Parasite Studies in Two Residual Spruce Budworm (*Choristoneura fumiferana* (Clem.)) Outbreaks in Quebec[1]

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Abstract *Canad. Ent.* 97: 129-136 (1965)

Parasite studies were carried out in two residual spruce budworm outbreaks in Quebec. Investigations were conducted during the last three years of the outbreak in the Lower St. Lawrence region and during the last year of the one in the Saguenay region. In the Lower St. Lawrence region decline of the insect population was initiated through aerial application of DDT over a period of three years, while in the Saguenay region the unfavourable condition of the forest stands apparently kept budworm numbers below peak outbreak levels. The incidence of mortality through the action of parasites was very high during the last year of both of these outbreaks and probably contributed to bringing about their collapse. *Meteorus trachynotus* Vier. has repeatedly been recovered in abundance during the last year of a number of budworm outbreaks and it was amongst the important parasites recovered in both outbreaks under discussion. Other species, however, that were abundant in one or the other of these two outbreaks had not been recovered in numbers before. The parasite complex and the relative abundance of each parasite species during budworm outbreaks is fairly constant at the time of peak host populations, but it is now apparent that they vary considerably at the time of outbreak collapse. Variations in the presence and relative abundance of alternate hosts probably account for this situation.

Introduction

Two very extensive outbreaks of the spruce budworm, *Choristoneura fumiferana* (Clem.) that lasted several years in Quebec came to an end in 1958 (Blais and Martineau 1960; Blais 1964). The first of these occurred in the region of the Laurentide Park in central Quebec and the other in the Lower St. Lawrence and Gaspé regions of the Province. In both instances, a small area of infestation persisted for some years after the collapse of the main outbreak. The first of these residual outbreaks covered approximately 70 square miles just to the east of Lake Ha! Ha! in the Saguenay River region, and maintained this size in succeeding years. The second residual outbreak occurred in the Patapedia and Rimouski watersheds in the Lower St. Lawrence region; in 1959, it covered approximately 50 square miles but in the next few years spread to cover an area of some 300 square miles. Aerial spraying operations were carried out between 1960 and 1962 in an effort to control this second residual outbreak before it could extend to the vast pulpwood stands in the region (Blais 1963). Spruce budworm populations returned to endemic conditions in both areas in 1962; this was a coincidence since the outbreaks were quite distinct. In the Saguenay River region parasite investigations were carried out only during the last year of the event, while in the Lower St. Lawrence region investigations were conducted during the last three years of the outbreak.

Methods

Field collections of spruce budworms were made during the larval and pupal stages. Previous knowledge of parasite behaviour prompted the collection of material at the following times: peak of the fourth instar, peak of the sixth instar, and peak of the pupal stage. In the Saguenay River region host material was obtained from two plots about 8 miles apart. In the Lower St. Lawrence region collections were made from two plots 6 miles apart, in 1960. The following year these two plots were in an area scheduled for treatment and only the first samples could be taken before the insecticide was applied; the last two collections

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TABLE I

Average population per 18-inch branch tip for sprayed and unsprayed locations during the early larval stage (pre-spray) and the pupal stage (post-spray) and per cent reduction in population between the two surveys for 1960, 1961 and 1962

Year	Treatment	No. of locations	Av. no. of insects per 18-inch branch		Per cent reduction in population
			Early larval stage (pre-spray)	Pupal stage (post-spray)	
1960	Unsprayed	40	8.9	3.3	63
	Sprayed	27	18.2	0.6	97
1961	Unsprayed	30	1.4	0.1	93
	Sprayed	15	12.3	0.1	99
1962	Unsprayed	43	0.1	—	—
	Sprayed	27	2.4	0.0	100

were made in a nearby untreated area. In 1962, budworms were so scarce in the Lower St. Lawrence region that collections were made by hand picking the insects from branches at eye level from several localities. The number of individuals per collection varied between 200 and 500 except in the Lower St. Lawrence region in 1962 when no pupae were found after 10 hours of diligent searching (Blais 1963), and as a consequence, pupal parasitism could not be assessed. In the Lower St. Lawrence region material was always obtained outside the spray area. The data on parasitism therefore refer to unsprayed budworm populations although the effect of spraying was felt indirectly through the drastic reduction of nearby host populations. The host material was reared in the laboratory, and the parasites were handled in the same manner as described in a previous paper (Blais 1960).

