Under these conditions we have produced seven generations in 23 months.

Acknowledgments

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HYMENOPTEROUS PARASITES OF THE HEMLOCK SAWFLY, *NEODIPRION TSUGAE* MIDDLETON, IN SOUTHEAST ALASKA, WITH A KEY TO LARVAL REMAINS

TOROLF R. TORGERSEN[1]

ABSTRACT

A key is supplied to identify parasitic Hymenoptera reared from hemlock sawfly cocoons in southeast Alaska. The key is based on the size of the exit hole in the host cocoon, and characters visible on the final-instar larval skin. Brief biological and descriptive notes are given for each species appearing in the key.

Introduction

The hemlock sawfly, *Neodiprion tsugae* Middleton, is an important defoliator of western hemlock, *Tsuga heterophylla* (Raf.) Sarg., in southeast Alaska. Heavy defoliation occurred during the early 1950's (Downing, 1957) and 1960's (Crosby, 1965). Usually epidemics are severe for only a year or two, but noticeable defoliation may continue for several years. Although outbreaks may subside with little immediate effect, top-killing and whole-tree mortality sometimes occur. This is especially true when the sawfly is found in association with or following infestations of the black-headed budworm, *Acleris variana* (Fernald) (Downing, 1959).

The parasite species reared from hemlock sawfly cocoons in Alaska were listed by Torgersen (1968). The paper includes a key to the parasite adults and notes on the abundance of each species. No dipterous parasites have been reared from the sawfly.

The following key, based on the appearance of mature larval remains and host cocoon, includes all but three of the parasite species reared from the sawfly in Alaska to date. The species were omitted because final-instar larval remains were not

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available for study. The parasites included in the following key are: *Amblymerus verditer* (Norton) (Pteromalidae); and *Itoplectis quadricingulatus* (Provancher), *Delomerista japonica diprionis* Cushman, *Rhorus* sp., *Lamachus* spp., *Mastrus* spp., and *Opidnus tsugae tsugae* (Cushman) (Ichneumonidae).

KEY TO PARASITES OF THE HEMLOCK SAWFLY BASED ON COCOON AND FINAL-INSTAR LARVAL REMAINS

1. Parasite exit hole in host cocoon less than 0.92 mm in diameter; final-instar cephalic structure apparently limited to mandibles (Fig. 1) ..... **Amblymerus verditer**

   Parasite exit hole greater than 0.94 mm in diameter; final-instar cephalic structure complete or nearly so (Figs. 2-7) 2

2(1). Final-instar cephalic structure with epistoma, pleurostomae, hypostomal spurs, and venter of labial sclerite approximating a ring; hypostomae absent (Fig. 7); spiracles as in Fig. 13 ..... **Itoplectis quadricingulatus**

   Final-instar cephalic structure not as above; hypostomae present (Figs. 2-6) 3

3(2). Vertex of final-instar head capsule with four heavily sclerotized areas; blade of mandible with a large tooth basally (Fig. 3); atrium of spiracle funnel-shaped (Fig. 10) ..... **Delomerista japonica diprionis**

   Vertex of final-instar head capsule without noticeable heavily sclerotized areas; blade of mandible without a large tooth basally (Figs. 2, 4-6); atrium not as above 4

4(3). Blades of mandibles very short (Fig. 4) ..... **Rhorus** sp.

   Blades of mandibles well developed (Figs. 2, 5, 6) 5

5(4). Labial sclerite incomplete ventrally; medial face of dorsal arms expanded and serrated; antennal socket only present (Fig. 5) ..... **Lamachus** spp.

   Labial sclerite complete ventrally; dorsal arms not markedly expanded or serrated; antennae present (Figs. 2, 6) 6

6(5). Stalk of spiracle longer than diameter of atrium (Fig. 9); cephalic structures as in Fig. 2 ..... **Mastrus** spp.

