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Spruce Budworms Handbook

Spruce Budworm Parasites in Maine: A Reference Manual for Collection and Identification of Common Species

In 1977, the United States Department of Agriculture and the Canada Department of the Environment agreed to cooperate in an expanded and accelerated research and development effort, the Canada/United States Spruce Budworms Program (CANUSA), aimed at the spruce budworm in the East and the western spruce budworm in the West. The objective of CANUSA was to design and evaluate strategies for controlling the spruce budworms and managing budworm-susceptible forests, to help forest managers attain their objectives in an economically and environmentally acceptable manner. The work reported in this publication was wholly or partially funded by the Program. This manual is one in a series on the spruce budworm.

Canada
United States
Spruce Budworms
Program

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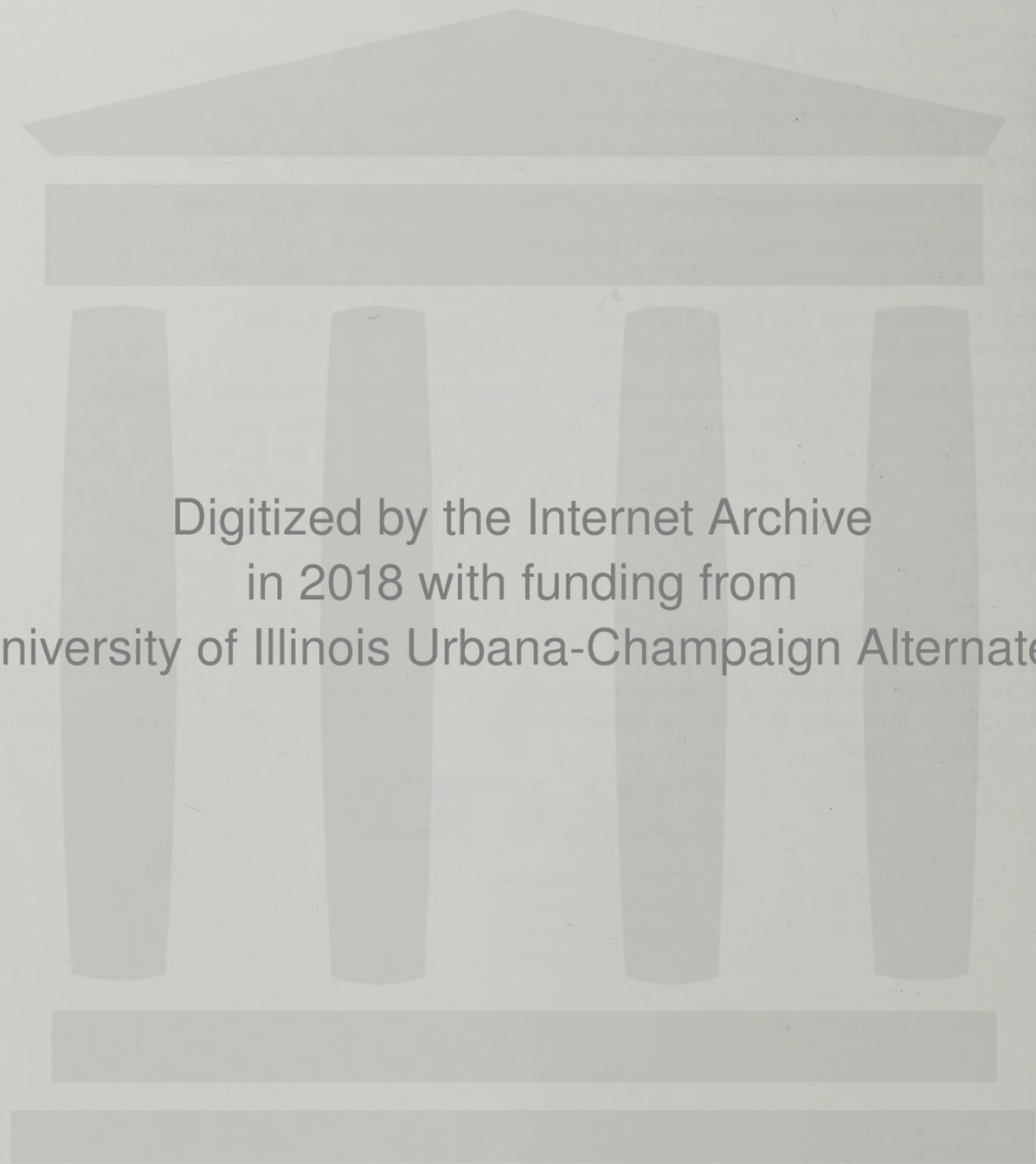

Spruce Budworm Parasites in Maine: A Reference Manual for Collection and Identification of Common Species

by

David A. Tilles and Norman E. Woodley[1]

Introduction

The spruce budworm, *Choristoneura fumiferana* (Clemens), is one of the most destructive forest insects in North America. This pest causes serious damage to spruce–fir forests throughout New England and the Lake States in the United States, and the Canadian Provinces of Ontario, Quebec, Nova Scotia, and Newfoundland (Baker 1972).

Major outbreaks occurring in Eastern North America eventually subside, probably as a result of climatic factors and the limited availability of food. Natural control agents (e.g., predators, parasites, disease) have shown little effectiveness in regulating budworm populations during outbreaks. However, between outbreaks, natural controls are important to maintain endemic budworm populations at low levels (Dearborn 1980).

Spruce budworm parasites include various species of wasps (Hymenoptera), and flies (Diptera). Adult parasites place their eggs (or larvae in some cases) on, in, or near the immature stage of their host. Either the egg, larva, or pupa of the budworm may be attacked, depending upon the species of parasite. The immature parasite feeds upon the internal tissues and body fluids of its host, killing the host before it reaches maturity.

Entomologists are often interested in determining the effects of parasites on specific budworm populations. In some cases, estimates of parasite numbers are needed to determine the effect that a particular pesticide may have on various natural enemies. Dearborn (1980) has suggested that parasitism might be used as one indicator of budworm population quality.

Prior to this publication, information pertaining to the collection, rearing, and identification of the more common budworm parasites was scattered throughout the scientific literature. Three keys to budworm parasites have been prepared; one addresses parasitic Hymenoptera in the Lake States (Wilson and Bean 1964), and the others deal with puparia (Ross 1952) and adults (Coppel 1960) of parasitic Diptera.

We have attempted to condense the present literature and supplement it with our own observations in order to prepare a manual that should facilitate identification of budworm parasites and estimation of parasitism levels. Most of the parasites treated in this manual are also found in other areas of the Northeast, and some range as far west as British Columbia. However, it should be emphasized that the keys in this manual may not be applicable to areas other than Maine.

In addition to the sections covering collection, identification, and life histories of common parasite species, an illustration of general external morphology of a parasitic wasp (fig. 43), a glossary, and two reference tables are presented in the appendix. Appendix Table 1 is a summary of the host stages attacked and the relative abundance of 18 of the common budworm parasites in Maine. Appendix Table 2 is a compilation of all 82 species reported to parasitize spruce budworm in North America. The species names in this manual follow those given in Arnaud (1978) and Krombein et al. (1979).

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The design and implementation of a parasite sampling project will depend upon study objectives, as well as numerous other biological (e.g., budworm population level, forest stand composition) and economic (e.g., manpower) constraints. In this section, we suggest guidelines for sampling parasites and provide examples of methods used by other workers.

When To Sample

Each parasite species is specialized to attack at a particular developmental stage of the budworm. Thus, to detect all species of parasites, collections must be undertaken at several stages in the host's life cycle. Suggested collection times are peak of the fourth instar, peak of the sixth instar (50-percent pupation), peak of the pupal stage (50-percent emergence), and peak of new (green) egg-mass deposition. If collections are made too early in a sampling period, hosts may not yet have been parasitized; late sampling carries the risk that parasites may have already emerged from their hosts. F. A. Titus[2] suggests using degree-day measurements to time the parasite collections. If 5.6°C is accepted as the temperature threshold, early-larval parasites should be collected at 222 degree-days, which will occur during the fourth instar. Late-larval parasites should be collected at 472 degree-days, which will coincide with sixth-instar development; and pupal parasites should be collected at 611 degree-days. If the degree-day method is not used to time budworm collections, another, but more difficult, alternative would be to sample budworm populations systematically at frequent intervals. Two references helpful for this procedure are McGugan (1954), for techniques to differentiate between different budworm instars, and Sanders (1980), for a review of techniques used in sampling budworm populations. Houseweart et al. (1982) reported that budworm egg-mass deposition spans about 27 days and peaks in early to mid-July. We suggest that egg parasites be sampled during the deposition period because egg parasites cause eggs to turn black, allowing all parasitism to be recorded. Specific information about budworm development in Maine may also be obtained from the Maine Forest Service Entomology Laboratory in Augusta.

[2]Unpublished internal report. Field and laboratory procedures for the study of spruce budworm parasitism. Maritimes Forest Research Centre, Fredericton, N.B., Canada. 1979. Degree-days are accumulated every day (starting in late winter) that the average daily temperature is higher than the threshold temperature at which development starts. For example, if the daily temperature was 10 °C for the first 3 days, and the temperature threshold was 5 °C, then a total of 15 degree-days would have been accumulated during those 3 days.

Design of Sampling Methods

Sample plots should be located in forest stands that contain a high proportion of balsam fir, *Abies balsamea* (L.) Mill., because parasite samples are most commonly collected from budworms on this tree species. Additionally, the chances are better that large numbers of budworm larvae can be located in stands containing a high proportion of balsam fir than in stands consisting mainly of spruce and/or hardwoods (Baker 1972).

The most commonly used sampling unit in the United States is a branch tip 18 inches (45.7 cm) long. If all sample branches are the same size, then the number of budworms or budworm parasites per branch tip can be converted into a useful standardized estimate of insect density. For example, Simmons (1973) presented a conversion factor to change budworm density estimates from branch tip to area of host foliage.

The abundance of different budworm parasites has been observed to vary, depending upon the relative size of the host populations. For example, the degree of parasitism by *Meteorus trachynotus* (Viereck) has been known to increase greatly during periods of sharply declining budworm populations (Miller 1963), whereas other parasites show density-dependent relationships with their budworm hosts (Miller 1963). It is, therefore, necessary to estimate budworm population levels concurrently with parasitism levels, if one is to obtain accurate estimates of actual parasitism.

