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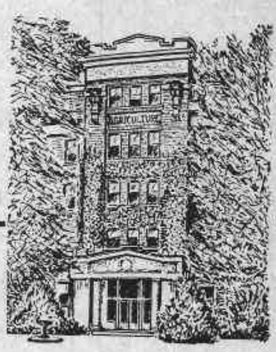
Balsam Woolly Aphid Predators Native to Oregon and Washington

Russel G. Mitchell

Agricultural Experiment Station
Oregon State University
Corvallis



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AUTHOR: Russel G. Mitchell was formerly research fellow in the Department of Entomology, Oregon State University. At present he is on the staff of the Pacific Northwest Forest and Range Experiment Station, Forest Service, United States Department of Agriculture, Portland, Oregon.

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Introduction

The balsam woolly aphid, *Chermes* (=*Adelges*) *piceae* Ratz., (Hemiptera: Chermidae) is an introduced pest from Europe causing serious damage in the western hemisphere to trees in the genus *Abies* (true firs). Currently it is one of the most destructive forest insects in the Pacific Northwest, where it attacks and kills Pacific silver fir, *Abies amabilis* (Dougl.) Forbes; subalpine fir, *A. lasiocarpa* (Hook.) Nutt.; and grand fir, *A. grandis* (Dougl.) Lind. As often happens with imported pests, the balsam woolly aphid was introduced into the New World without its natural enemies. As a result, aphid populations often climb to epidemic status very soon after initial establishment in an area, seemingly checked only by the limit of suitable host supply.

As yet there are no known quick remedies to halt balsam woolly aphid outbreaks. Organic phosphate insecticides, such as malathion, are effective in controlling infestations on ornamentals, but are not feasible for large-scale control in forests. Logging heavily infested areas may exert some control, but its greatest value lies in salvaging dead and dying timber. Because adequate silvicultural and chemical controls are not available, a biological control program involving introduction of foreign insect predators was begun by the United States Forest Service in 1957. Complementing this program was a comprehensive study of native predators affecting the balsam woolly aphid in the Pacific Northwest—the subject of this bulletin.

The predator study reported herein was conducted as a cooperative project between the Pacific Northwest Forest and Range Experiment Station, United States Forest Service, and the Entomology Department, Oregon State University. Its primary objectives were to: (1) collect and identify native predators of the balsam woolly aphid; (2) learn as much as possible about life history and behavior of significant predator species; and (3) evaluate predator effectiveness in controlling aphid populations. The main period of study covered the years 1957, 1958, and 1959.

Background Information on the Balsam Woolly Aphid

First introduction of *Chermes piceae* in North America is believed to have occurred about 1900 in southeastern Canada (Balch, 1952). There, and subsequently in New England, it became a serious pest of balsam fir, *A. balsamea* (L.) Mill. In 1928, the insect was found on the west coast in the San Francisco Bay area, California, (Annand, 1928). Serious damage to grand fir in Oregon's Willamette Valley about 1930 announced the insect's first appearance in the Pacific Northwest (Keen, 1938). In 1954, an aggressive outbreak was discovered in a high-value Pacific silver fir forest in southwestern Washington (Johnson and Wright, 1957). Further investigations the same year revealed infestation also in subalpine fir forests, covering some 276,000 acres and extending into Oregon. Subsequent years revealed continual increase in extent of infestation, both in Oregon and Washington. By 1957, the infestation covered nearly 600,000 acres (Whiteside, 1958). Since then, the outbreak area has decreased somewhat in size with some localities showing reduced severity of infestation, while others have been growing progressively worse. One of the most serious infestations is in the Mount St. Helens area of Washington, where over a billion and a half board feet of Pacific silver fir was killed or seriously weakened by 1958 (Pope, 1958). Additional tree mortality of an unknown amount has occurred since the 1958 survey.

Chermes piceae differs from most chermids in that it has abandoned the typical pentamorphic life cycle in which there is an alternation between primary and secondary hosts. In North America, the insect has been found to be of one form, a completely parthenogenetic one feeding solely on trees in the genus *Abies.* The winged progrediens form, present in Europe and southeastern Canada, has not been found in the Pacific Northwest.

The balsam woolly aphid in the Pacific Northwest has three nymphal instars per generation and from two to four generations per year, depending on elevation (Mitchell et al., 1961). The adult is purple to black, wingless, and nearly spherical. It is nearly always covered with a wool-like secretion and usually is found with a clutch of amber-colored eggs. Maximum adult size seldom exceeds 1 mm., and the newly hatched crawler may be as small as 0.35 mm. With the exception of the first instar, all stages closely resemble the adult and live out the entire life span anchored by their stylets to one spot on the bark surface. The first instar has two distinct forms: The first is a long-legged, amber-colored crawler which seeks out the feeding location; the second is a black, flattened, resting form which usually is referred to as the neosistens stage. The crawler, usually aided by wind, accomplishes dispersal.

Once the crawler has selected a feeding location, it inserts its long, thread-like mouthparts into the cortical tissue of the host and begins feeding on sap nutrients. As it feeds, it also pumps saliva into the tree. The saliva is believed to contain a toxic material which adversely affects the tree, causing hypertrophy of tissues in the xylem.

An attack by the balsam woolly aphid may take one of two forms: (1) a light infestation in the crown area; or (2) a mass attack on the main stem. Symptoms of attack and nature of damage are strikingly different in the two types of infestation. Crown infestations kill or inhibit buds, thus preventing new growth. As old needles are gradually shed, the crown becomes increasingly ragged and thin until the tree finally dies from lack of manufactured food. This process may take years. A stem attack usually is more serious. It indirectly affects the tracheids and soon reduces the flow of transpiration water between the roots and crown. Such an infestation may kill a tree in two to three years. Crown distortion may be a symptom of this type of infestation, but frequently does not become conspicuous because the trees die so quickly.

Identification of Arthropods Associated with Chermes piceae

This bulletin does not list all the arthropods found associated with *C. piceae* during the study. Only those forms observed as positive predators and those suspected of being predators are discussed. Scavenger insects and mites, such as psocids and orbatids, often were noted during the investigation; but they are not included because they had little or no influence on aphid populations. There was no sign of parasitism, nor is there any reference in the literature to the balsam woolly aphid being attacked by parasites.