   Stalk of spiracle shorter than diameter of atrium (Fig. 12); cephalic structures as in Fig. 6 ..... **Opidnus tsugae tsugae**

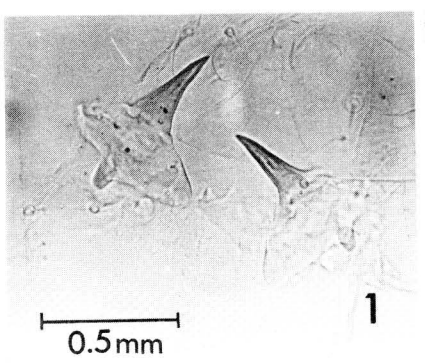
Methods

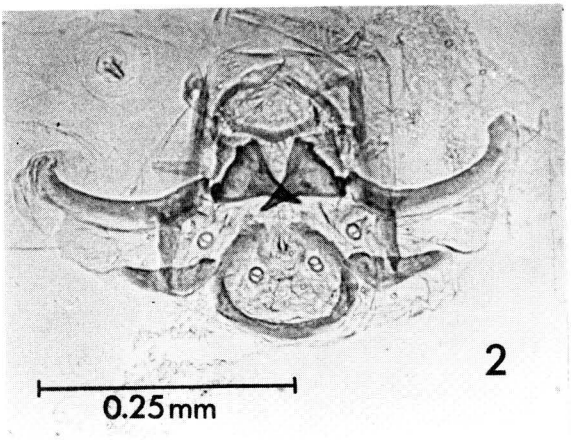
Collections of sawfly eggs, larvae, and cocoons were made at several locations in southeast Alaska from 1964 through 1967. Branches with sawfly eggs were collected in May, and larval collections were made at intervals during the larval development period from about mid-June to mid-August. Cocoons were collected throughout the year to obtain all life stages of parasites.

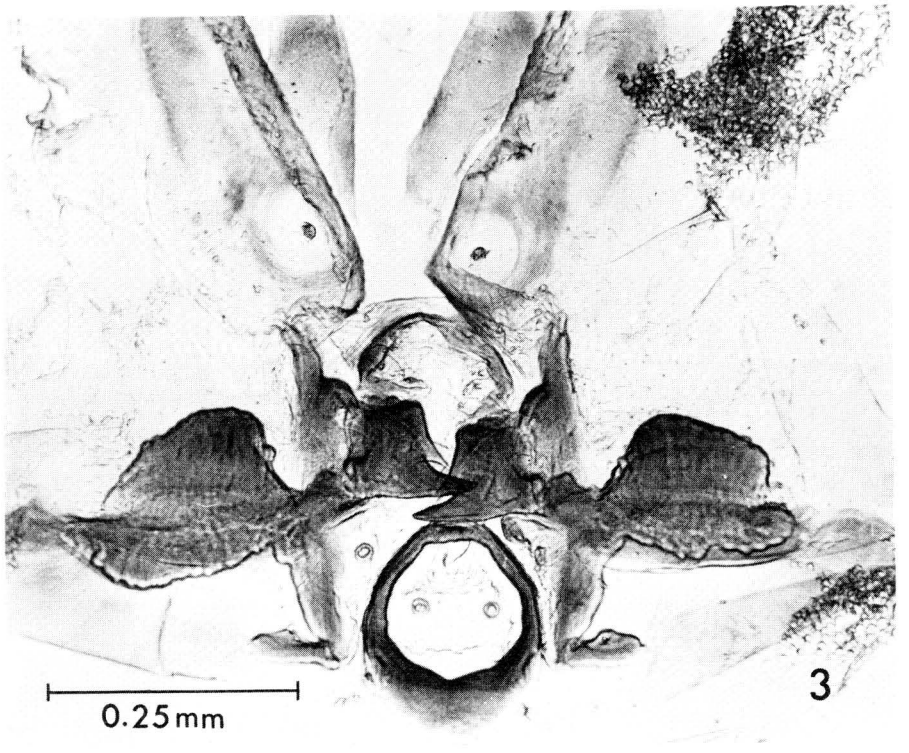
In the laboratory, egg-bearing branches were placed in plastic rearing cages at room temperature. Larvae were placed in rearing cages containing fresh hemlock foliage which was replaced as needed. Cages were examined daily and dead or moribund larvae removed along with newly formed cocoons. Mortality was recorded, and moribund larvae and the cocoons were placed in individually coded gelatine capsules. Capsules were kept in controlled temperature cabinets at 16 or 21°C. Field-collected cocoons also were put in capsules and placed in cabinets. Fall-collected cocoons were kept at 7°C for 30 to 60 days before transferring them to the warmer cabinets. Emerging parasites were removed daily, identified, and the emergence data recorded by species. Parasites were kept with the cocoons from which they emerged.