In Weseloh's (1976) review of forest insect parasite behavior, he stressed that parasites in a forest stand are often unequally distributed between different plant species and microhabitats. Thus, variability between samples can be minimized by collecting from trees of the same species that are similar in such respects as height, percentage of live crown, and exposure to light. In addition, branches should be removed from the same aspects (e.g., NE, SW) and crown levels. In the Northeast, generally accepted methods are to sample for larval and pupal parasites at midcrown levels of balsam fir, as suggested by Kemp and Simmons (1976). Houseweart et al. (1982) sampled for egg parasites in the upper crowns of balsam fir because the largest proportion of budworm eggs are usually deposited in this region.

The number of budworm larvae sampled must be large if parasitism rates are to be accurately determined.[3] Sampling must be more intensive in areas with low budworm populations than in areas with high populations. Because sampling intensity (i.e., the number of branches sampled before obtaining a predetermined number of budworms required by the sampling plan) is inversely proportional to budworm numbers, formulae can be developed that use sampling intensity to compute budworm density. In this way Kemp and Simmons (1976) have standardized parasite sampling procedures so that budworm densities may be estimated with little extra effort.

Sometimes, trees are spaced so closely that it is not possible to sample branches from more than one or two aspects of any single tree in the group. In such cases, the cluster of trees can be treated as a single tree for sampling purposes. When budworm populations are low, clusters of trees offer an additional advantage over single trees because more branches may be available for intensive sampling.

To reduce sampling error due to intertree variability, it is advisable to sample branches from the same trees or clusters of trees during each collection period. This may extend to also sampling the same sites during the following year, since some parasites (e.g., *Glypta* and *Apanteles fumiferanae)* attack during one season and emerge during the next (Brown 1946a, b). Then, it may be necessary to relate the number of emerging parasites to budworm populations from the previous year.

Simmons and Chen (1974) have described a method of estimating the proportion of parasitism caused by *Apanteles* and *Glypta* spp. that involves sampling foliage for parasite cocoons. The advantage of this method is that no rearing or dissection is needed. However, a rather involved mathematical formula or a computer program (available from the authors[4]) must be used.

Collecting Techniques

Branches can be removed from trees with a sectional pole pruner. To prevent loss of larvae during branch removal, a basket can be attached to the pruner. However, baskets are cumbersome and are not necessary for collecting pupae or egg masses. Stein (1969) describes a modified pole pruner with a holding clip that firmly grasps the branch as it is being lowered from the tree. It can be used for sampling pupae, larvae, or eggs.

If they are to be counted in the field, small budworm larvae may be removed from branches by gently tapping the branch over a white drop cloth. Care should be taken to ensure that those larvae held tightly in by their webbing are also dislodged. Large larvae and pupae are easier to locate and can be hand-picked to avoid unneccessary damage. All larvae should be handled only with featherweight forceps or a fine-tipped paintbrush.

If larvae are to be counted in the laboratory rather than in the field, they can be transported directly on fresh balsam fir foliage in containers with adequate ventilation. Bradbury (1978) placed sample branches with larvae in plastic bags which were then transported to the laboratory for processing.

Pupae are delicate and during transport must be placed in sturdy containers (e.g., petri dishes) or sandwiched between two layers of cotton. Empty pupal cases should also be collected, since they may represent successful emergence of unparasitized budworms. (See section on damage to the pupal case caused by emerging budworm adults and their parasites.)

All collected insects should be kept shaded and cool (preferably at less than 40 °F) in the field and en route to the laboratory. This is especially critical if they are in plastic bags.

Handling of Collected Insects—Two different strategies are employed to recover budworm parasites. Parasites of early-stage larvae can be collected by dissecting fourth-instar budworms, or larvae can be reared in the laboratory until their parasites emerge. Dissection has the advantage that data can be acquired promptly, without prolonged rearing procedures. However, some of the rarer parasites of fourth- and fifth-instar budworm (e.g., *Enytus* or *Synetaeris),* are extremely difficult to identify unless they are allowed to develop to the adult stage.

Late-larval, pupal, and egg parasites should always be allowed to emerge from their hosts. For egg and pupal parasites, this is relatively easy, as eggs and pupae require little care other than regulation of temperature and humidity. However, larger larvae must be provided with a continuous supply of food, and their excrement may require periodic removal.

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[3]For example, Bradbury (1978) collected a minimum of 100 larvae or pupae per plot at each of the sampling stages; Kemp and Simmons (1976), 200 per plot.

[4]Dr. Gary Simmons, Dept. of Entomology, Michigan State University, East Lansing, MI 48824.

During periods when budworm populations are low and parasite populations are high, multiparasitism may occur among several parasite species (e.g., *M. trachynotus, Actia interrupta* Curran, *Omotoma fumiferanae* Tothill). Although more than one parasite may have attacked the host, usually, only one species emerges. Consequently, parasitism estimates based solely on larval rearings may underestimate the actual attack rate.

Dissection Techniques for Spruce Budworm Larvae— Kemp and Simmons (1976) described a method of dissecting budworm larvae that allows recovery of early larval parasites. They recommend refrigerating the larvae at 7 to 10 °C after collection, if they are not to be dissected immediately. Although larvae can be stored for several days in this manner, it is still preferable to process larvae within a day after collection. The cooled larvae are also less agile and are easier to handle than those stored at room temperature. Each larva to be dissected is placed under a dissecting microscope and held down with a probe. The sharp edge of a syringe needle is then used to make an incision just behind the head capsule. The blunt side of the needle can be used to force the body contents out through the cut. This must be done carefully because the delicate parasites are easily damaged. Nearly mature parasite larvae, when present, may be found within these body contents.

Another effective dissection method is to make a longitudinal cut along the entire dorsal midline of the larva with the sharp edge of a syringe needle. The cuticle may then be separated to expose the body contents. Titus[2] preferred using a black background as the dissection surface, to contrast with the lighter colored parasites. He also recommended dissecting small larvae in 60-percent ethanol. In contrast, Bradbury (1978) found that 70-percent ethanol formed a cloudy solution and killed the parasites, making them more difficult to locate. He preferred dissecting fourth-instar budworms in water and tearing the host larva apart by pulling on each end of it with a dissecting needle. Parasites then "popped" out into the water.

Immature parasites should be preserved in 70-percent ethanol if they are to be retained for identification later, but it is preferable to identify them as soon as possible because they lose their natural colors during storage. Parasite larvae most likely to be recovered during the dissections include *Apanteles fumiferanae* Viereck, *Glypta fumiferanae* (Viereck), and the less common *Synetaeris tenuifemur* Walley.

Rearing Spruce Budworm Parasites—Stehr (1954) suggested that budworm larvae be reared under an 18 h light/16 h dark regime at 21.5 ± 1° C and 68-, to 75-percent relative humidity. Again, budworm larvae should not be handled directly, but should be manipulated with a soft, fine-tipped paintbrush.

Larvae can be reared on a synthetic diet. Since its preparation is time consuming and usually requires that the raw materials be acquired in bulk (McMorran 1965), commercially prepared diet should be used for small rearing operations. Synthetic diet and 1 oz plastic creamer cups and lids can be acquired from a biological supply house.[5] A minimum of 20 l must be purchased at approximately $5.00/l. Between 500 and 600 larvae can be reared on 1 l of diet.

Grisdale (1970) described rearing techniques with synthetic diet. Ten ml of diet was poured into each creamer cup. After it cooled, an antifungal solution (1.5 g sorbic acid + 0.6 g methyl-p-hydroxybenzoate in 100 ml ethyl alcohol) was sprayed on the surface of the diet and the inner surfaces of the cup with an atomizer. Larvae were placed into each cup; the cups were then fitted with cardboard (unwaxed) lids and inverted. According to Dearborn,[6] cannibalism is likely if more than one larva is reared in each cup. However, Grisdale (1970) had problems with cannibalism only with six or more larvae per cup. If insufficient diet remains in the cup or if the diet becomes dry, larvae should be carefully transferred to a new cup with fresh diet. Titus[2] recommends checking for parasites, dead larvae, pupae, and mold every 2 days.

Balsam fir foliage is the least expensive type of budworm diet, but frequent foliage collection can be demanding, and care must be taken to avoid adding to the sample other budworms that may already be on the foliage. Newly opened balsam fir buds are the best source of food. If they are unavailable, fresh balsam fir foliage tips will suffice. Bradbury (1978) reared sixth-instar budworms individually in inverted 25 × 95 mm shell vials, plugged with absorbent cotton to reduce fungus development. Fir tips were replaced and excrement removed twice before the

[5]Bioserve, Inc., P.O. Box B.S., Frenchtown, NJ 08825. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product to the exclusion of others that may be suitable.

[6]Personal communication from R. G. Dearborn, Maine Forest Service, Entomology Laboratory, Augusta, ME 04473.

budworms pupated. Stehr (1954) reared four to six larvae together in each 16 × 100 mm petri dish, using balsam fir buds as food. **Note:** If several larvae are held together, newly developed pupae should be transferred to a separate container, to eliminate any confusion regarding the origin of a resulting parasite.

Titus[2] and Bradbury (1978) placed individual budworm pupae into 9 × 42 mm shell vials plugged with cotton. They had problems with parasites (especially tachinids) escaping from loosely plugged vials. Kemp and Simmons (1976) reared as many as 10 pupae together in petri dishes 100 mm in diameter and cautioned that emerging moths should be removed from the dishes because their wing scales can asphyxiate the remaining budworm pupae and parasites. Budworm pupae from which neither moths nor parasites emerge should be dissected and their contents identified, if possible.

If dipterous puparia are to be reared to the adult stage, they may need to undergo a cold period before they can complete development. Titus[2] ended this dormant state by placing the puparia in a rodent-proof covered tray with moistened peat moss and leaving the tray outdoors over the winter. Adult flies then emerged within a few weeks after their return to room temperature.

To locate budworm egg masses in the laboratory, branches should be examined according to procedures outlined by Dixon et al. (1978). Needles with egg masses can be placed in shell vials and tightly corked to prevent emerging parasites from escaping. After 2 weeks' time, egg parasites can be collected and the percentage of black (parasitized) eggs determined (Houseweart et al. 1982).