This is not the first attempt to catalog native predators associated with chermids, although the only other study in North America was one by Brown and Clark (1956b) in eastern Canada. Studies in Europe were: Wilson's investigation of predators attacking *Pineus* species in the British Isles (1938), Pschorn-Walcher's and Zwölfer's work on *Chermes* spp. in central Europe (1956), another study by Pschorn-Walcher and Zwölfer in Sweden (1956), and a study in central Europe by Schremmer (1956).

Methods and procedures of study

Predator observations and collections were made on four species of aphid-infested true fir. One European silver fir, *Abies alba* Miller, and several Pacific silver, subalpine, and grand firs were studied. An attempt was made to find trees in areas representative of the region's infestation zone. Table 1 presents general locations of the trees, species represented, and approximate elevations of study areas.

Table 1. ELEVATION, LOCATION, AND TREE SPECIES STUDIED AT PREDATOR COLLECTION AREAS

Location	Tree species	Elevation
		feet
Toutle and Green River drainages, Washington	*A. amabilis*	2,500-3,500
Wind River Arboretum (Near Carson, Washington)	*A. alba and A. lasiocarpa*	1,000
Black Rock, Oregon (Upper Warnick Creek drainage)	*A. amabilis*	2,800
Corvallis, Oregon	*A. grandis*	230
Benton-Lane Park (Near Monroe, Oregon)	*A. grandis*	350
Willamette Pass, Oregon	*A. lasiocarpa*	4,000

In 1957, collections and observations were made at least every two weeks in each area except Benton-Lane Park, which was not visited until 1958. In 1958 and 1959, travel to the more distant places, such as Toutle River and Green River, Washington, was curtailed, although biweekly observations were continued in the other areas.

The main period of investigation was from spring of 1957 through fall of 1959; although random observations and collections also were made during 1960 and 1961. Later collections were made in the course of other duties and were largely checks on data collected previously. These checks were frequently made in localities other than areas listed in Table 1.

Rearings to obtain adult predators were undertaken both in the field and in the laboratory. In the field small plastic cages with screen tops were used to isolate individual predators. Cages were attached to the tree by embedding them in a ring of modeling clay pressed onto the bark. Such cages proved useful in rearing neuropterons, but were not so successful for syrphids which pupate in the soil. Nevertheless, they were useful in rearing syrphids to the mature larval stage. Caging in the field also was useful in determining if an insect was merely an associate of *C. piceae* or definitely a predator.

For predators pupating only in forest litter, small trays made of plastic screen rimmed with eight-gauge wire were devised to catch larvae falling from the tree. This method was used successfully with one syrphid and was also helpful in locating small itonidid larvae. Three species of syrphids were found, however, that would neither pupate when caged on the tree nor drop into trays. For those species, puparia were obtained by hand picking mature larvae and rearing them in wet sand.

Large collections of nearly all species were best obtained by felling infested trees and bringing short log-bolts into the laboratory. Predators could then be collected as they pupated on the log or under the log on the floor of the rearing room. To associate adults with pupae and parasites with hosts, it was necessary to rear each insect individually.

Early in the investigation, some difficulty was experienced in laboratory rearings, especially with dipterons. Conditions too damp or too dry arrested development and often killed the adults or produced malformed specimens. Extreme moisture favored the development of fungi. Rearing in gelatine capsules over damp sand finally proved to be the most satisfactory method for small flies. Large species were best reared on damp sand in 4-inch shell vials. To discourage fungi, the soil was covered with sterilized gauze and the vials loosely plugged with surgical cotton.

A field problem was that of detecting very small predator species and then determining if they were predaceous. Adapting a binocular microscope to fit an elevator-type camera tripod solved this problem in part (Figure 20). This equipment permitted minute coverage of nearly 90 square inches of bark surface without moving the tripod. More important though, both hands were left free to handle vials, probes, etc. Both microscope and tripod were light enough to be carried easily by one man. Chief disadvantages of the technique were (1) much time was required to cover a relatively small bark area, and (2) the apparatus could be operated only from the ground. The latter shortcoming was overcome by removing the microscope's rack and pinion and replacing it with a metal "dog." The microscope was then suspended by an adjustable strap attached to a limb or a nail driven into the tree. This adaption allowed considerable maneuverability. The disadvantage was that the microscope was difficult to focus, and one hand was needed to hold it steady.

Known and possible predators collected

In 3 years of study, 26 species of arthropods were found in close relationship with the balsam woolly aphid in the Pacific Northwest. This section lists those species that were positively predaceous on the balsam woolly aphid and also those found associated with the host, and thus only possibly predaceous. Syrphids were identified by the late Professor C. L. Fluke of the University of Wisconsin and by Dr. H. S. Telford of Washington State University; chamaemyiids by Dr. J. F. McAlpine of the Entomology Research Institute, Canada Department of Agriculture, Ottawa; one anthocorid by J. D. Lattin of Oregon State University; and one derodontid by Kenneth M. Fender of McMinnville, Oregon. All other insects and mites were determined by various specialists in the United States National Museum, Washington, D. C. A list of the known and possible predators follows.

KNOWN PREDATORS

Class INSECTA

Diptera: Syrphidae—*Cnemodon rita* Curran
Diptera: Syrphidae—*Syrphus vitripennis* Mg.
Diptera: Syrphidae—*Syrphus opinator* O. S.
Diptera: Syrphidae—*Metasyrphus lapponicus* Zett.
Diptera: Syrphidae—*Metasyrphus attenuatus* Hine
Diptera: Chamaemyiidae—*Leucopis* sp. I
Diptera: Chamaemyiidae—*Leucopis* sp. II
Diptera: Chamaemyiidae—*Leucopis* sp. III
Diptera: Itonididae—*Lestodiplosis* sp.
Diptera: Itonididae—Undetermined species
Neuroptera: Hemerobiidae—*Hemerobius neadelphus* Gurney
Neuroptera: Chrysopidae—*Chrysopa quadrimaculata* Burm.
Neuroptera: Chrysopidae—*Chrysopa* sp.
Coleoptera: Coccinellidae—*Mulsantina picta* (Rand)
Coleoptera: Derodontidae—*Laricobius nigrinus* Fender
Hemiptera: Anthocoridae—*Acompocoris lepidus* (V. D.)