In the Saguenay region, budworm populations were assessed by counting the number of insects on one eighteen-inch branch tip from the mid-crown of each of 20 mature balsam fir trees for each plot at each collection. In the Lower St. Lawrence region budworm populations were assessed for the area as a whole by making counts on one eighteen-inch branch tip from the mid-crown of each of five mature balsam fir trees from a large number of localities in both sprayed and unsprayed areas. The counts were made during the early larval stage and the late pupal stage. The egg population was sampled in August each year of study in both regions; the sequential sampling technique developed by Morris (1954) and perfected by Webb *et al.* (1958) was applied.

Apparent parasitism was calculated for each parasite species recovered and aggregate parasitism was calculated according to the method described by Blais (1960).

Results

Since the results differed little between plots within a region the data were pooled for each of the two regions. The average number of budworm per 18-inch branch tip for the first, second, and third collections in the Saguenay region was 6.0, 3.8, and 1.0 respectively. Table I gives the average population per 18-inch branch tip for sprayed and unsprayed areas during the early larval stage and the pupal stage and the per cent reduction in population between the two surveys for 1960, 1961 and 1962 in the Lower St. Lawrence region.

TABLE II
List of parasite species reared from spruce budworm in two residual outbreak areas in Quebec from 1960 to 1962

Hymenoptera

Braconidae:
- *Apanteles fumeferanae* Vier.
- *Meteorus trachynotus* Vier.

Ichneumonidae:
- *Apechthis ontario* (Cress.)
- *Exochus nigripalpis tectulum* Tow. and Tow.
- *Glypta fumiferanae* (Vier.)
- *Horogenes cacoeciae* (Vier.)
- *Horogenes* sp.
- *Itoplectis conquisitor* (Say)
- *Mesochorus sylvarum* Curt.
- *Phaeogenes hariolus* (Cress.)

Trichogrammatidae:
- *Trichogramma minutum* Riley

Pteromalidae:
- *Amblymerus verditer* (Nort.)
- *Psychophagus omnivorus* (Wlkr.)

Diptera

Tachynidae:
- *Actia interrupta* (Curr.)
- *Eumea caesar* (Ald.)
- *Lypha setifacies* (West.)
- *Madremya saundersii* (Will.)
- *Nemorilla pyste* (Wlk.)
- *Phryxe pecosensis* (Tns.)
- *Winthemia amoena* (Mg.)

Metopiidae:
- *Pseudosarcophaga affinis* (Fall.)
- *Sarcophaga aldrichi* Park.

In the Saguenay region, population density in 1962 was approximately five times lower than during the peak years of a budworm outbreak. Since the spruce budworm feeds almost exclusively on the current year's growth and since balsam fir foliage is retained on the branches from five to seven years, it is possible to determine past defoliation by carefully examining consecutive years of foliage growth. This was done in 15 localities scattered through the Saguenay outbreak area. Defoliation was generally more severe from 1959 to 1961 than in 1962, indicating that budworm populations had been higher before 1962.

In the Lower St. Lawrence region an attempt was made to spray as much of the infested area as possible each year; therefore, populations were higher in the localities in the areas scheduled for treatment than in those outside. In this region, the number of insects was highest in 1960, a noticeable reduction occurred in 1961, and by the spring of 1962, although still at epidemic level, populations were very low. In both regions, budworm populations had returned to endemic conditions by August 1962 as indicated by the egg surveys. No eggs were found in the 15 localities sampled in the Saguenay region nor in the 64 localities sampled in the Lower St. Lawrence region.