All collected adult parasites should be preserved in 70-percent ethanol or mounted on an insect pin. Parasite larvae and puparia should be preserved in 70-percent alcohol. Oman (1952) presented a comprehensive review of insect collecting and preservation techniques.

Key to the Adult Stages of Common Parasites of the Spruce Budworm in Maine

(Adapted from Wilson and Bean 1964, Coppel 1960)

1. Parasite emerged from spruce budworm egg mass; minute insects; length about 1 mm or less ..... Hymenoptera; *Trichogramma* sp. (p.20)

   Parasite emerged from spruce budworm larva 2
   Parasite emerged from spruce budworm pupa 11

Parasites from Budworm Larvae

2. With four membranous wings; body not bristled (Hymenoptera) 3

   With two membranous wings, the hind pair reduced to small, knoblike structures; body with many long bristles (Diptera) 8

Hymenoptera

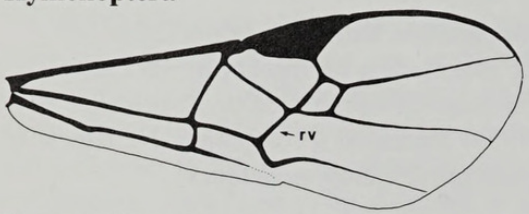


Figure 1—Front wing of a braconid wasp. rv = recurrent vein.

3. Front wing with one recurrent vein (rv) (fig. l) (Braconidae) 4

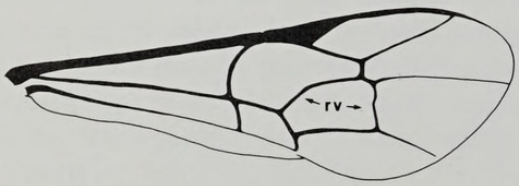


Figure 2—Front wing of an ichneumonid wasp. rv = recurrent vein.

Front wing with two recurrent veins (rv) (fig. 2) (Ichneumonidae) 6

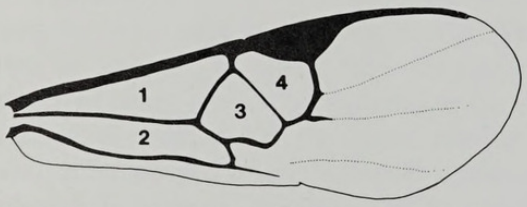


Figure 3—Front wing of an *Apanteles* sp. wasp.

4. Forewing with four closed cells (fig. 3); eyes with dense hairs present over entire surface; thorax and abdomen black .... *Apanteles fumiferanae* Viereck (p.22)

   Front wing with five or six closed cells; eyes bare or at most with sparse hairs on surface; thorax and abdomen with some yellow coloration ... 5

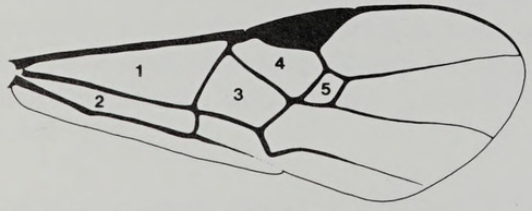


Figure 4—Front wing of *Meteorus trachynotus* Viereck.

5. Forewing with five closed cells; cell $1R_s$ (= Cell 5) somewhat square (fig. 4); eyes with short, sparse hairs .... *Meteorus trachynotus* (Viereck) (p.23)

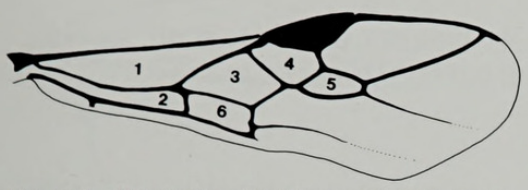


Figure 5—Front wing of a *Macrocentrus* sp. wasp.

Forewing with six closed cells; cell $1R_s$ (= Cell 5) elongate (fig. 5); eyes completely bare ..... *Macrocentrus* sp. (p.23)

6. Petiole or first segment of abdomen (gaster) broad, when viewed from above appearing nearly as broad as other segments; tergites 2–4 with deep impressions shaped like an inverted "V"; ovipositor very long, about as long as gaster ..... *Glypta fumiferanae* (Viereck) (p. 24)

Petiole narrow, when viewed from above; appearing much narrower than remainder of gaster, especially toward base; tergites of gaster smooth, without deep impressions; ovipositor much shorter than gaster 7

7. Legs mostly yelow-orange, including entire hind femur .... *Enytus montanus* (Ashmead) (p. 23)

Legs mostly brown to black, with hind femur especially dark .... *Synetaeris tenuifemur* Walley (p.24)

Diptera

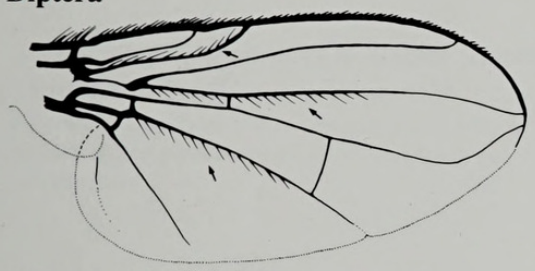


Figure 6—Wing of *Actia interrupta* Curran.

8. Eyes bare; wing veins R_1, R_{4+5} and CuA_1 with numerous setae (fig. 6) ..... *Actia interrupta* Curran (p.20)

Eyes with dense hairs over entire surface; wings with setae only on base of R_{4+5} (fig. 7) 9

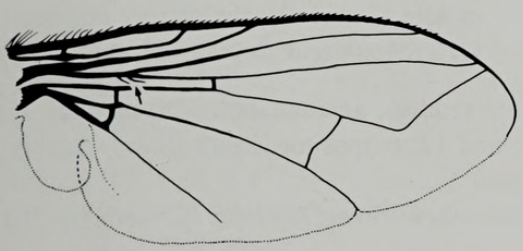


Figure 7—Wing of *Lypha setifacies* (West).

9. Most of scutellum usually yellowish (always yellowish at least at apex), contrasting with coloration of rest of thorax .... *Phryxe pecosensis* (Townsend) (p.22)

Scutellum dark colored, concolorous with rest of thorax 10

10. Palpi yellow; wing with four or five long setae on base of R_{4+5} (fig. 7); body with distinctly bronze coloration . *Lypha setifacies* (West) (p. 21)

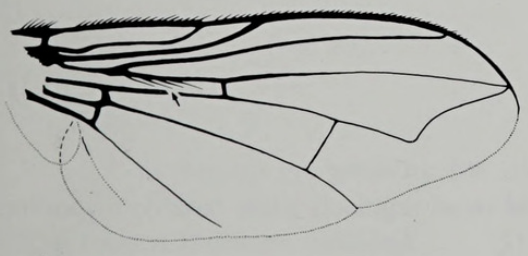


Figure 8—Wing of *Aplomya caesar* (Aldrich).

Palpi black; wing with one or two short bristles on R_{4+5} (fig. 8); body with only faint bronze reflections ..... *Aplomya caesar* (Aldrich) (p. 20)

11. With four membranous wings; body not bristly (Hymenoptera) 12

    With two membranous wings, the hind pair reduced to small, knoblike structures; body with many long bristles (Diptera) 16

Hymenoptera

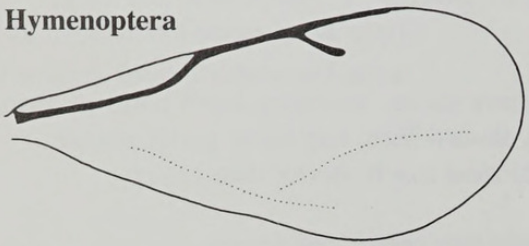


Figure 9—Front wing of a Pteromalid wasp.

12. Small insects, 3 mm or less in length; brilliant metallic green body; front wing without closed cells (fig. 9) (Pteromalidae) 13

    Much larger insects, usually at least 8 mm long; not metallic green but most of body reddish or black; front wing with several closed cells (Ichneumonidae) 14

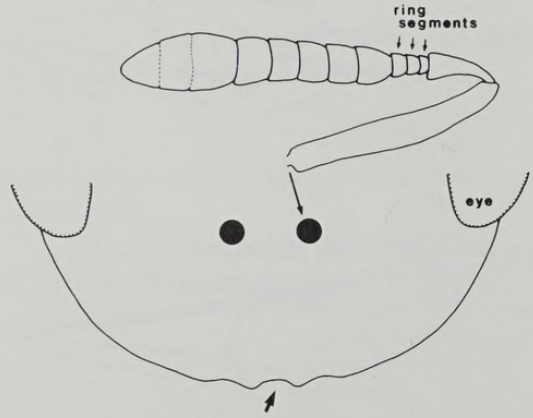


Figure 10—Anterior of head of *Mesopolobus verditer* (Norton).

13. Antennae with three ring segments; middle of oral margin shallowly notched (fig. 10) ..... *Mesopolobus verditer* (Norton) (p.27)

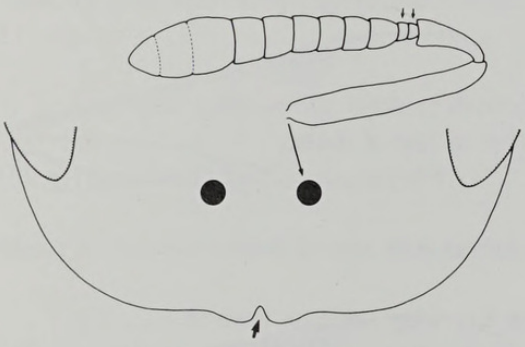


Figure 11—Anterior view of head of *Psychophagus tortricis* (Brues).

    Antennae with two ring sements; middle of oral margin sharply notched (fig. 11) ..... *Psychophagus tortricis* (Brues) (p.27)

14. Abdomen with basal half or more reddish; antenna dark with medial white band at segments 10, 11, and 12; ovipositor sheath short, scarcely protruding beyond end of abdomen .... *Phaeogenes maculicornis hariolus* (Cresson) (p.26)

    Abdomen dark, sometimes with yellowish bands on apices of segments, but without basal red area; antenna entirely black, without contrasting white band near middle; ovipositor sheath protrudes well beyond end of abdomen 15

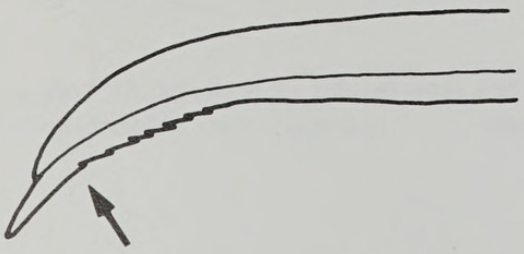


Figure 12—Tip of ovipositor in *Ephialtes ontario* (Cresson).