Information on host and parasite remains was obtained from dissections of cocoons from which known species of parasites emerged. Data such as size and shape of exit hole, color and shape of parasite cocoon, disposition of meconium and parasite larval and host remains, and other pertinent observations were noted.

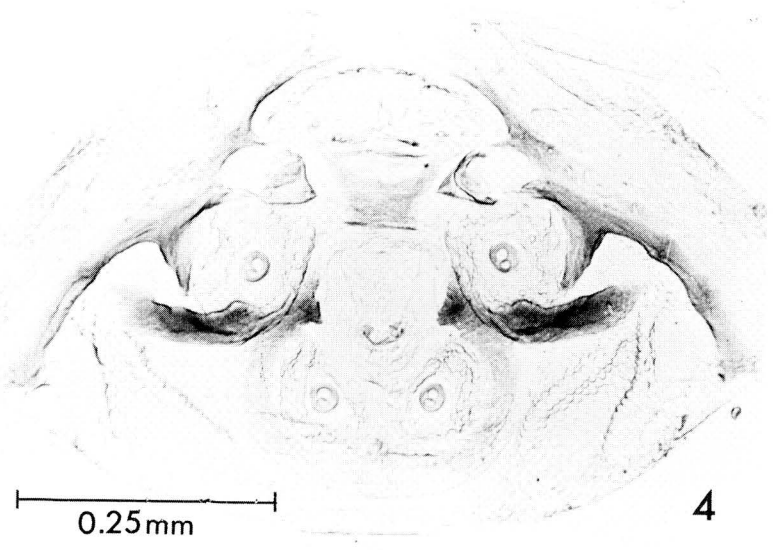
Mature parasite larval remains were mounted on microscope slides for study. Parasite larval skins were first thoroughly wetted by dipping in 95% ethanol, then soaked in a 10% potassium hydroxide solution for 15