A total of 22 species of parasites was recovered in these studies (Table II). Fifteen species were common to the two regions: two species, *Horogenes* sp. and *Horogenes cacoeciae* (Vier.) were obtained only from the Saguenay region;

TABLE III
Apparent parasitism by the more common parasite species recovered from two study areas by years

Species	Study area	Apparent parasitism		
		1960	1961	1962
A. fumiferanae	S.[1]			3.8
	L. St. L.	6.1	7.8	7.5
G. fumiferanae	S.			1.8
	L. St. L.	3.2	7.3	2.5
M. trachynotus	S.			11.6
	L. St. L.	7.7	21.4	5.1
A. ontario	S.			15.2
	L. St. L.	2.1	14.9	—
A. interrupta	S.			0.8
	L. St. L.	0.2	2.0	32.0
E. caesar	S.			26.7
	L. St. L.	1.0	1.0	—
P. pecosensis	S.			6.5
	L. St. L.	0.2	1.5	—
L. setifacies	S.			9.2
	L. St. L.	2.3	1.3	2.9
S. aldrichi	S.			10.4
	L. St. L.	1.2	6.0	—

[1]S = Saguenay
L. St. L. = Lower St. Lawrence

whereas five species, *Exochus nigripalpis tectulum* Tow. and Tow., *Amblymerus verditer* (Nort.), *Psycophagus omnivorus* (Wlkr.), *Pseudosarcophaga affinis* (Fall.), and *Trichogramma minutum* Riley were found only in the Lower St. Lawrence region. None of the species recovered in only one of the two regions was found in abundance. Apparent parasitism for the nine more abundant species (those that reached over 5% apparent parasitism during at least one of the years of study) is shown in Table III.

Hymenoptera

Apanteles fumiferanae Vier. and *Glypta fumiferanae* Vier. are the only two species that are univoltine and can definitely complete their life cycle in the budworm. Previous studies (Blais 1960; Miller 1963) indicated that parasitism by *A. fumiferanae* was relatively low during peak outbreak years and that it increased during the last year of the outbreak. The present data do not confirm this trend. In the Saguenay region, parasitism by *A. fumiferanae* was low during the last year of the outbreak, while in the Lower St. Lawrence region this parasite remained at a fairly constant level during the last three years of budworm attack. In other studies it has been found that parasitism by *G. fumiferanae* reached a peak of between 10 and 15% during the peak years of a budworm gradation and then declined (Miller 1963). This parasite species was rare during the year of collapse in both outbreaks under study; it had been somewhat more abundant in the Lower St. Lawrence in 1961, but not in 1960. *Meteorus trachynotus* Vier. although relatively rare during the peak years of budworm attack has repeatedly been observed to increase considerably at the time of outbreak collapse (Dowden and Carolin 1950; Jaynes and Drooz 1952; McGugan and Blais 1959; Blais 1960; Miller 1963). In 1962, in the Saguenay area apparent parasitism by this species was fourth in importance and reached 11.6%. In 1961,

TABLE IV

Aggregate parasitism for larvae and pupae and total aggregate parasitism for two regions for each year of study

Year	Study area	Aggregate parasitism[1]		
		Larvae	Pupae	Total
1960	L. St. L.[2]	22.4	7.2	29.6
1961	L. St. L.	38.2	19.8	58.0
1962	L. St. L.	55.2	—	—
	S.	59.1	25.7	84.8

[1]Calculated according to Blais (1960).
[2]L. St. L. = Lower St. Lawrence.
S. = Saguenay.

the year before collapse in the Lower St. Lawrence area, apparent parasitism by *M. trachynotus* showed a spectacular increase over that of 1960, and reached 21.4%, the highest of any species; in 1962, however, parasitism by this species dropped considerably. *Apechthis ontario* (Cress.) is known as a relatively rare parasite of the spruce budworm in Canada, yet apparent parasitism by this ichneumonid in 1961 reached 14.9% in the Lower St. Lawrence area, and 15.2% in 1962 in the Saguenay region making it one of the most important.