15. Face extensively yellow in male, at least along eye margins in female; middle tarsi black; hind tarsal segments white basally; ovipositor hooked downward at tip (fig. 12) .... *Ephialtes ontario* (Cresson) (p.25)

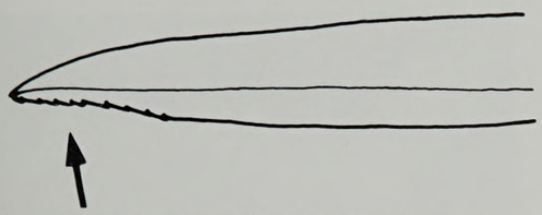


Figure 13—Tip of ovipositor in *Itoplectis conquisitor* (Say).

Face black; middle and hind tarsal segments strongly black and white banded; ovipositor sheath straight (fig. 13) ..... *Itoplectis conquisitor* (Say) (p. 26)

Diptera

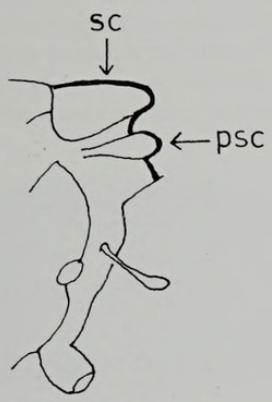


Figure 14—Lateral view of a dipteran thorax with a well-developed postscutellum. sc = scutellum; psc = postscutellum.

16. Eyes hairy; postscutellum (psc) bulging just below rim of scutellum (sc) (fig. 14) (Tachinidae) 17

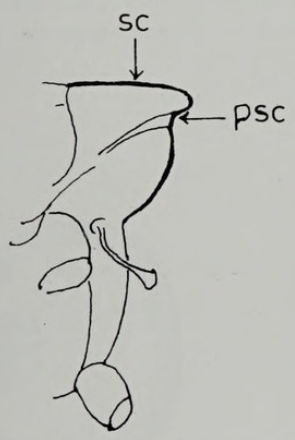


Figure 15—Lateral view of a dipteran thorax with a poorly developed postscutellum. sc = scutellum; psc = postscutellum.

Eyes bare; postscutellum not bulging just below rim of scutellum (fig. 15) (Sarcophagidae) ..... *Agria housei* Shewell (p. 24)

17. Scutellum with at least some yellowish coloration which contrasts with coloration of rest of thorax 18

Scutellum wholly black, color similar to rest of thorax ..... *Aplomya caesar* (Aldrich) (p. 20)

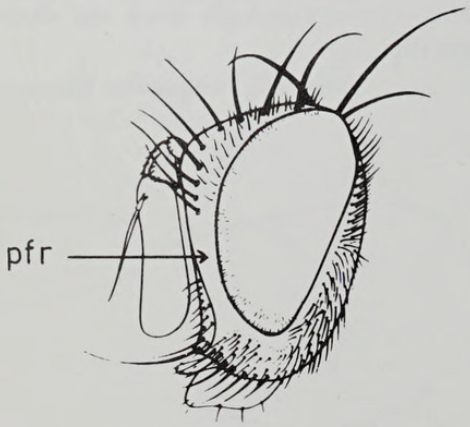


Figure 16—Head of *Phryxe pecosensis* (Townsend). pfr = parafacial region (from Coppel 1960).

18. Palpi black; antennae black; parafacial region bare (fig. 16) . . . . . *Phryxe pecosensis* (Townsend) (p. 22)

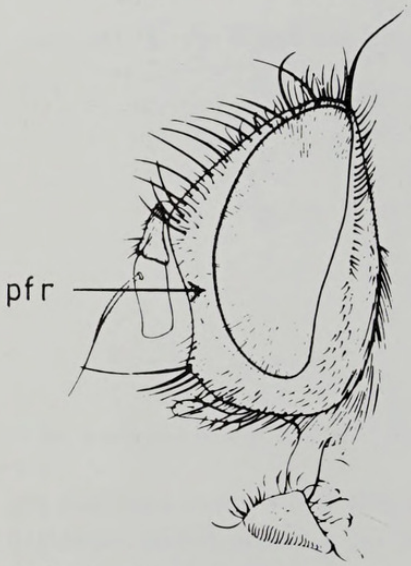


Figure 17—Head of *Omotoma fumiferanae* (Tothill). pfr = parafacial region (from Coppel 1960).

Palpi yellow; antennae with some reddish-yellow coloration; parafacial region hairy (fig. 17) . . . . . *Omotoma fumiferanae* (Tothill) (p. 25)

Key to Puparia of Common Dipteran Parasites of the Spruce Budworm in Maine

(adapted from Ross 1952)

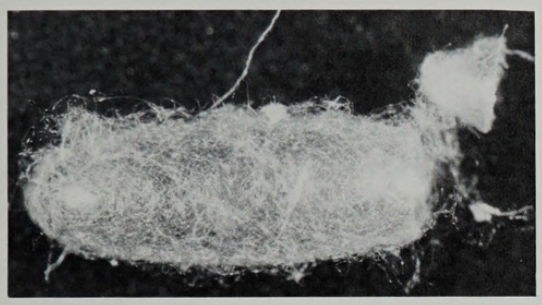


Figure 18—Cocoon of braconid. Ichneumonid cocoons are similar. The actual pupa is inside, and the adult emerges by cutting off the head end of the cocoon, which can be seen at the upper right. Note the fibrous nature of the cocoon, which is much different from the smooth puparium of Diptera.

Both cocoons of hymenopterous and puparia of dipterous parasites may be found after they have emerged from cultured budworm larvae. Hymenoptera cocoons (fig. 18, a braconid example) are distinctive, usually appearing fibrous as they are actually spun by the parasite larva. It is not possible to identify hymenopteran parasites simply from the cocoon because the cocoons are all similar in appearance.

Figure 19—Puparium of tachinid. The puparium is actually the hardened skin of the last larval instar. It is quite smooth and not composed of fibers. The adult fly emerges by popping off the head end. The posterior spiracles, important for identification of tachinid and sarcophagid species, are indicated by the arrow.

In contrast, puparia of Diptera (fig. 19) are quite distinctive, even between species. They are smooth, because they are formed from the skin of the last larval stage, and are not made of fibers. Spiracles are easily seen on both dipterous larvae and puparia; thus, the following key, based primarily on the appearance of the spiracles, may be used to identify both dipterous larvae and puparia.

1. Emerged from spruce budworm larva 2

   Emerged from spruce budworm pupa 5

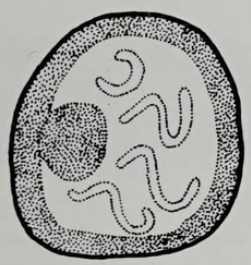


Figure 20—Posterior spiracle from a *Phryxe pecosensis* (Townsend) puparium.

2. Each posterior spiracle with four strongly sinuate slits (fig. 20) ..... *Phyrxe pecosensis* (Townsend) (p.22)

   Each posterior spiracle with three slits 3

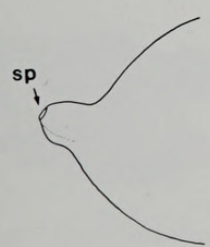


Figure 21—Posterior end of an *Actia interrupta* Curran puparium as seen from lateral view. sp = spiracle.

3. Posterior spiracles borne on a distinct protuberance of the last segment; each spiracular slit rather short and nearly straight (fig. 21) .... *Actia interrupta* Curran (p.20)

   Posterior spiracles not borne on a distinct protuberance; spiracular slits longer, but also more or less straight 4

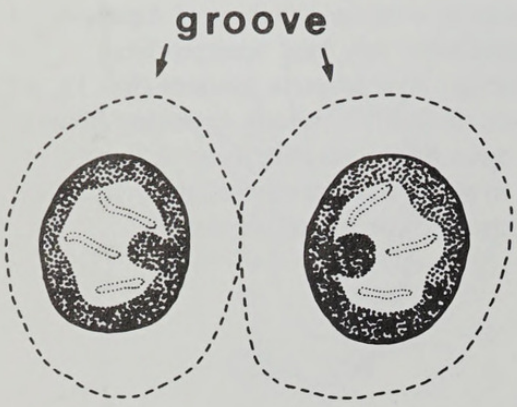


Figure 22—Posterior spiracles and spiracular groove as seen in a *Lypha setifacies* (West) puparium from posterior view.

4. Posterior spiracles surrounded by a more or less well-defined groove; puparium rugose (fig. 22) ..... *Lypha setifacies* (West) (p. 21)

   Posterior spiracles without a groove surrounding them; puparium glossy ..... *Aplomya caesar* (Aldrich) (p. 20)

5. Posterior spiracles in a deep cavity on the posterior surface of the last abdominal segment and partly hidden from view .... *Agria housei* Shewell (p. 24)

   Posterior spiracles level with the posterior surface of the last abdominal segment 6

6. Each posterior spiracle with four strongly sinuate slits (fig. 20) .... *Phryxe pecosensis* (Townsend) (p. 22)

   Each posterior spiracle with three more or less straight slits 7

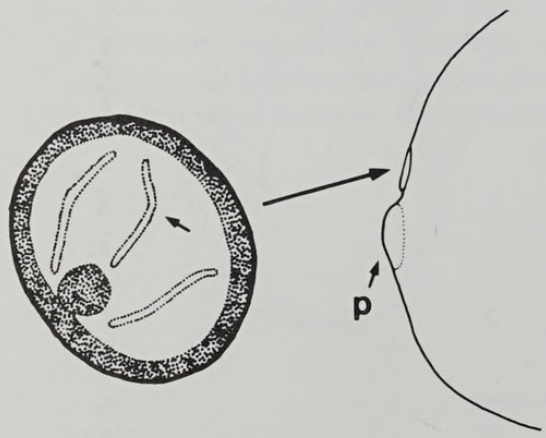


Figure 23—Posterior end of an *Omotoma fumiferanae* (Tothill) puparium from lateral view, with posterior spiracle illustrated. p = protuberance.