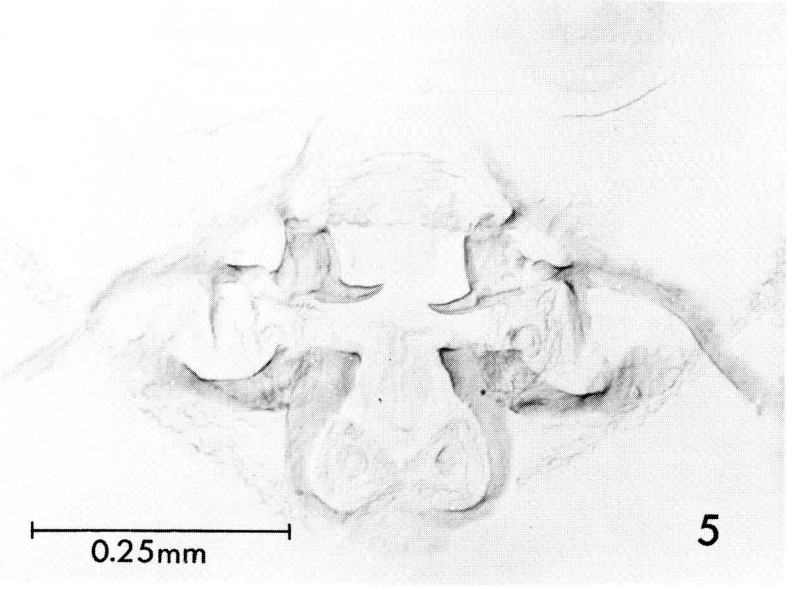




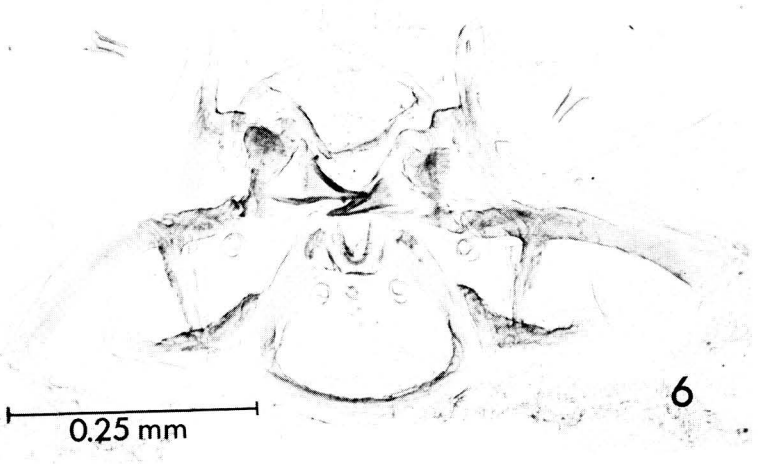


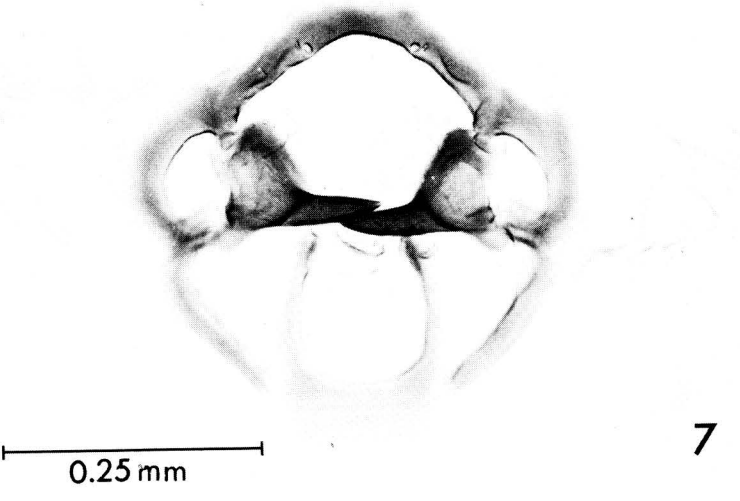
Figs. 1-3. Final-instar cephalic structures: 1, **Amblymerus verditer** (Norton); 2, **Mastrus** sp.; 3, **Delomerista japonica diprionis** Cushman