Diptera

Actia interrupta (Curr.), a parasite that emerges from sixth-instar larvae, has never been recorded as occurring in abundance in the numerous studies on parasites of the spruce budworm carried out in Canada and the United States. This species was rare in the Saguenay area and during the first two years of study in the Lower St. Lawrence area, but in 1962, apparent parasitism by *A. interrupta* in this region showed a very great increase and reached 32.0%, the highest of any recorded in these studies. *Eumea caesar* (Ald.), *Phryxe pecosensis* (Tns.), *Lypha setifacies* (West.) and *Sarcophaga aldrichi* Park. were abundant in the Saguenay region, especially *E. caesar* with an apparent parasitism of 26.7%. In 1960 and 1961, these parasites were relatively rare in the Lower St. Lawrence region, except perhaps *S. aldrichi* which was recovered in some numbers in 1961. Because of the collapse of the outbreak no pupae were collected from this region in 1962, and thus parasitism by *E. caesar*, *P. pecosensis* and *S. aldrichi* could not be determined.

Since parasitism was the only mortality factor measured, the proportion of the original population that died from the action of parasites cannot be calculated. However, aggregate percentage parasitism is a measure that has repeatedly been used in connection with spruce budworm parasite investigations (Dowden and Carolin 1950; Jaynes and Drooz 1952; McGugan and Blais 1959; Blais 1960) and it may serve as a basis for comparison. In eastern Canada, aggregate parasitism during the peak years of budworm outbreaks usually varies between 20 and 40%. During the declining years of an outbreak and more specifically during the year of collapse the action of parasites may increase considerably. Aggregate parasitism for larvae and pupae and total aggregate parasitism for each region for each year of study are shown in Table IV. In 1962, aggregate parasitism in the Saguenay region amounted to 84.8%. This compares with the highest figures of aggregate parasitism obtained during the final year of other outbreaks.

Unfortunately, parasite studies were not carried out before 1962 in this region and the action of parasites during the years preceding the final year of the outbreak is unknown.

The high incidence of parasitism in this region was largely attributable to the complex of dipterous parasites that attacked the sixth-instar larvae and the pupae. Some hymenopterous parasites, namely *M. trachynotus* and *A. ontario* were also quite important. In the Lower St. Lawrence region aggregate parasitism in 1960 was comparable to that encountered elsewhere during peak outbreak periods. In 1961, aggregate parasitism was twice that of the previous year mostly due to an increase in the action of *M. trachynotus* and *A. ontario.* Total aggregate parasitism could not be calculated for this region in 1962, since the collapse of the outbreak in July prevented an assessment of pupal parasitism, but larval parasitism did show a marked increase over that of the previous year and this was mostly attributable to the very high incidence of *A. interrupta* which more than compensated for the decrease shown by *G. fumiferanae* and *M. trachynotus.*

Discussion

The residual outbreak in the Saguenay region maintained itself from 1959 to 1962. This outbreak was confined to young stands of balsam fir averaging about 30 years and covering approximately 70 square miles, and could not increase in size since practically all stands of mature fir in that region were killed during the widespread outbreak which came to an end in 1958 (Blais 1964). It has long been known that mature and overmature stands of balsam fir offer conditions more propitious to budworm attack than immature stands due to a complexity of factors (Blais 1952; Morris 1963). It appears that in the case of this residual outbreak budworm populations could not remain at epidemic level beyond 1962 because of the marginal conditions offered by the type of stands present and probably because of the confined size of the area under attack. The high degree of parasitism during the last year of attack has been a characteristic of other outbreaks and it is significant that in the Saguenay region this phenomenon occurred when budworm populations were already greatly reduced.

In the Lower St. Lawrence region, the spruce budworm situation was very different from that in the Saguenay region because the outbreak was not confined geographically and it could have spread to the vast adjoining stands of mature balsam fir. In effect a considerable amount of spreading had occurred before the outbreak was brought under control in 1962 through the combined action of chemical treatment and of natural control factors (Blais 1963). The action of parasites appears to have been important amongst the natural control factors that brought about the collapse. It has been shown that predation by birds, especially evening grosbeaks (*Hesperiphona vespertina*), was also significant (Blais and Parks 1964).