Class ARACHNIDA: Order ACARINA

Trombidiformes: Anystidae—*Anystis* sp.
Trombidiformes: Trombidiidae—*Allothrombium* sp.

POSSIBLE PREDATORS

Class INSECTA

Diptera: Syrphidae—*Metasyrphus amalopsis* (O. S.)

Neuroptera: Hemerobiidae—*Hemerobius conjunctus* var. *conjunctus* Fitch

Neuroptera: Raphidiidae—*Agulla* sp. near *adnixa* (Hagen)

Coleoptera: Coccinellidae—*Cycloneda polita* Csy.

Class ARACHNIDA: Order ACARINA

Trombidiformes: Bdellidae—*Biscirus uncinatus* (Krm.)

Trombidiformes: Anystidae—*Anystis agilis* (Banks)

Trombidiformes: Tydeidae—*Tydeus* sp.

Mesostigmata: Phytoseiidae—*Typhlodromus bakeri* (Garmen)

Predator occurrence

Timing of predator occurrence varied considerably from year to year, but was fairly constant in relation to the development of the prey. Figure 1 presents the sequence of predator eggs and larvae at three study areas in 1959. Also shown, for correlating predator timing with that of the prey, is occurrence of susceptible *C. piceae* stages during the same year.

Predator density is not included in Figure 1, largely because it is even more variable than date of occurrence. Density not only differs greatly from year to year but also from place to place within the same year. For instance, *S. opinator* appeared in very large numbers in 1958 at Corvallis, but was difficult to find in 1959. Conversely, it was extremely abundant in 1959 at Willamette Pass, but scarce in 1958. About the only constant feature of predator density noted through 1958 and 1959 was the relatively high spring and early summer populations as compared to those present in the fall. On the basis of aggregate predator population throughout the year, 75% of the predators occurred before the start of the last aphid generation.

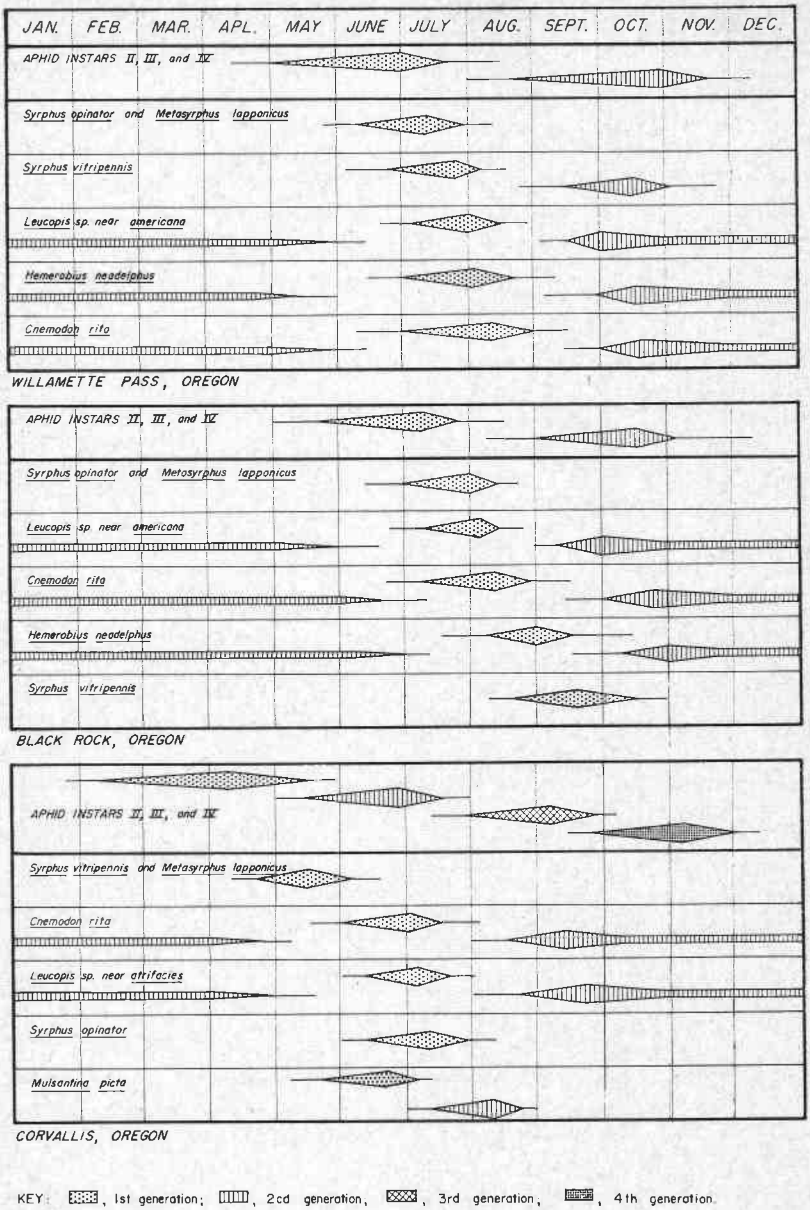

FIGURE 1. Summary of predator and prey occurrence at three locations in Oregon in 1959.

Field key to immature insect predators

The key in this section will distinguish the more common native insect predators associated with *C. piceae* in the Pacific Northwest. It is based on mature larvae and nymphs and is designed to be used with a 10x hand lens. Mites are not included; they are best separated by using family characteristics described in the text by Baker and Wharton (1952). Attempts were made to avoid color characteristics as main separation features in the key, although in one instance, between *Syrphus opinator* and *Metasyrphus lapponicus*, it could not be avoided; no other way was found for distinguishing these two insects in the field. Color, however, is often the most grossly conspicuous feature of an insect and therefore is useful in field determination. For this reason, it is frequently used in the key as a secondary separation character, especially in those instances where color is easily described and relatively constant.

Not all insects found associated with the balsam woolly aphid are included in the key. A few species were omitted either because the immature stages are unknown or because only a few specimens were collected. One insect, *Aphidoletes thompsoni,* which is not a native predator but a European import, is also included in the key because it shows promise of becoming established in the Pacific Northwest and because of its similarity with two native itonidids.