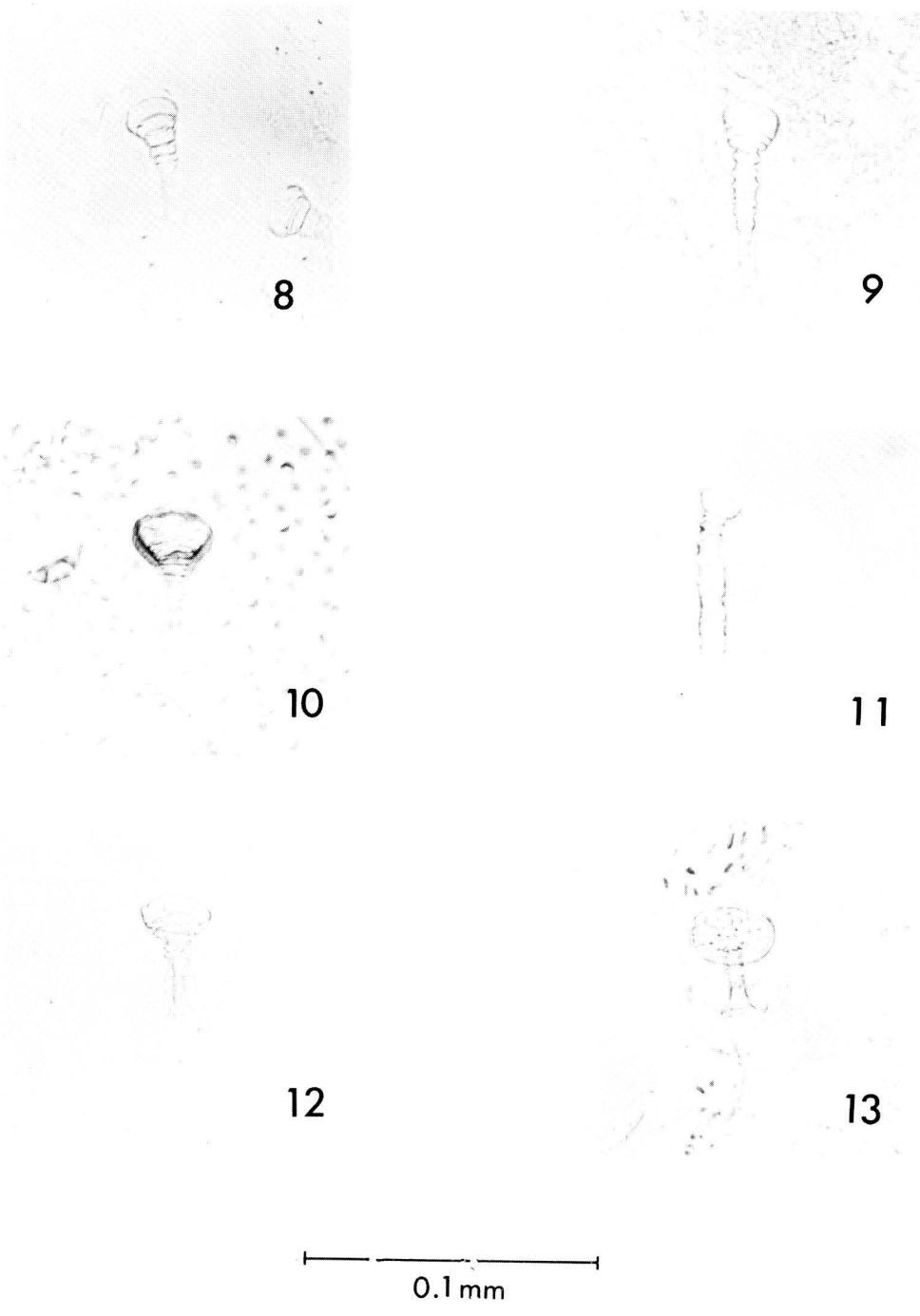


Figs. 4-5. Final-instar cephalic structures: 4, **Rhorus** sp.; 5, **Lamachus** sp.