7. A distinct, well-developed protuberance present, ventral to the posterior spiracles, noticeable in profile and projecting beyond the spiracles (fig. 23); middle spiracular slit usually distinctly bent near middle (fig. 23) ..... *Omotoma fumiferanae* (Tothill) (p. 25)

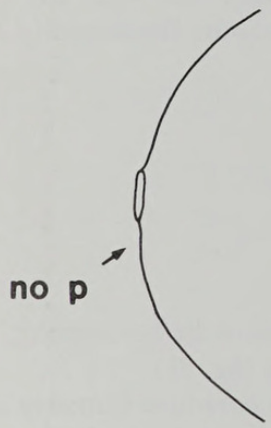


Figure 24—Posterior end of an *Aplomya caesar* (Aldrich) puparium from lateral view.

   Protuberance ventral to posterior spiracles very poorly developed, not noticeable in profile, and not projecting beyond the spiracles themselves; middle spiracular slit straight (fig. 24) .. *Aplomya caesar* (Aldrich) (p. 20)

Damage to Spruce Budworm Pupal Cases Caused by Emergence of Some Common Parasite Groups

Figure 25—Spruce budworm pupal skin after normal emergence of an adult moth (dorsal view). Note distinct split on dorsal area of thorax (arrow).

Figure 26—Spruce budworm pupal skin after normal emergence of an adult moth (lateral view). Note the antennal cases which have become separated from the main body of the pupal skin (arrow).

Figure 27—Spruce budworm pupal skin showing damage caused by an emerging tachinid fly maggot. Note that there is little noticeable damage and the antennal cases are still attached to the main body. Maggot emerged from space indicated by arrow.

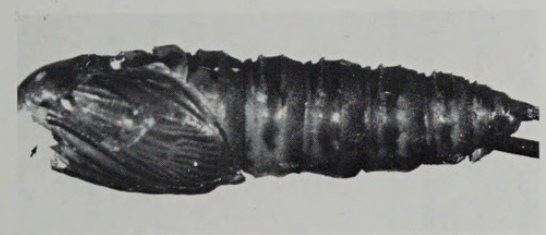


Figure 28—Spruce budworm pupal skin showing damage caused by an emerging ichneumonid larva. Note large emergence hole near head end of pupa (arrow).

Figure 29—Spruce budworm pupal skin showing damage caused by emerging pteromalids. Note tiny, round emergence holes (arrows).

Some general identifications can be made from empty pupal cases of the spruce budworm, from which either the budworm moth or various parasites have emerged. The following notes and accompanying photographs should prove useful for identifying empty pupal cases.

- Normal budworm emergence. When the adult budworm emerges from its pupal skin, a well-defined split of the skin occurs in the head region, usually leaving the anterior end appearing somewhat frayed (fig. 25). The antennal sheaths are separated from the main body of the pupal skin during emergence (fig. 26).

When various parasites emerge from a budworm pupa, the sheaths remain closely appressed to the pupal skin, and the anterodorsal splitting does not occur.

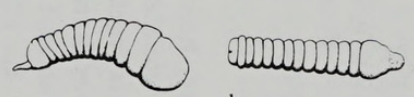
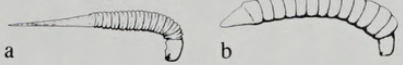
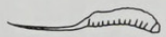
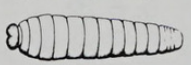
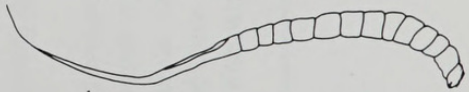
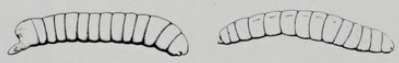
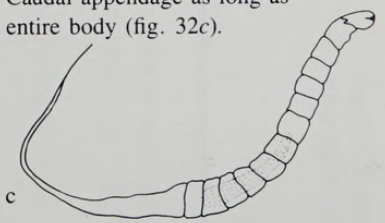
- Dipteran emergence. When Diptera emerge from a budworm pupa, they do so as maggot larvae. Because the fly maggot is fairly soft, when it breaks through the pupal skin of the budworm, usually near the wing cases, it causes little damage to the pupal skin. The only evidence of dipteran emergence is a small crack near the wing cases, which leaves no frayed areas or distinct holes (fig. 27).

- Ichneumonid emergence. While it is not possible to specifically identify ichneumonid species by characteristic damage which they cause to the budworm pupa, it is possible to determine that an ichneumonid in general has emerged. These wasps chew a large characteristic hole at the anterior end of the budworm pupa from which they escape (fig. 28). The hole does not have frayed margins, and may be dorsal, ventral, or in the anterior portion of the pupal skin.

- Pteromalid emergence. Because several pteromalids usually emerge from a single budworm pupa, characteristic damage to the pupal skin results. These tiny wasps chew small, nearly round holes in the pupal skin, through which they escape. Holes are about 1 mm in diameter and may be anywhere on the pupal skin (fig. 29).

Using the above criteria, a general evaluation of parasitism by major parasite groups can be determined by collecting empty budworm pupal skins.

Morphological Comparisons Between Three Hymenopterous Larvae Found in Association with Early-Instar Spruce Budworm in Maine

Instar of parasite	Braconidae	Ichneumonidae	
	Apanteles fumiferanae Viereck	*Glypta fumiferanae* (Viereck)	*Synetaeris tenuifemur* Walley
1	Caudal appendage only as long as the last segment itself (fig. 30*a*,*b*).  a b	Newly eclosed larva with long caudal appendage which becomes only as long as the last three segments during this instar (figs. 31*a*,*b*).  a b	Caudal appendage as long as entire body (fig. 32*a*).  a
2	Last segment with large, bilobed caudal appendage (fig. 30*c*).  c	Caudal appendage only as long as the last segment itself (not short, large, and bilobed) (fig. 31*c*).  c	Caudal appendage as long as entire body (fig. 32*b*).  b
3	Eight pairs of visible spiracles (on segments 2, 4–10); conspicuous round, lateral swellings present on segments 2–10. Emerges from budworm at this stage (fig. 30*d*).  d	Caudal appendage very short, as long as the last segment early in this instar, shorter as the instar matures (figs. 31*d*,*e*).  d e	Caudal appendage as long as entire body (fig. 32*c*).  c
4	Prepupa, in cocoon (fig. 30e).  e	Nine pairs of visible spiracles (on segments 2, 4–11) rudiments of wing buds and leg buds present; lateral lobes present on segments 4–11; emerges from budworm at this stage (figs. 31*f*,*g*).  f g	Caudal appendage as long as preceding five segments (fig. 32*d*).  d

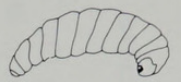
Instar of parasite	Braconidae	Ichneumonidae	
	Apanteles fumiferanae Viereck	*Glypta fumiferanae* (Viereck)	*Synetaeris tenuifemur* Walley
5		Spins cocoon (fig. 31h).  h	Caudal appendage much shorter; leg buds present (figs. 32c, d).  c  d
General notes	Often associated with midgut of the budworm larva.	Often associated with dorsal fat body of the budworm larva.	

Figure 30—Larvar instars of *Apanteles fumiferanae* Viereck (Adapted from Brown 1946a). a = first-early; b = first-late; c = second; d = third; e = fourth.

Figure 31—Larval instars of *Glypta fumiferanae* (Viereck) (adapted from Brown 1946b). a = first-early; b = first-late; c = second; d = third-early; e = third-late; f = fourth; g = ventral view of fourth; h = fifth.

Figure 32—Larval instars of *Synetaeris tenuifemur* Walley (adapted from Miller and Renault 1963). a = first; b = second, c = third; d = fourth; e = fifth-early; f = fifth-late.

Figure 33—*Trichogramma minutum* Riley emerged from a saddled prominent (*Heterocampa guttivitta* [Walker]) egg.

Figure 34—*Omotoma fumiferanae* (Tothill), a representative of Tachinidae. Note the very bristly body.

Egg Parasites

Hymenoptera: Trichogrammatidae

Trichogramma minutum *Riley* (fig. 33)—This minute wasp is the only parasite known to attack eggs of the spruce budworm. It is distributed widely throughout North America and attacks many hosts in six different insect orders (Anderson 1976). As yet, no relationship has been shown between the rate of parasite attack and budworm density. In general, *T. minutum* parasitizes up to 15 percent of the spruce budworm egg-mass population. However, Hewitt (1912) reported parasitism rates as high as 77 percent in Ontario and Quebec. Eggs are attacked beginning immediately after oviposition, and adult wasps emerge within about 2 weeks (Houseweart et al. 1982).

T. minutum may be easily recognized by its extremely small size; wings with only one distinct vein and no closed cells; three-segmented tarsi; and its usually yellowish coloration. The only other small wasps that are parasites of the budworm are the metallic Pteromalidae, which emerge from budworm pupae, never from budworm eggs.

Larval Parasites

Diptera: Tachinidae (fig. 34)

Actia interrupta *Curran*—This fly is a very rare parasite of budworm larvae in Maine, although Blais (1965) reported parasitism rates as high as 32 percent in Quebec. Both fifth- and sixth-instar budworms are attacked. The mature parasite maggot emerges from the sixth instar of the host and overwinters as a pupa in the soil.

Adult—This is the smallest tachinid fly (length 5 mm) discussed in this handbook. It may easily be recognized by its bare eyes; all other tachinids that parasitize the spruce budworm have hairy eyes. *Actia* is also unique in having rows of bristle-like setae on the dorsal surfaces of wing veins R_1, R_{4+5} and CuA_1 (fig. 6). The large third antennal segment in Actia is only slightly smaller than the eye when viewed in profile.

Immature Stages—Maggots and puparia of *A. interrupta* have posterior spiracles which are borne on a well-developed, posteriorly projecting process of the last abdominal segment (fig. 21). No other species of parasitic Diptera in this manual have such a structure.

Aplomya caesar (*Aldrich*)—An uncommon parasite of the budworm in Maine, *A. caesar* rarely attacks more than 6 percent of the budworm population. However, Jaynes and

Drooz (1952) have reported parasitism rates as high as 32 percent in New York State, while Blais (1965) has observed 27-percent parasitism in Quebec. Fifth- and sixth-instar budworms are attacked and the parasite emerges from either the sixth instar or the budworm pupa. The parasite overwinters as a pupa in the soil.