Studies of other outbreaks have led to the conclusion that the action of parasites was not effective during peak years of a budworm attack and that it was only after the host population had been reduced through other factors such as food depletion or weather that parasitism increased (McGugan and Blais 1959; Blais 1960; Miller 1963). It appears that in the case of the two residual outbreaks under discussion the same situation prevailed. In the Lower St. Lawrence area the initial reduction in budworm populations was brought about through chemical treatment. It is not known how the decline in the Saguenay area was brought about but unfavourable stand conditions and the restricted size of this outbreak were probably responsible.

All species of parasites that attack spruce budworm except *A. fumiferanae*, *G. fumiferanae* and possibly *H. cacoeciae* are suspected or are known to winter over in alternate hosts (Miller 1963). Some parasite species may even require more than two host species to complete a one-year cycle. Therefore the density of most parasite species of the spruce budworm is limited by the presence and abundance of alternate hosts. In order that a parasite requiring an alternate host be abundant during a budworm outbreak, the alternate host must also be present in outbreak proportions. Because this seldom happens, it is only when budworm populations are returning to endemic conditions that the relative abundance of many parasites can show an increase. This explains the parasite complex and the relative abundance of each species during the peak years of budwork attack; at that time the proportion of the host population attacked by parasites requiring alternate hosts is usually very small.

Although the parasite complex and degree of parasitism are fairly constant during peak outbreak periods, they vary considerably during the last phase of outbreaks. One of the parasite species, *M. trachynotus*, recovered in some numbers in the present studies has frequently been associated with the decline of other outbreaks. However, a number of species, namely *A. ontario*, *A. interrupta* and *E. caesar* that were most common during the last year of one or both of these two outbreaks, have rarely been recovered in large numbers during the decline of other outbreaks. Likewise certain species credited with having played an important rôle in accelerating the decline of other outbreaks were rare or absent in the two outbreak areas under discussion. When budworm populations are returning to a low level, the presence and relative abundance of alternate hosts become very important and determine the parasite complex. Since the presence and relative abundance of alternate hosts can be expected to vary in time and place it is not surprising therefore to find variations in the occurrence of parasite species during the last phase of spruce budworm outbreaks.

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Rearing Root Maggots, Chiefly *Hylemya brassicae* (Bouché) (Diptera : Anthomyiidae) for Bioassay[1]

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Details of a method of mass rearing eggs and larvae of the cabbage root maggot, *Hylemya brassicae* (Bouché) for bioassay and of continuous propagation of all stages of the pest are described. The technique was equally suitable for rearing the onion maggot *H. antiqua* (Meig.), the seed corn maggot *H. calicrura-liturata* (Rond.) and the carrot rust fly, *Psila rosa* (L.). Under the conditions described, 2000-2500 eggs or first-instar larvae of *H. brassicae* were obtained from 50-60 female flies in 24 hours, or 1000-1200 mature larvae or pupae were reared from eggs produced by 25 female flies in approximately 20 days.

Several papers have been published describing methods and techniques for rearing the cabbage root maggot, *Hylemya brassicae* (Bouché) (Schoene 1916; Sherwood and Pond 1954; Read and Welch 1962). This paper describes a much simplified technique developed at Charlottetown during the past two years for rearing and handling large numbers of *H. brassicae* eggs, larvae, puparia and adults for bioassay; it also includes further information on the biology and habits of the pest. The technique is equally suitable for efficient rearing of the seed corn maggot, *H. cilicrura-liturata* (Rond); the onion maggot, *H. antiqua* (Meig.); and the carrot rust fly, *Psila rosa* (L.), with oviposition attractants and larval food being replaced by the appropriate food for the larvae of the particular pest species being studied. The temperatures reported in this paper for rearing *H. brassicae* are also suitable for rearing the other root pests, but no detailed information is available on the exact conditions required to prevent the pupae of these other pests from going into diapause.

Methods and Results

The two types of cages used for rearing are shown in Fig. 1, the cone-shaped ones being used for collecting flies as they emerge from pupae in the soil and the cylindrical ones for maintaining the flies during the oviposition period. The newly emerged flies move into the upper cone-shaped cages and are then sorted and transferred to the cylindrical rearing cages via the hole in the side used for the watering vials. The cages are made of 30-mesh plastic screen sewn on a

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