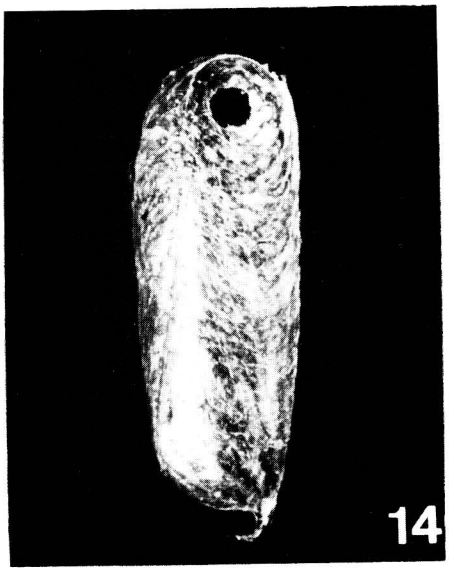


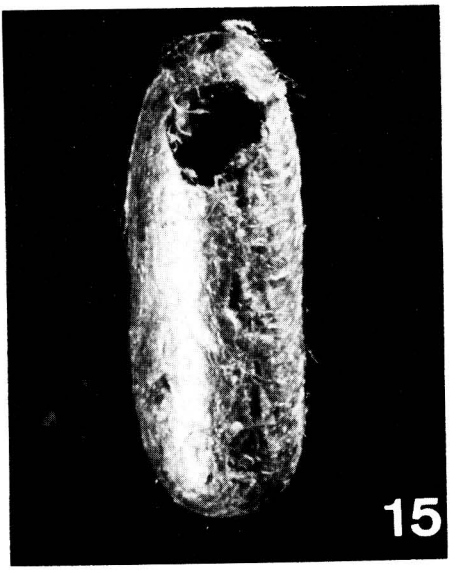


Figs. 6-7. Final-instar cephalic structures: 6, **Opidnus tsugae tsugae** (Cushman); 7, **Itoplectis quadricingulatus** (Provancher).



Figs. 8-13. Spiracles of final-instar larvae: 8, **Amblymerus verditer** (Norton); 9, **Mastrus** sp.; 10, **Delomerista japonica diprionis** Cushman; 11, **Lamachus** sp.; 12, **Opidnus tsugae tsugae** (Cushman); 13, **Itoplectis quadricingulatus** (Provancher).





Figs. 14-15. Parasite exit holes in cocoons of **Neodiprion tsugae** Middleton: 14, exit hole of **Amblymerus verditer** (Norton); 15, exit hole of **Opidnus tsugae tsugae** (Cushman).

to 30 minutes, or until the skin was soft enough to manipulate. No staining was done; the softened skin was washed in water and mounted on a microscope slide in a nonresinous mounting medium (Turtox CMC-10). Photographs of the cephalic structures and spiracles were taken using a trinocular compound microscope fitted with a 35mm camera.

Biological and Descriptive Notes

Amblymerus verditer (Norton)

A. verditer (Figs. 1, 8, and 14) usually occurred as a secondary parasite of the sawfly. This species was a primary parasite in 10 cases out of 94 studied. The primary parasites on which *A. verditer* developed were *Opidnus tsugae tsugae, Itoplectis quadricingulatus,* and *Lamachus* spp. Furniss and Dowden (1941) listed *A. verditer* as a parasite whose role as a primary or secondary was uncertain.

Laboratory emergence of *A. verditer* occurred from mid-August through early September, from cocoons collected in the field from early May through mid-August. This species was usually a solitary parasite, but multiple emergences of up to 11 individuals from the same cocoon were recorded.

A single exit hole (Fig. 14), rarely two, is cut in the sawfly cocoon even when multiple emergence is involved. The nearly round hole is ca. 0.8 mm (0.7-0.9 mm) in diameter; subapical, sometimes apical or on the side. No parasite cocoon is constructed. The white final-instar larval skin is usually closely associated with the fractured, honey-colored pupal skin. *A. verditer* remains are found in the sawfly cocoon with the primary parasite larval or pupal remains.

Final-instar cephalic structure with only mandibles clearly visible (Fig. 1); antennae prominent. The final-instar larval remains of *A. verditer* were described and illustrated by Finlayson (1960b).

Itoplectis quadricingulatus (Provancher)

I. quadricingulatus (Figs. 7, 13) oviposits on sawfly larvae in cocoons; rarely, the host is a pupa. Cocoons collected in the field produced parasites by the first week in June, and adults were collected in the field by the third week in June. Field-collected cocoons obtained as late as mid-August produced parasites in the laboratory within 2 or 3 weeks. Considering the long period over which *I. quadricingulatus* emerges during the summer, it is possible that this species is multivoltine in Alaska. This possibility was suggested by Furniss and Dowden (1941) who collected this species in Oregon. *I. quadricingulatus* is also a parasite of the black-headed budworm, *Acleris variana,* in Alaska.