Adult—Among the dipteran parasites that emerge from budworm larvae and pupae, the entirely black scutellum will separate *Aplomya* from other adult tachinids with hairy eyes. *Actia interrupta* has a yellowish scutellum but has bare eyes. *Lypha setifacies* also has at least some yellowish coloration on the scutellum but differs from *Aplomya* in having yellow palpi (*Aplomya* has black palpi). See the discussion under *Lypha* for other differences.

Immature Stages—*Aplomya* puparia are similar to those of *Lypha,* which also emerge from budworm larvae; but *Aplomya* puparia have larger posterior spiracles and lack the spiracular groove found in *Lypha* (fig. 22). *Aplomya* may also emerge from the pupa of the budworm and is most similar to puparia of *Omotoma,* which also emerge from budworm pupae. However, *Aplomya* (fig. 24) lacks the ventral protuberance found in *Omotoma* (fig. 23) and has the middle spiracular slit straight, while it is at least slightly bent in *Omotoma* (fig. 24).

Figure 35—*Lypha setifacies* (West), Tachinidae. Another common fly parasite.

Lypha setifacies (*West*) (fig. 35)—This species is probably the most abundant tachinid parasite of spruce budworm in Maine. Jaynes and Drooz (1952) reported that parasitism by this fly increased in Maine from 3 percent in 1950 to 17 percent in 1951. The increase in 1951 was associated with a sudden drop in the budworm population. The life cycle is basically similar to that of *A. interrupta.*

Adult—This tachinid has hairy eyes, a dark-colored scutellum and yellow palpi; a combination of characters not found in other Diptera emerging from budworm larvae. It is most similar to *Aplomya,* but *Lypha* has more and longer setae on the base of wing vein R_{4+5} (fig. 7). In addition, the body of *Lypha* has an overall bronzy sheen, whereas *Aplomya* is black, with little metallic coloration. The third antennal segment is shorter in *Lypha* than in *Aplomya,* but this difference is difficult to appreciate without specimens of both for comparison.

Immature Stages—Puparia of *Lypha* are quite similar to those of *Aplomya,* which may also emerge from budworm larvae. The posterior spiracles are much smaller in *Lypha,* although again this is difficult to ascertain unless the two can be directly compared. In addition, the spiracles of

Lypha are surrounded by a shallow but rather well-defined groove (fig. 22) that is absent in *Aplomya*. The surface of the puparium is rugose in *Lypha* but glossy in *Aplomya*.

Phryxe pecosensis (*Townsend*)—*P. pecosensis* is distributed over a wide geographic area and parasitizes a wide variety of lepidopterous hosts. It is a frequent parasite of the western spruce budworm, *Choristoneura occidentalis* Freeman, but relatively uncommon in Maine populations of spruce budworm. Jaynes and Drooz (1952) reported that mortality due to this parasite reached 27 percent in New York State. Unlike that of *L. setafacies,* increases in *P. pecosensis* parasitism are not associated with decreases in the host population. This fly is active from May to October and produces several generations each year. Parasite larvae emerge from either the sixth instar or pupae of the budworm. Pupation occurs quickly, and a new generation of adults soon emerge to attack alternate hosts. Parasite maggots then overwinter in their alternate hosts.

Adult—Phryxe can be distinguished from other Diptera that emerge from budworm larvae by the yellowish coloration of at least the apex of the scutellum. The only other dipterous parasite with a yellowish scutellum is *Omotoma,* which also has yellowish palpi and hairy parafacials (fig. 17). *Omotoma* emerges only from budworm pupae, while *Phryxe* can emerge from either budworm larvae or pupae. *Actia* has bare eyes and may easily be separated from *Phryxe,* which has hairy eyes.

Immature Stages—The late-instar maggot and puparium of *Phryxe* are easily distinguished by the very distinctive posterior spiracles, which possess four strongly sinuate slits (fig. 20). All other fly parasites of the budworm have only three spiracular slits which are essentially straight.

Hymenoptera: Braconidae

Apanteles fumiferanae *Viereck* (fig. 36)—Five species of *Apanteles* (table 2) and one of *Dolichogenidea*[5] attack budworm in Maine and throughout the Northeast. Mason (l974) has constructed a key to these species, but *A. fumiferanae* Viereck is by far the most common in Maine. Oviposition is believed to occur in first-instar budworms either before or after the budworm spins the hibernaculum. The parasite larva then overwinters in the second- instar budworm and emerges from the fourth-instar budworm, after which it spins a characteristic cocoon on the nearby foliage.

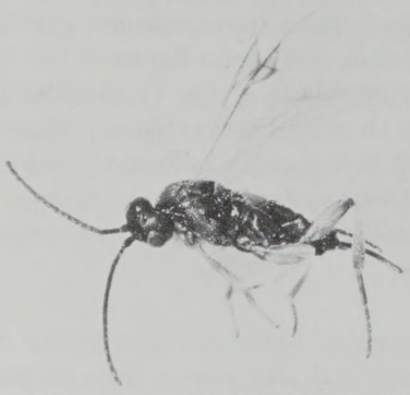


Figure 36—*Apanteles* sp., Braconidae. Note the overall black body coloration, and the relatively short ovipositor.

[5]*Apanteles absona* Meusebeck was recently reclassified as *Dolichogenidea absona* (Meusebeck).

Adult—Apanteles spp. may be easily recognized by their distinctive forewings, which have only four closed cells (fig. 3). The other two common braconids that parasitize the spruce budworm in Maine have five or six closed cells in the forewing. The bodies of *Apanteles* spp. are dark, while both *Meteorus* and *Macrocentrus* have yellowish or light brown bodies. The densely hairy eyes of *Apanteles* are also distinctive. *A. fumiferanae* can be differentiated from other species of *Apanteles* attacking spruce budworm by its bright reddish hind femora and tibiae.

Macrocentrus spp.—These are extremely rare parasites of spruce budworm in Maine, and little is known about the biology of this parasite.

Adult—This yellowish braconid is similar to *Meteorus* in general appearance but has completely bare eyes and six closed cells in the forewing (fig. 5). The two taxa are contrasted below in the following note on *Meteorus*.

Figure 37—*Meterous trachynotus* (Viereck), Braconidae. Note pale body coloration and relatively long ovipositor. *Macrocentrus* is similar in general appearance.

Meteorus trachynotus (*Viereck*) (fig. 37)—This is a common parasite of spruce budworm throughout the Northeast and is well known for its ability to increase in abundance during declining budworm outbreaks (Miller 1963). It attacks fifth- or sixth-instar budworm, emerges from the sixth instar, and pupates on nearby foliage. A new generation of adults appears in late July and early August. It is not clear whether the adults overwinter and attack budworm the following spring or require an alternate host in which to spend the winter. Indications are that this species does require an alternate host, which would limit its ability to increase its populations in response to increasing budworm populations. Miller (1963) reported parasitism rates as high as 80 percent on several plots in Ontario.

Adult—Meteorus has five closed cells in the forewing (fig. 4), an overall yellowish or brownish coloration, and sparsely hairy eyes. It is superficially similar to *Macrocentrus;* however, the latter has six closed cells in the front wing (fig. 5) and bare eyes. In addition, the wing cell $1R_s$ is nearly square in *Meteorus,* but elongate in *Macrocentrus*.

Ichneumonidae

Enytus montanus (*Ashmead*)—*E. montanus* was previously named *Horogenes patens* (Townes). It is a rare parasite that is occasionally found when fourth-instar budworm larvae are dissected. Little is known of its biology.

Figure 38—*Glypta fumiferanae* (Viereck), Ichneumonidae. Note long ovipositor (arrow).

Adult—This wasp is most similar to *Synetaeris tenuifemur,* for both of them are smaller than any of the other more common Ichneumonidae that parasitize the spruce budworm in Maine. *Enytus* has conspicuously orange-yellow legs, while *Synetaeris* has dark legs.

Glypta fumiferanae (*Viereck*) (fig. 38)—This is a common parasite of budworm larvae throughout the Northeast, with a life history very similar to that of *A. fumiferanae*. Miller (1963) postulated that parasitism in the boreal forest type will rarely exceed 20 percent and probably ranges between 10 and 15 percent, with the highest rates corresponding to the peaks in the budworm population.

Adult—This is the largest ichneumonid known to emerge from budworm larvae in Maine. The impressions on tergites 2–4 of the gaster are distinctive, and no other common ichneumonid parasite of the budworm has these impressions. The ovipositor, nearly as long as the gaster, is also distinctive. The other two ichneumonids that emerge from budworm larvae are noticeably smaller than *Glypta,* and both of these have a slender first segment of the gaster, while the first segment is broad in *Glypta*.

Synetaeris tenuifemur *Walley*—A relatively rare parasite in Maine, this wasp has been reported to parasitize up to 60 percent of the budworms on experimental plots in New Brunswick (Miller 1963). *S. tenuifemur* overwinters in a cocoon attached to tree foliage. Adults emerge in early spring and attack second- and third-instar budworms. The host develops very slowly, doing little feeding but remaining alive until August, when the parasite larva emerges and spins its cocoon.

Adult—This species is similar in size to *Enytus* and both species emerge from budworm larvae. Both are much smaller than *Glypta,* the only other ichneumonid commonly emerging from the budworm larva. In addition, both *Enytus* and *Synetaeris* have a slender first segment of the gaster. *Synetaeris* may be easily separated from *Enytus,* which has orange-yellow legs. The front legs in *Synetaeris* may be somewhat yellowish, but the middle and hind legs are always dark.

Pupal Parasites

Diptera: Sarcophagidae

Agria housei *Shewell*—This species is a well-known parasite of western spruce budworm and other Lepidoptera, Orthoptera, and Hymenoptera. *A. housei* was introduced

into eastern Canada in the 1950's (Coppel et al. 1959). Although it may actually be native to Eastern North America, it is rarely found parasitizing Maine budworm pupae. The late-larval or pupal stage of the budworm is attacked, and the parasite maggot then emerges from the host pupa, forms a puparium, and overwinters in the soil. The taxonomic confusion concerning this species was summarized, and resolved, by Shewell (1971).