FIELD KEY

1. Larvae without legs 2
   Larvae or nymphs with legs 12

2. Posterior respiratory processes absent; larvae pinkish to light orange; not exceeding 4 mm. in length (Itonididae) 3
   Posterior respiratory processes present, either fused into one median projection or separated into two lateral projections; larvae not pinkish or orange; length 2.5-15.0 mm. 5

3. Ventral surface with 10 distinct pairs of pseudopods; body hairs conspicuous (Figure 12A) .... *Lestodiplosis* sp.
   Ventral surface without pseudopods; body hairs not conspicuous 4

4. Larva with a distinct pair of sclerotized, curved, anal horns; body broadest in posterior half (Figure 12B) .... Unknown Itonidid

Larva without anal horns, cauda produced into squared, fleshy projections; body broadest in middle portion of frontal half (Figure 12C) .... *Aphidoletes thompsoni*

5. Posterior respiratory processes separated into two lateral protrusions (Figures 11A, B, and C) (Chamaemyiidae) 6

Posterior respiratory processes fused into one median protrusion (Syrphidae) 8

6. Larva conspicuously covered with spines; posterior respiratory processes only slightly longer than wide and not subspherical (Figures 10B and 11C) .... *Leucopis* sp. I

Larvae without conspicuous spines; posterior respiratory processes either distinctly longer than wide or subspherical 7

7. Posterior respiratory processes distinctly longer than wide; larva light grey in color (Figure 11A) .... *Leucopis* sp. II

Posterior respiratory processes subspherical; larva yellow in color (Figure 11B) .... *Leucopis* sp. III

8. Larvae with prominent, fleshy pseudopods on ventral surface; posterior respiratory process closely appressed to body and situated in triangular shaped pocket 9

Larvae with ventral surface smooth; posterior respiratory process distinctly elevated 10

9. Larva mostly pale green with light brown to black, chevron-shaped patterns dorsally (Figures 6B and 7) .... *Syrphus opinator*

Larva mostly brown with dark brown to black, chevron-shaped patterns dorsally (Figures 8A and 9) .... *Metasyrphus lapponicus*

10. Body margin with large number of conspicious spine-like projections, cerci-like projections especially prominent (Figure 19A) .... *Metasyrphus amalopsis*

Body margin without spine-like projections 11

11. Larva with fleshy, caudal protuberances, one on each side of respiratory process; body color uniform dirty yellow to olive green (Figure 2B) .... *Cnemodon rita*

Larva without caudal protuberances; body multicolored, especially fat bodies in dorsal vessel region (Figure 4B) .... *Syrphus vitripennis*

12. Mouthparts sickle-like, distinct from above 13

Mouthparts chisel-like or produced into a rostrum, only barely or not at all visible from above 15

13. Body smooth, without tubercles or conspicuous long hairs; lacking trumpet-shaped empodium between tarsal claws (Figure 13B) (Hemerobiidae) .... *Hemerobius neadelphus*

Body roughened with lateral tubercles and having conspicuous long hairs; trumpet-shaped empodium present (Chrysopidae) 14

14. Dorsal surface of head with four diagonal black lines and one small, central V-shaped marking; body covered with trash gathered from aphid-wax masses (Figures 16A and B) .... *Chrysopa quadrimaculata*

Dorsal surface of head with three black areas delineating a white, Y-shaped design; body not covered with trash (Figure 15A) .... *Chrysopa* sp.

15. Antennae conspicuous; much longer than length of head (Anthocoridae) .... *Acompocoris lepidus*

Antennae reduced, shorter than length of head 16

16. Prothorax the same size or longer than the combined meso- and metathorax; body uniformly black (Rhaphidiidae) .... *Agulla* sp.

Prothorax shorter than combined meso- and metathorax; body black and white or yellow-green 18

17. Body with considerable number of heavy spines; color black with white margins and white mid-dorsal line (Figure 17B) (Coccinellidae) .... *Mulsantina picta*

Body densely covered with long, fine hairs; color yellow to yellow-green (Figure 18A) (Derodontidae) .... *Laricobius nigrinus*

Descriptions and Habits of Known Predators

This section presents descriptions and biological information on native predators found attacking the balsam woolly aphid in the Pacific Northwest. Since predator adults are seldom seen, descriptions feature the immature forms. Larval drawings were made by microprojection of specimens cleared in lacto-phenol and mounted in Hoyer's solution. To reduce needless written description, great care was taken to make the drawings as accurate as possible.

All photographs but one were taken with a standard 4x5-inch clinical camera or a 35 mm. Exakta. Desired magnifications with the Exakta were obtained with (1) a Bausch and Lomb binocular dissecting microscope, (2) a Zeiss monocular compound microscope, or (3) a bellows-scope with extension tubes.

Cnemodon rita (Diptera: Syrphidae)

This is the region's most abundant and possibly most important predator of *C. piceae*. It is present throughout the infested zone and was collected on almost every aphid-infested tree, regardless of how light the prey density or how isolated the tree. Appearance of the four insect stages is shown in Figure 2.

DESCRIPTIONS OF IMMATURE STAGES. The adult *C. rita* is described by Curran (1921).

Egg (Figure 2A). Length, 0.75 to 0.90 mm.; width, 0.25 to 0.30 mm. Color pearl white. Shape fusiform in outline but slightly more pointed at the micropylar end. Dorsal surface strongly arched and distinctly sculptured with 9 to 12 longitudinal carinae. Ventral surface flat, glabrous.