Exit hole roughly round, ca. 1.6 mm (1.1-2.2 mm) in diameter. Margin jagged, with slivers of cocoon attached to the edge or loose inside the cocoon. Parasite cocoon thin, semitransparent, light brown or white; laid down inside of and closely appressed to host cocoon, or may be limited to a silken disc covering the host remains. Host remains are at end of cocoon opposite exit hole or adjacent to it. Final-instar larval remains loosely associated with meconium at end of cocoon opposite exit hole; sometimes absent.

Final-instar cephalic structure characterized by lack of hypostomal arms; general aspect suggests a sclerotized ring surrounding the mandibles (Fig. 7). Atrium of spiracle flattened above and below, with a scattering of projections on the inner wall. A short stalk leads to a well-developed closing apparatus (Fig. 13).

Delomerista japonica diprionis Cushman

D. japonica diprionis (Figs. 3, 10) parasitizes the hemlock sawfly larva within the cocoon. According to Furniss and Dowden (1941), this parasite is univoltine; the egg is laid externally on the larva and the winter is passed as a mature larva. In Alaska, adults in flight have been collected on 23 June, and the latest adult emergence from field-collected cocoons was early August.

Mean diameter of emergence hole is ca. 1.6 mm (1.0-2.2 mm). Exit hole round or oval; situated with at least its margin reaching the apex, sometimes subapical; margin jagged with crescent-shaped pieces of cocoon loosely attached. Host remains are near exit hole or at opposite end of cocoon. Parasite cocoon apparently absent, represented only by a dark brown silken cap walling off the host remains. Parasite remains consist of a dark final-instar exuvium and a lighter yellow or cream pupal skin, one or both of which may be missing.

Final-instar head capsule typified by having four heavily sclerotized areas on the vertex. Cephalic structures heavily sclerotized; hypostomae well developed; blade of mandible with a heavy tooth basally (Fig. 3). Atrium funnel-shaped, opening into a well-defined closing apparatus (Fig. 10). Skin with conspicuous setae. The final-instar cephalic structure and spiracles were described and illustrated by Finlayson (1960a).

Rhorus sp.

A single specimen of *Rhorus* (Fig. 4) was reared from a sawfly cocoon collected 30 July 1963.

Exit hole round with a jagged margin; 1.5 mm in diameter; subapical. Parasite cocoon thin, silky white, laid down on wall of host cocoon. Sawfly larval remains walled off outside of parasite cocoon. Parasite remains associated with the meconium at opposite end from exit hole.

Final-instar cephalic structure

characterized by mandibles with poorly developed blades, incomplete epistoma, and lightly sclerotized labial sclerite with dorsal arms bearing serrations medially (Fig. 4). Larval skin with pebbled surface; no spiracles were found.

Lamachus spp.

Lamachus spp. (Figs. 5, 11) reared from the hemlock sawfly were identified by taxonomists as *Lamachus* sp., or *Lamachus tsugae* or a new species near it. According to Furniss and Dowden (1941), *L. tsugae* Cushman and *L. oregon* Cushman (= *L. angularis* (Davis)) are parasites of *Neodiprion tsugae* in Oregon. Their studies indicated that *L. oregon* and *L. tsugae* parasitized late-instar larvae and emerged from the cocoon the following spring.

In Alaska, no sawflies collected as larvae yielded parasites in this genus. However, dissections of late-instar larvae revealed the presence of *Lamachus* larvae within them. Field-collected cocoons had parasites emerging from early June through early July. Cocoons containing sawfly larvae parasitized by *Lamachus* spp. were collected by late July.

Exit hole very jagged with some slivers hanging from the margin; ca. 1.6 mm in diameter (1.4-1.9 mm); margin reaching apex of cocoon. Host a larva; remains closely appressed to inside of its cocoon. A thin white parasite cocoon is laid down inside of host cocoon. Final-instar larval and pupal remains are associated with the meconium at opposite end of cocoon from exit hole. Final-instar cephalic structure with labial sclerite incomplete ventrally, and with expanded and serrated dorsal arms (Fig. 5). Atrium of spiracle small, little larger than stalk (Fig. 11).