Adult—The postscutellum, which is flat (fig. 15), will easily distinguish this species from the other flies, all of which are Tachinidae and have an expanded, bulging postscutellum (fig. 14). Also, *A. housei* is the only fly species emerging from budworm pupae that has bare eyes.

Immature Stages—The maggots and puparia of *A. housei* are distinctive in that the posterior spiracles are recessed within a deep cavity on the posterior surface of the last abdominal segment, partly hidden from view. All other dipterous parasites of the spruce budworm have the spiracles on the surface of the last segment and easily visible.

Tachinidae

Omotoma fumiferanae (*Tothill*)—This species is well known as a parasite of both the western spruce budworm and the spruce budworm in Maine. It attacks and emerges from the budworm pupa. About 25 percent of the parasite pupae develop into adults the first year. Their fate is unknown. The other 75 percent overwinter in the soil (Coppel and Smith 1957).

Adult—This is the largest parasitic fly that emerges from the spruce budworm in Maine, although some smaller individuals may overlap in size with other tachinid parasites. *Omotoma* has distinctive light brownish to yellowish coloration on the scutellum, and thus is similar only to *Phryxe* among the pupal parasites. It differs from *Phryxe* in having yellow palpi and hairy parafacials (fig. 17). *Phryxe* has dark palpi and bare parafacials (fig. 16).

Immature Stages—The puparium of *Omotoma* is quite similar to that of *Aplomya,* which may also emerge from the budworm pupa. The protuberance below the posterior spiracles (fig. 23) and the bent middle spiracular slit (fig. 23) will usually serve to identify *Omotoma*. Poorly developed puparia may be difficult to distinguish because the protuberance may not be well formed.

Figure 39—*Ephialtes ontario* (Cresson), Ichneumonidae. Note that ovipositor is hooked near tip, middle tarsi are not banded (arrows).

Hymenoptera: Ichneumonidae

Ephialtes ontario (*Cresson*) (fig. 39)—Jaynes and Drooz (1952) reported that this parasite was fairly common in

Maine during the years 1949–51. It appears to be most abundant during the early years of a spruce budworm outbreak. *E. ontario* attacks and emerges from the budworm pupa. It overwinters as a larva in a variety of alternate hosts.

Adult—This genus can be separated from other Ichneumonidae that emerge from spruce budworm pupae by the yellowish coloration on the face. In the male, the face is completely yellow; in the female, the face is yellowish only along the margins of the eyes. In *Phaeogenes* the areas lateral to the antennae may be pale brownish, but the markings are not as well developed as they are in *Ephialtes*. *Ephialtes* is quite similar in appearance to *Itoplectis,* but pale abdominal bands are reduced or lacking in *Ephialtes,* the tip of the ovipositor is hooked downward (fig. 12), and the middle tarsi are not banded as they are in *Itoplectis*.

Figure 40—*Itoplectis conquisitor* (Say), Ichneumonidae. Note that tip of ovipositor is straight, and middle tarsi are distinctly banded (arrows).

Itoplectis conquisitor (*Say*) (fig. 40)—*I. conquisitor* is a well-known parasite that attacks a wide range of moth species (Miller 1963). Although rare as a parasite of the budworm in Maine, *I. conquisitor* has been reported parasitizing 8 percent of the budworm in New York State (Jaynes and Drooz 1952). It attacks and emerges from budworm pupae and probably overwinters in an alternate host.

Adult—This genus is quite similar in appearance to *Ephialtes* but differs from it in that the face of both sexes is entirely black, the end of the ovipositor straight (fig. 13), and the middle tarsi strongly and distinctly banded. In addition, the abdomen is conspicuously marked with narrow, transverse, light bands.

Figure 41—*Phaeogenes maculicornis hariolus* (Cresson), Ichneumonidae. Note that ovipositor is very short, and antennae have a distinct white band near the middle (arrows).

Phaeogenes maculicornis hariolus (*Cresson*) (fig. 41)—This taxon was previously known as *P. hariolus* but was recently reduced to a subspecies of *P. maculicornis*. It is occasionally found parasitizing Maine budworm in moderately high numbers. It is particularly abundant during the later stages of budworm outbreak, unlike *E. ontario,* which tends to be more common during the outbreak's earlier stages. *P. maculicornis* overwinters as an adult and probably does not require an alternate host.

Adult—This species can be distinguished from other ichneumonid parasites of budworm pupae by the reddish coloration on the base of the rather short, stout abdomen. It has very short ovipositor sheaths. The white band near the middle of the antenna is also quite distinctive.

Figure 42—*Mesopolobus verditer* (Norton), Pteromalidae. The two common pteromalids that parasitize the spruce budworm are similar in general appearance. Note the short, elbowed antennae and the wings which have only one distinct vein.

Pteromalidae

Mesopolobus verditer (*Norton*) (fig. 42) **and Psychophagus tortricis (*Brues*)**—These strikingly colored wasps are rarely reared from budworm pupae in Maine. However, when they are present, as many as a dozen of this polyembryonic species may emerge from the same budworm pupa. Some taxonomists believe that these wasps are hyperparasitic on certain pupal parasites of the budworm, while others believe them to be primary parasites. Both views may be correct, since these wasps may behave differently in different situations.

Adult—Both species of Pteromalidae that emerge from spruce budworm pupae are small (less than 3 mm), and are bright, metallic green wasps. This coloration easily separates them from the other Hymenoptera (all ichneumonids) that emerge from budworm pupae. Ichneumonids are much larger and mostly black. *M. verditer,* with three ring segments on its antennae (fig. 10) is easily separated from *P. tortricis,* which has only two (fig. 11).

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General External Morphology of a Parasitic Wasp

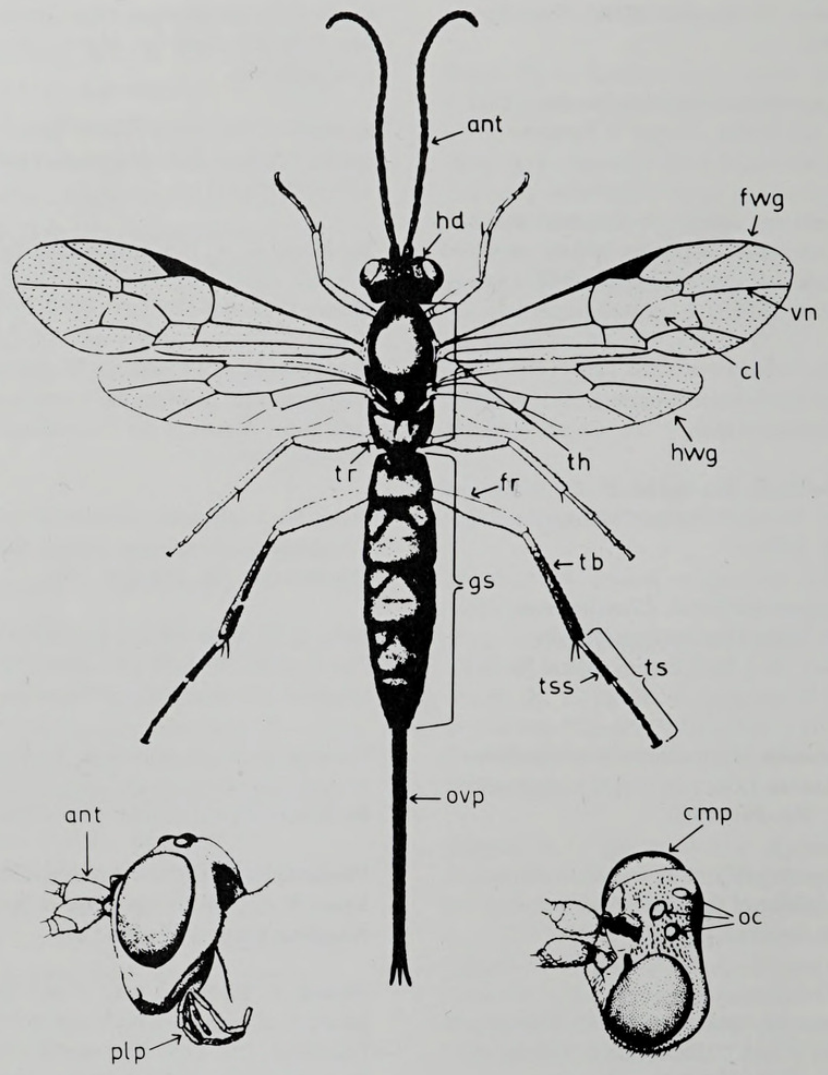

Figure 43.

Figure 43 (from Brown 1946b) represents the external morphology of the parasitic wasp *Glypta fumiferanae* (Viereck). We include it as a refresher on the anatomical structures typical of such parasites and mentioned elsewhere in this manual. Key to abbreviations: ant = antenna, cl = cell, cmp = compound eye, fr = femur, fwg = forewing, gs = gaster, hd = head, hwg = hindwing, oc = ocelli, ovp = ovipositor, plp = palpi, tb = tibia, th = thorax, tr = trochanter, ts = tarsi, tss = tarsal segment, vn = vein.

Glossary

Abdomen—the hindmost of an insect's three main body divisions.

Antennal ring segments—from one to three markedly compressed segments immediately following the second antennal segment in some Hymenoptera.

Anterior—at or situated in front; foremost; opposed to posterior.

Apex—that part of any joint or segment opposite the base by which it is attached; that point of a wing farthest from the base or at the end of the costal area.

Basal—at or pertaining to the base or point of attachment to or nearest the main body.

Bilobed—divided into two lobes, the lobes often rounded.

Caudal—of or pertaining to the tail or anal end of the insect body.

Cell—a space in an insect wing partly or completely surrounded by veins.

Density-dependent factor—a controlling factor that is governed by the density of the population controlled.

Diapause—spontaneous state of dormancy during an insect's developmental period.

Dorsal—of or pertaining to the upper surface.

Eclosion—emergence of the adult insect from the pupa; the act or process of hatching from the egg.

Emarginate—notched; with an obtuse, rounded or quadrate section cut out from a margin.

Endemic population—normal, low level of a population as opposed to epidemic or outbreak.

Femur (pl., femora)—the leg segment between the trochanter and tibia.

Gaster—the remaining part of the abdomen posterior to the constricted first abdominal segment in Hymenoptera.

