.6	11	31	-	100	30	-
Oxamyl	MB	3.1	25	49	26	90	16	68
Permethrin	MB	1.5	24	35	22	37	78	100
Phosphamidon	SD	5.6	20	27	-	100	92	-
Phosphamidon	MB	1.5	32	25	-	89	100	-
Phosphamidon	BP	-	13	17	-	98	96	-
Propoxur	SD	5.6	13	0	-	100	99	-
Propoxur	MB	1.5	13	8	-	90	100	-
Thiofanox	SD	4.5	-	0	5	-	100	100
Controls	-	-	56	48	44	-	-	-

[a] MB = mist blower; SD = soil drench; BP = bark paint applied 1.2 m above ground, width depending on basal diameter and active ingredient of product (e.g., 2.5-cm band/2.5-cm basal diameter for 50% emulsifiable concentrate.

Kusch 1977, 1978, 1979) but are combined here into one table for easy reference. The use of some of the insecticides listed in Table 2 is currently under review. Acephate, carbofuran, and oxydemeton-methyl require special labelling; the phosphamidon registration has been cancelled. The status of these and other insecticides may change again as the review proceeds.

In 1977, 26 tests were applied: 12 foliar sprays applied with a backpack mist blower; 11 soil drenches; and 3 bark paint treatments with 15 insecticides. Acephate, diazinon, methidathion and oxydemeton-methyl, dimethoate, phosphamidon, carbofuran, oxamyl, and propoxur all gave good results in either soil drench, foliar spray, or bark paint. Permethrin and fenvalerate gave fair results only when applied as foliar spray. Trace phytotoxicity occurred in some plots but was confined to a few branches in the lower crown.

Twenty-nine tests were applied in 1978: 13 foliar sprays; 12 soil drenches; and 4 bark paint treatments using 16 insecticides. Most chemicals tested in 1978, including oxydemeton-methyl + trichlorfon, thiofanox, and fosthietan, gave good results. Results with diazinon, carbaryl, and oxamyl were lower in 1978, because foliar application rates were reduced by half the dosage.

In 1979, eight tests were evaluated, consisting of 5 foliar sprays and 3 soil drenches. Results of the soil drenches were similar to those previously reported. The soil method is more effective than the foliar spray or the painting of a band of undiluted dimethoate around the trunk below the branches as soon as the leaves are fully opened. Only one soil treatment is usually necessary to control all species in one year; the banding method requires at least two applications. The soil drench method also does not injure the cambium or decrease in efficacy if the infestation persists for many years.

The best controls were obtained when, in late May after the leaves were fully opened, undiluted dimethoate 23.4% emulsifiable concentrate was applied at the rate of 50 mL for each 2.5 cm of tree stem diameter measured 1.2 m above ground (Drouin and Kusch 1977, 1978, 1979). The solution was applied at the base of the infested tree as directed. One soil treatment is usually sufficient to control all three species in one season. This control has the added advantage of eliminating spray drift and subsequent chlorosis of nearby plants. This method also kills the developing eggs within the leaves, and any residual leaf-mining insects in the soil. Excessive insecticide must not be applied, or damage will result. After application of the insecticide, the base of the tree must be watered thoroughly until the soil and root mass is saturated. This is most important to obtain good control. Soil drenches on newly transplanted trees should be avoided as they may not be effective or may cause injury, depending on the state of the root system.

Painting a band of undiluted dimethoate (Cygon 2E) around the trunk below the branches when the leaves are fully opened (late May) is the most widely used method. The chemical is absorbed into the plant and carried up into the leaves. This treatment is not used on trees less than 2.5 cm or more than 15 cm in diameter or on newly transplanted birch trees because injury may result. The application is repeated in early July, but the insecticide should not be painted on the same band area as earlier.

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