Mastrus spp.

All specimens of *Mastrus* spp. (Figs. 2, 9) collected were solitary parasites of larvae, and sometimes pupae. The earliest collection date for sawfly cocoons from which *Mastrus* emerged was 2 September. The specimens of *Mastrus* spp. collected in this study were classified by taxonomists as *Mastrus* sp., *Mastrus* sp. nr. *argeae* (Vier.), and *Mastrus* sp. ? n.

Exit hole regular or slightly irregular in outline; diameter ca. 1.2 mm (1.2-1.4 mm); margin reaching to apex or slightly below. Parasite cocoon the same size and shape as host cocoon; dark brown to buff; sometimes two-layered with inside layer lighter in color.

Final-instar cephalic structure (Fig. 2) resembles *Opidnus tsugae tsugae* (Fig. 6), but smaller; width of labial sclerite ca. 0.15 mm (0.14-0.17 mm). Stalk of spiracle longer than diameter of atrium Fig. 9).

Opidnus tsugae tsugae (Cushman)

O. tsugae tsugae (Figs. 6, 12, and 15) is the most common parasite reared from sawfly cocoons in Alaska (Torgersen, 1968). The host within the cocoon is usually a larva, but in about 5 percent of the dissections, pupal host remains were found. Furniss and Dowden (1941) recorded this species under the name *Aptesis* (*Pezoporus*) *tsugae* Cush., as a parasite of the sawfly in Oregon. They indicated that it was apparently multivoltine and attacked cocoons containing the prepupa.

In Alaska, *O. tsugae tsugae* adults are in flight by early June. Laboratory emergence from cocoons collected during June was complete by the first week in July. The following year's brood are present in cocoons collected in mid-August.

Exit hole roughly round or larger in one dimension; mean diameter ca. 1.4 mm (1.1-1.9 mm). Margin of exit

hole jagged, usually with pieces of cocoon adhering to it (Fig. 15). Hole situated apically or subapically. Parasite cocoon thin, laid down as a layer on inside of host cocoon; host remains are walled off outside parasite cocoon. Parasite final-instar remains are closely associated with the meconium.

Final-instar cephalic structure (Fig. 6) similar to *Mastrus* spp. (Fig. 2), but larger; width of labial sclerite in *O. tsugae tsugae* ca. 0.20 mm (0.17-0.22 mm). Stalk of spiracle shorter than diameter of atrium (Fig. 12).

Acknowledgments

The author gratefully acknowledges the assistance of Miss L. M. Walkley of the Insect Identification and Parasite Introduction Branch, Agricultural Research Service, U.S.D.A., Washington, D.C., for identifying many of the parasites collected in connection with this study; and (Mrs.) Christine Andrew for assisting with slide preparations and photomicrographic work.

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FINAL-INSTAR LARVAE OF TWO HYMENOPTEROUS PARASITES OF A WOOD-BORING BEETLE, *TETROPIUM VELUTINUM* LECONTE (COLEOPTERA: CERAMBYCIDAE)

THELMA FINLAYSON[1]

ABSTRACT

Characteristics of the cephalic structures, spiracles and skin of final-instar larvae of two hymenopterous parasites, **Helconidea occidentalis** (Cress.) and **Rhimphoctona atrocoxalis** (Ashm.), whose cocoons were found in galleries of the wood-boring beetle, **Tetropium velutinum** LeConte, are described and illustrated.

The species of wood-infesting Coleoptera of economic importance to western larch, *Larix occidentalis* Nuttall in British Columbia were investigated by Dr. D. A. Ross, Forest Entomology Laboratory, Canada Department of Forestry, Vernon, B.C. (Ross 1967 a, b). During the course of that investigation two species of parasites were reared, and subsequently a section of log from which they emerged was made available to the author for study. As specific information on wood-boring beetles and their parasites is scarce this log from which both beetles and parasites had

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