First instar larva (Figure 3A). Length, 0.75 to 1.40 mm.; width, 0.22 to 0.47 mm. Mean length of mouth-hooks, 0.19 mm. Color translucent white when first hatched, becoming dirty grey after feeding. Larva cylindrical, slender; gradually tapered at both ends, with head and cauda somewhat blunt. Ventral surface rather flat; only rudimentary signs of pseudopods. Body weakly rugose transversely, with each somite divided into three to five annulets. Integument covered with microscopic, hyaline papillae, giving larva a faint granular appearance. Head segment, particularly around mouth opening, conspicuously covered with microscopic spinules; patches of spinules also present on ventral surface of first two thoracic segments. Body

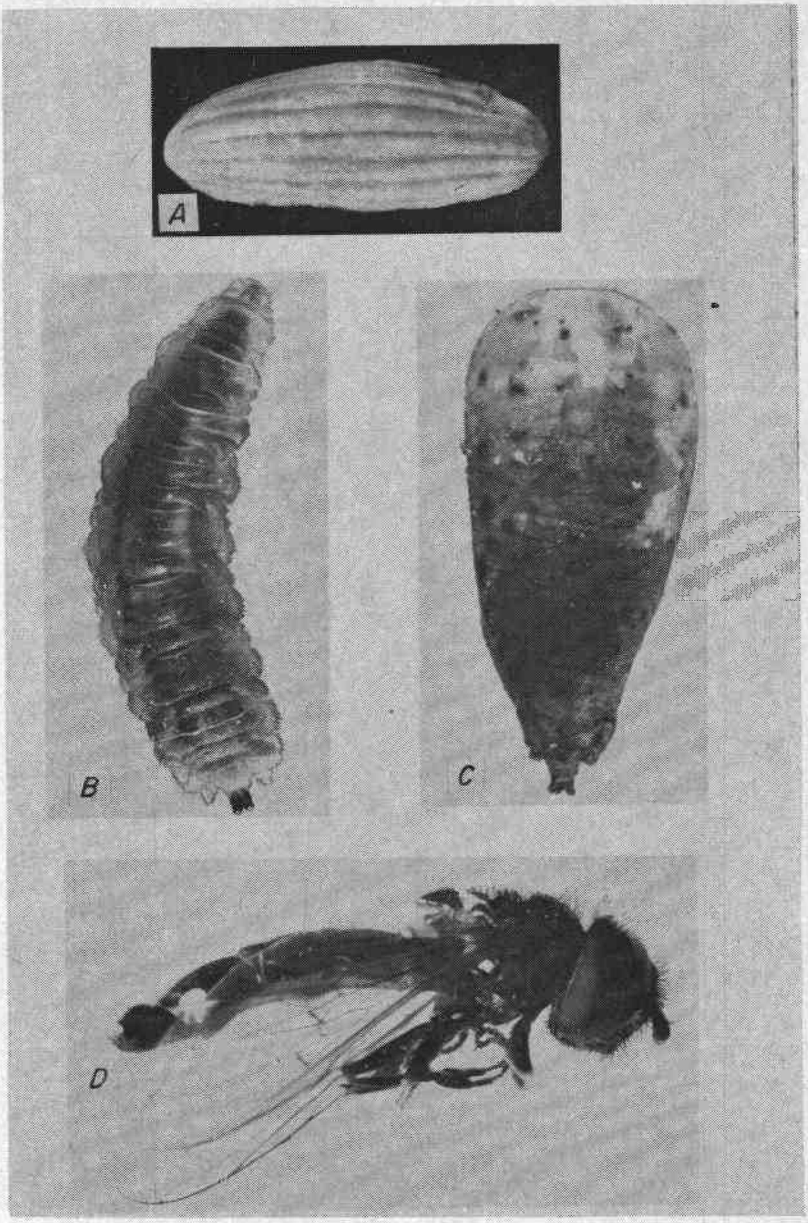

FIGURE 2. *Cnemodon rita* Curran: A, egg; B, third instar larva; C, puparium; and D, adult male.

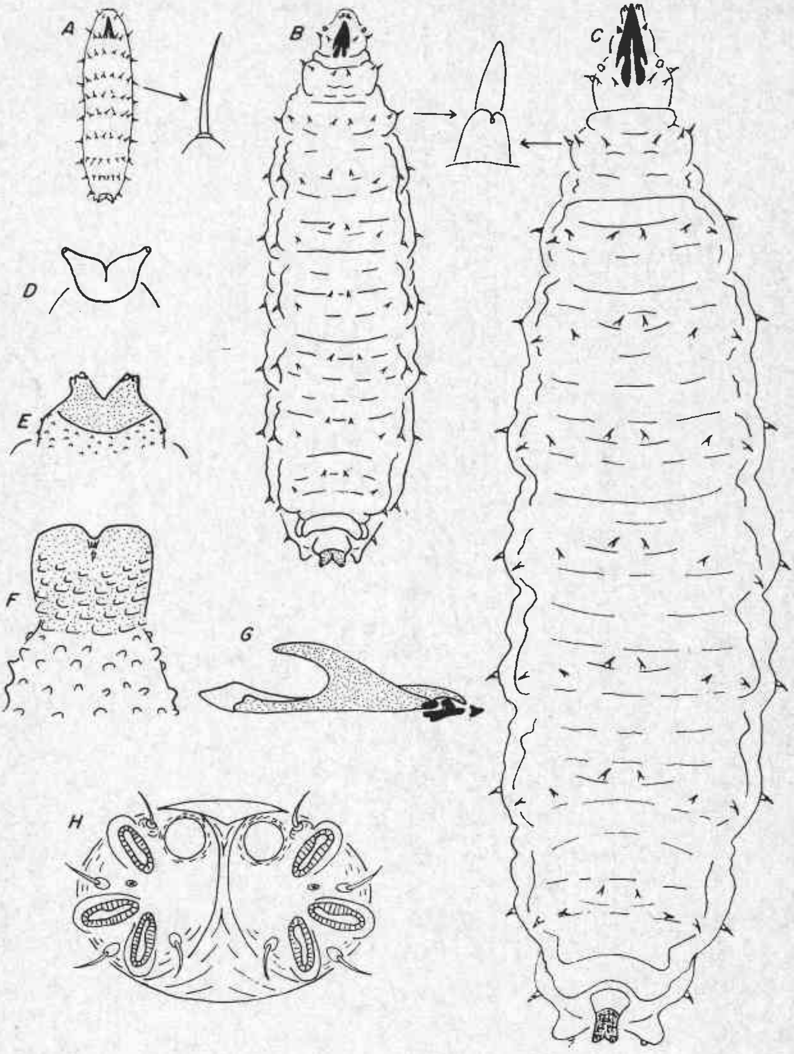

FIGURE 3. Drawings of *Cnemodon rita* Curran larvae: A, first instar larva; B, second instar larva; C, third instar larva; D, first instar respiratory process; E, second instar respiratory process; F, third instar respiratory process; G, third instar mouth-hook; and H, third instar spiracular plate.