Hibernaculum—the small silken web in which second-instar spruce budworms spend the winter.

Host—the organism in or on which a parasite lives; and the plant on which an insect feeds.

Hyperparasite— parasite that parasitizes (attacks, kills) another parasite.

Instar—the period or stage between molts in the larva, numbered to designate the various periods (e.g., the second-instar larva is the stage between the first and second larval molts).

Lateral—relating, pertaining, or attached to the side.

Medial—referring to, or at the middle.

Oral—pertaining to the mouth.

Ovipositor—the egg-laying appendage.

Palpus (pl., palpi)—small, antennalike appendages of an insect's mouthparts.

Parafacial region—in Diptera, the region between the face and the anterior margin of the eye on either side.

Parasite—an animal that lives in or on the body of another animal, at least during part of its life cycle.

Petiole—basal stalk of abdomen in Hymenoptera.

Polyembryony—the case in which a single egg develops into more than one offspring.

Posterior—at or situated behind; hindmost; opposed to anterior.

Prepupa—a quiescent instar between the end of the larval period and the pupal period proper.

Protuberance—any elevation above the surface; a swelling.

Pupa (pl., pupae)—the resting, inactive instar in insects with complete metamorphosis; the intermediate stage between the larva and the adult stages of such an insect.

Puparium (pl., puparia)—in higher Diptera, the thickened, hardened, barrellike larval skin within which the pupa is formed.

Rudiment—the beginning of any structure or part before it has developed.

Rugose—wrinkled, marked with coarse elevations.

Sclerite—a hardened body wall plate, usually bordered by sutures or membraneous areas.

Scutellum—a dorsal, thoracic sclerite posterior to the mesonotum.

Segment—a subdivision of the body or an appendage, between joints or articulations.

Seta (pl., setae)—a rather short, stiff, pointed hair.

Sinuate—wavy, specifically referring to edges or margins, or referring to wing veins.

Spiracle—an external opening of the insect's respiratory (tracheal) system.

Tarsus (pl., tarsi)—the part of the leg beyond the tibia, usually consisting of two to five divisions.

Tergite—a sclerite on the upper surface of an insect's body.

Thorax—the body region behind the head which bears the legs and wings.

Tibia (pl., tibiae)—the leg segment between the femur and the tarsus.

Transverse—running across; intersecting the longitudinal axis at right angles.

Ventral—pertaining to the under or lower surface.

Table 1—Host stage preference and relative abundance of spruce budworm parasites in Maine[1]

Classification	Stage of host[2]		Relative abundance			Reference
	Attack	Emergence	Rank[3]	Percent	Comments	
Hymenoptera						
Braconidae						
Meteorus trachynotus (Vier.)	L_5 L_6	L_6	U	0.4–35	4,5	Blais (1965)
Apanteles fumiferanae Viereck	L_1	L_5 L_6	A	15–28		Brown (1946a)
Macrocentrus spp.			R	0–1		Lewis (1960)
Ichneumonidae						
Ephialtes ontario (Cress.)	P	P	C	1–20		Blais (1965)
Itoplectis conquisitor (Say)	P	P	R	0–3		Blais (1960)
Phaeogenes maculicornis hariolus (Cress.)	P	P	U	1–15		
Glypta fumiferanae (Vier.)	L_1 L_2	L_5 L_6	U	2–11	5	Brown (1946a) Lewis (1960)
Synetaeris tenuifemur Walley	L_1 L_3	L_4	R	0–1	4,5	Miller and Renault (1963)
Enytus montanus (Ashmead)	L_4	L_5 L_6	R	0–1		
Pteromalidae						
Psychophagus spp.	P				6	
Amblymerus spp.	P				6	
Trichogrammatidae						
Trichogramma minutum Riley	E	E	A	2–34		Thomas (1966), Kemp and Simmons (1978), Houseweart et al. (1982)
Diptera						
Tachinidae						
Lypha setifacies (West)	L_5 L_6	L_6	U	1–17	4	Brooks (1945)
Actia interrupta Curran	L_5 L_6	L_6	R	0–1	4,5	Blais (1965)
Omotoma fumiferanae (Toth.)	L_5 L_6	P	U	0–3		Coppel and Smith (1957)
Aplomya caesar Aldr.	L_5 L_6	L_6, P	U	2–6	4,5	
Phryxe pecosensis (Tnsd.)	L_5 L_6	L_6, P	U	1–12	5	Maw and Coppel (1953)
Sarcophagidae						
Agria housei Shewell	L_5 L_6, P	P	U	1–5		Coppel et al. (1959)

[1]Adapted from Dearborn (1980).

[2]E = egg; L^1 = first larval stage, L^2 = second larval stage, etc.; P = pupa.

[3]Parasite population survey data for Maine were averaged from data reported by Jaynes and Drooz (1952), Thomas (1966), and Bradbury (1978).
R (rare) = 0–2% parasitism rate
U (uncommon) = 3–9% parasitism rate
C (common) = 10–14% parasitism rate
A (abundant) = 15% or greater parasitism rate

[4]Percent parasitism has been known to increase significantly in periods of declining budworm populations.

[5]Although it is uncommon or rare in Maine, this parasite has been shown to be abundant in other areas of the Northeast.

[6]Suspected of being hyperparasites.

Table 2—Insect parasites reported parasitizing spruce budworms (*C. fumiferana and C. occidentalis*) in North America

A. Diptera known to parasitize the spruce budworm[1]

Taxon	*Comments*
Muscidae	
Muscina stabulans (Fallén)	Europe, USSR, Alaska–Newfoundland, Southern Georgia, and Arizona
Phoridae	
Megaselia spp.	
Sarcophagidae	
Agria housei Shewell	
Sarcophaga aldrichi Parker	
Sarcophaga cooleyi Parker	
Tachinidae[2]	
Actia interrupta Curran	
Aplomya caesar (Aldrich)	
Ceromasia auricaudata Townsend	Western; but introduced and may be established in Manitoba, Newfoundland, and New Brunswick
Ceromasia aurifrons Townsend	
Compsilura concinnata (Meigen)	Introduced and established
Hemisturmia tortricis (Coquillett)	
Lypha setifacies (West)	
Madremyia saundersii (Williston)	
Nemorilla pyste (Walker)	
Omotoma fumiferanae (Tothill)	
"Phorocera" incrassata Smith	Western; introduced and may be established in Ontario, New Brunswick, and Newfoundland
Phryxe pecosensis (Townsend)	
Phyrxe vulgaris (Fallén)	
Pseudoperichaeta erecta (Coquillett)	
Sturmia spp.	Recorded from New Brunswick, Quebec
Tachinomyia nigricans Webber	
Winthemia spp.	Recorded from British Columbia, New Brunswick
Xanthophyto spp.	

B. Hymenopterous parasites of the spruce budworm[3]

Taxon	*(Comments*
Chalcidoidea	
Eulophidae	
Dicladocerus spp.	
Syntomosphyrum esurus (Riley)	
Elachertus aeneoniger Girault	Collected from endemic level budworm populations in Vermont[4]
Chalcididae	
Brachymeria intermedia (Nees)	Introduced in Maine, possibly established[5]
Pteromalidae	
Habrocytus phycidis Ashmead	
Mesopolobus milleri (Crawford)	Western States only
Mesopolobus verditer (Norton)	
Psychophagus omnivorus (Walker)	
Psychophagus tortricis (Brues)	
Torymidae	
Monodontomerus minor (Ratzeburg)	From Connecticut and New York, south; west to California; Europe

[1]Coppel (1960).
[2]Arnaud (1978).
[3]Krombein et al. (1979).
[4]Hanson (1982).
[5]Leonard (1975).

Ichneumonoidea			
Braconidae			
Agathis acrobasidis (Cushman)	New Jersey and North Dakota, south		
Agathis binominata Muesebeck			
Apanteles aristoteliae (Viereck)			
Apanteles fumiferanae Viereck			
Apanteles morrisi Mason			
Apanteles petrovae Walley			
Apanteles polychrosidis Viereck			
Bracon cushmani (Muesebeck)	Pennsylvania, south		
Bracon politiventris (Cushman)			
Charmon gracilis (Provancher)			
Clinocentrus fumiferanae Muesebeck	New York, Minnesota		
Dolichogenidea absona (Muesebeck)			
Macrocentrus iridescens French			
Macrocentrus peroneae Muesebeck			
Meteorus ruficeps (Nees)	Introduced; probably not established		
Meteorus trachynotus Viereck			
Microgaster canadensis Muesebeck			
Oncophanes americanus (Weed)			
Orgilus lateralis (Cresson)			
Ichneumonidae			
Acropimpla alboricta (Cresson)			
Campoplex spp.	Collected from endemic level budworm populations in Vermont[4]		
Chorinaeus excessorius Davis			
Chorinaeus longicalcar Thomson			
Enytus montanus (Ashmead)	Previously known as *Horogenes patens* Townes		
Ephialtes annulicornis (Cresson)			
Ephialtes ontario (Cresson)			
Exeristes comstockii (Cresson)			
Exochus nigripalpis tectulum Townes			
Gelis spp.	Collected from endemic level budworm populations in Vermont[4]		
Glypta fumiferanae (Viereck)			
Ischnus inquisitorius atricollaris (Walsh)			
Ischnus minor Townes			
Itoplectis conquisitor (Say)			
Itoplectis evetriae Viereck			
Itoplectis quadricingulata (Provancher)			
Mastrus laplantei Mason			
Mesochorus sylvarum Curtis	Collected from moderate and endemic level populations in Vermont[4]		
Parania geniculata (Holmgren)			
Phaeogenes maculicornis hariolus (Cresson)			
Phytodietus fumiferanae Rohwer	Introduced in eastern Canada but apparently not established		
Pimpla [Coccygomimus] tenuicornis Cresson	Reared from moderate level budworm populations in Vermont[4]		
Pterocormus gestuosus (Cresson)			
Scambus decorus Walley			
Scambus hispae (Harris)			
Stictopisthus flaviceps (Provancher)	Reared from endemic level budworm populations in Vermont[4]		
Syspasis tauma (Heinrich)			
Theronia atalantae fulvescens (Cresson)			
Tranosema rostrale (Brischke)			
Trichogrammatidae			
Trichogramma minutum Riley			