distinguished by nine transverse rows of two-segmented spines on prothorax, metathorax, and first seven abdominal segments; distal portion of spines about 15 times longer than basal portion. Number and position of spines on each segment follows: Thorax I—10 spines, one pair dorsal, one pair dorsolateral, one pair lateral, and two pair lateroventral. Thorax III—12 spines, one pair dorsal, one pair dorsolateral, one pair lateral, two pair lateroventral, and one pair ventral. Abdominal segments I through VII—14 spines each, two pair dorsal, one pair dorsolateral, one pair lateral, two pair lateroventral, and one pair ventral. Ventral and lateroventral spines on all segments positioned one annulet anterior to main row. Venter of metathorax with three pair of rudimentary spine bases on annulet anterior to the main row of spines. Abdominal segment VIII, the caudal segment, with six spines—one pair lateral and two pair lateroventral extending from a pair of blunt, fleshy lobes. Larva metapneustic; spiracles situated on two widely divergent, unsclerotized processes arising from caudal segment (Figure 3D); each process terminating with four setae and two spiracular openings.

Second instar larva (Figure 3B). Length, 2.86 to 4.40 mm.; width, 0.49 to 0.59 mm. Mean length of mouth-hooks, 0.31 mm. Color varying from light grey to yellowish-green; dark gut often outwardly visible. Shape similar to first instar only more pointed anteriorly and more arched dorsally. Secondary segmentation distinct. Hyaline papillae larger and more conspicuous than first instar. Body distinguished by nine rows of two-segmented spines as first instar, but spines differ by being broader, more blunt, and having distal and proximal portions subequal in length. Number of spines reduced from first instar with loss of ventral spines on thorax and first seven abdominal segments and two pair of lateroventral spines on abdominal segment VIII. Spine arrangement varies from Instar I in one respect: central pair of dorsal spines on last six rows is placed one annulet anterior to main row. Larva amphipneustic; spiracles on prothorax and last abdominal segment. Anterior respiratory process heavily sclerotized, peg-like projections on outer margins of dorsum. Posterior processes distinctly sclerotized, slightly divergent, but fused on a common base (Figure 3E). Each process terminates in a plate with three elliptical spiracular openings, four long setae, and a subcircular spiracular scar situated at the inner margin and at a level distinctly lower than spiracular openings.

Third instar larva (Figures 2B and 3C). Length, 4.00 to 8.80 mm.; width, 0.80 to 1.28 mm. Mean length of mouth-hooks, 0.55 mm. Color yellow-green when feeding and olive-drab in prepupal stage; dark gut often outwardly visible. Shape as Instar II only more strongly arcuate dorsally and fusiform in outline. Integument densely covered with conspicuous, spine-like, hyaline papillae; particularly evident on caudal respiratory process. Segmental spine arrangement and number identical to second instar—10 spines on each of the 2 thoracic segments and 12 spines on each of the first 7 abdominal segments. Venter flattened and with rudiments of spines on metathorax as Instar II. Caudal lobes large and conspicuous. Spiracle arrangement as second instar except posterior respiratory process subpedunculate and completely fused; sclerotized portion asperate with irregular rectangular projections (Figure 3F). Spiracular plates as shown in Figure 3H with three irregular, cirrose, slit-like spiracular openings set on slightly raised elliptical carinae; four stout setae about as long as spiracular openings; and a nearly circular, slightly raised spiracular scar. Combined width of spiracular plates, 0.21 to 0.23 mm.

Puparium (Figure 2C). Length, 3.7 to 4.5 mm.; width, 1.6 to 1.9 mm. Color dull brown to ash grey with randomly located dark areas. Shape convex dorsally and concave ventrally; elongated and flattened above and below when parasitized. The pair of caudal, fleshy lobes of the larva remain distinct as two hardened nodules lateral to the base of the posterior respiratory process. Spiracular plates retain characteristics described for Instar III. Operculum lines of weakness distinct.

LIFE HISTORY AND BEHAVIOR. *C. rita* has two generations per year. Time of occurrence is presented in Figure 1. Ovipositing females were observed at Corvallis from May 15 to May 30. Although adults were not seen later than May 30, appearance of unhatched eggs until mid-June suggested an oviposition period lasting as long as 30 days. This compares favorably to the flight time recorded for *Cnemodon dreyfusiae* Del. and P. -W., a closely related European species (Delucchi et al., 1957). Eggs were laid singly on bark surface, in crevices, and in balsam woolly aphid egg masses. Incubation period at room temperature was 3 to 4 days.

Egg deposition occurred as frequently on the shaded sides of trees as on the exposed. However, most early spring oviposition was noted on stand-edge trees. Oviposition occurred largely on warm days, 70° F. or more; although one female was observed laying eggs while it was raining and much cooler.

Duration of the first larval stadium was 4 to 5 days at room temperature. Length of the second stadium is not known, although laboratory rearings showed it to be at least 4 days. The feeding period of the third instar was 8 to 10 days. After feeding ceased, larvae went into a diapause-like state for 15 days before pupation. Adults emerged 9 to 10 days after the puparium was formed.

Field observations suggest that length of time between oviposition by the first and second generations is about 60 days. By subtracting the 29 days that the insect is in larval diapause and the pupal and egg stages, it is calculated that the first generation larva spends about 30 days actively feeding in the field.

Pupation occurred either in the soil or on the trees. Soil was the most common location, although many remained on trees when heavy lichen growth was present. *C. rita* drops directly from the tree when pupating in the soil, a habit permitting use of a tray for easy collection. Winter is passed in the larval or pupal stage and on the tree or in the soil. Those remaining on the tree usually burrow deeply in lichen.

NATURAL ENEMIES. The following hymenopterous parasites were reared from *C. rita:*

Chalcidoidea: Encrytidae—*Syrphophagus smithi* Kam.
Chalcidoidea: Pteromalidae—*Pachyneuron allograptae* Ashm.
Ichneumonidae: *Syrphoctonus* sp.
Ichneumonidae: *Phthorima* sp.

The chalcids, which are superparasites, attacked the pupal stage and accounted for the greatest amount of parasitism. The ichneumonids are larval parasites, *Syrphoctonus* sp., appearing to be the more prevalent of the two genera; parasitism by this species was sometimes quite significant. Only one case of parasitism by *Phthorima* sp. was noted.

Aggregate parasitism experienced by *C. rita* was highly variable. In some collections it reached 90%, while in others it was very low. It appears that the greatest percentage occurs during the second generation when the syrphid population is relatively low.

Two instances were noted where *C. rita* was preyed upon, once by an unknown ant and another time by a syrphid, *Metasyrphus amalopsis.* However, such predation is believed to be rare.

DISCUSSION. Although *C. rita* is found throughout most of the summer and at almost all prey densities, it is seldom abundant on any one tree. Its value as an effective predator is further impaired because it does not appear until after the first balsam woolly aphid generation has reached its peak. Then, the predator population drops to very low levels when the second aphid generation is heaviest. It is quite probable that *C. rita* has several hosts. The insect has been observed attacking an unknown species of *Pineus* at two different areas.

Syrphus vitripennis (Diptera: Syrphidae)

This is the region's second most abundant predator. It is apparently holarctic, being found in Europe as well as North America. In the Pacific Northwest, *S. vitripennis* was observed at every collecting point, although associated only with long established, heavy aphid populations. The species' four stages are illustrated in Figure 4.

DESCRIPTION OF IMMATURE STAGES. The adult of *S. vitripennis* is described in most detail by Fluke (1933).

Egg (Figure 4A). Length, 1.12 to 1.27 mm.; width, 0.49 to 0.52 mm. Color yellowish-white when first laid, later developing a greenish cast. Subcylindrical in shape with micropylar end slightly smaller in diameter. Entire surface conspicuously covered with numerous peg-like projections.

First instar larva (Figure 5A). Length, 1.35 to 2.26 mm.; width, 0.36 to 0.50 mm. Mean length of mouth-hooks, 0.27 mm. Color uniform pale green. Larva cymbiform in outline; widest at caudal end. Integument finely granulate and microscopically shagreened. Larva rugose transversely but with secondary segmentation only weakly developed. Head segment, particularly ventral surface, conspicuously covered with microscopic spinules; patches of spinules also present on ventral surface of first two thoracic segments. Ventral surface of larva generally flat but with rudimentary pseudopods on each somite; widely scattered spinules usually present around pseudopods from metathorax through last abdominal segment. Arrangement and number of segmental spines identical to first instar of *C. rita,* except for the last abdominal segment which has only one pair of spines (lateral). Vestigial spines on venter of metathorax as with *C. rita.* Spines two-segmented as *C. rita;* distal portion about 15 times longer than proximal segment. Larva metapneustic as first instar *C. rita;* respiratory processes distinctly separate, slightly raised, partially sclerotized, and terminating with two elliptical spiracular openings.

Second instar larva (Figure 5B). Length, 2.95 to 5.50 mm.; width, 0.80 to 1.40 mm. Mean length of mouth-hooks, 0.54 mm. Pleural areas pale sea-green or yellow in spring generation; russet brown in fall generation. Double orange and black mid-dorsal line extending from thoracic region to posterior respiratory process. Lateral to the mid-dorsal line on each abdominal segment are globules

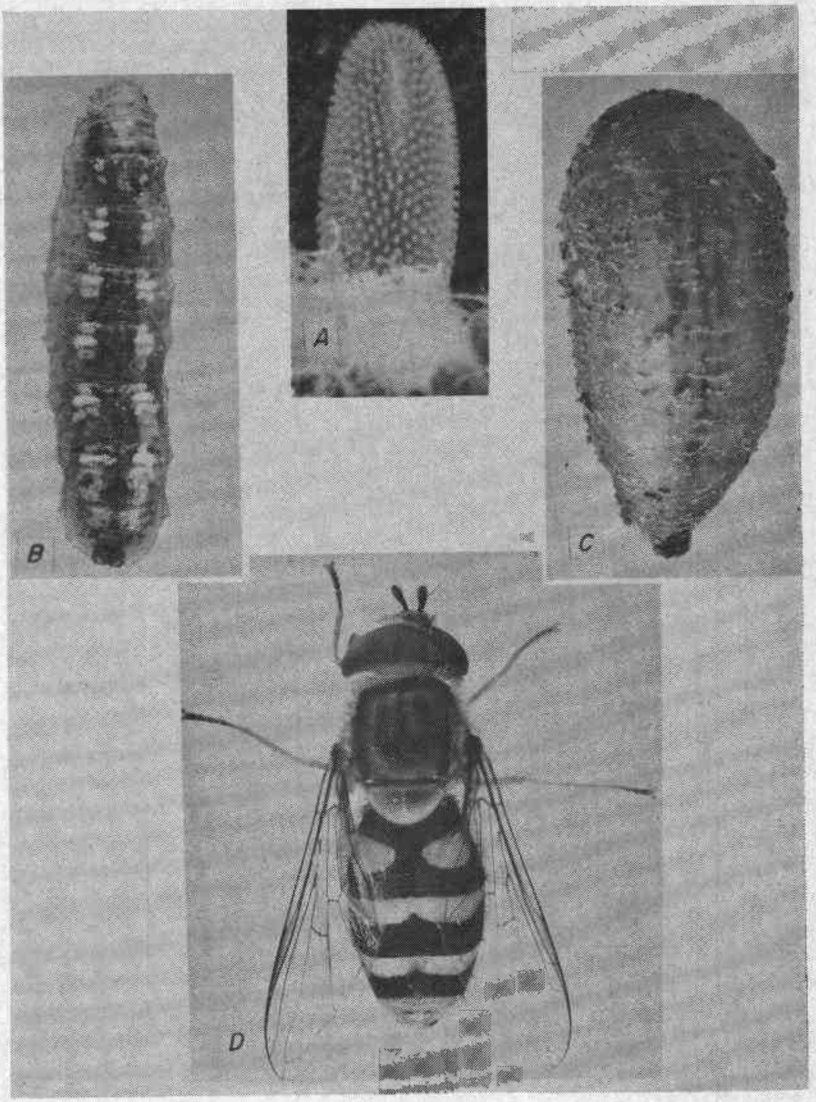

FIGURE 4. *Syrphus vitripennis* Mg.: A, egg; B, third instar larva; C, puparium; and D, male adult.

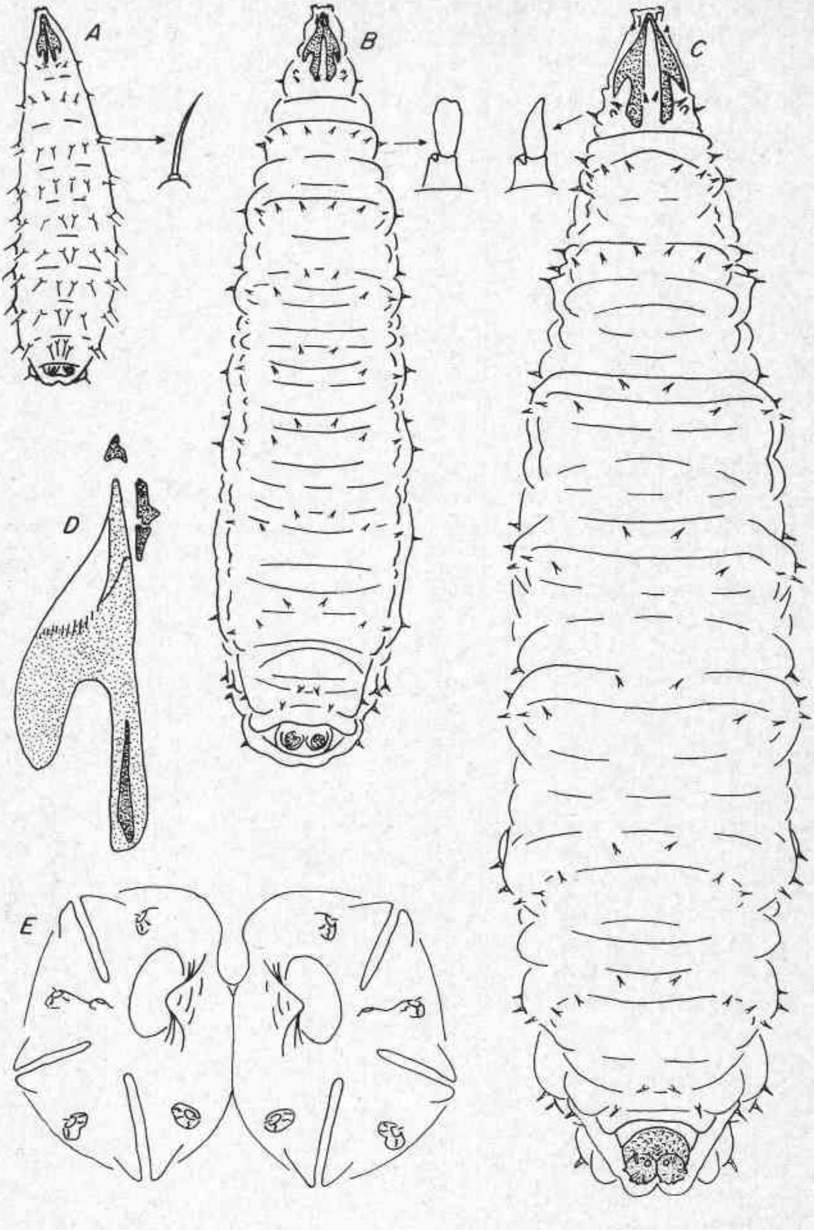

FIGURE 5. Drawings of *Syrphus vitripennis* Mg. larvae: A, first instar larva; B, second instar larva; C, third instar larva; D, third instar mouth-hooks; and E, spiracular plate of third instar.

of black extending laterad and then diagonally cephalad and caudad to form a rough "H"-shaped design; lateral to "H" designs are irregularly shaped whitish-grey patches. Larval outline similar to first instar except less tapered at the anterior end; slug-like when inactive. Integument more granulate than first instar; moderately rugose transversely with each segment divided into two to five annulets. Head and ventral segments same as Instar I. Arrangement and number of segmental spines identical to those of second instar *C. rita*. Spines two-segmented, the proximal and distal halves subequal; distal portion very blunt. Larva amphipneustic as are *C. rita* Instars II and III; posterior spiracular process incompletely fused with plates slightly raised, sclerotized, and distinctly separate, but closer together than in first instar; each plate terminating with a circular spiracular scar, four minute setae, and three elliptical spiracular openings.

Third instar larva (Figures 4B and 5C). Length, 6.4 to 10.5 mm.; width, 1.4 to 3.0 mm. Mean length of mouth-hooks, 0.92 mm. Color similar to second instar, becoming light brown in pleural areas just prior to pupation; occasionally the mottling in the mid-dorsal area becomes faint or disappears and larva becomes uniform pale brown or light green. Larval outline similar to second instar. Numerous small, hyaline papillae give integument a distinct granular appearance. Number and arrangement of segmental spines identical to second instar larva—10 spines on prothorax, 10 on metathorax, 12 on abdominal segments I through VII, and 2 on abdominal segment VIII. Spines two-segmented as Instar II, but with distal portion coming to a distinct point. Spiracle arrangement as second instar except posterior respiratory process more distinct and completely fused into one heavily sclerotized protrusion. Spiracular plates characterized by three cirrose, slit-like spiracular openings on slightly raised carinae, one subelliptical spiracular scar, and four small setae situated on conspicuous truncated nodules (Figure 5E); nodules ridged on sides in such a way as to appear fractured; mean width across both spiracular plates, 0.58 mm.

Puparium (Figure 4C). Length, 5.2 to 6.2 mm.; width, 2.7 to 3.1 mm. Color uniform yellow-brown with distinct silky sheen. Larval color pattern usually shows through integument for a short period after pupation; adult abdominal design outwardly visible 2 to 3 days before emergence. Viewed from above, puparium has an inflated appearance suggesting a hanging drop of oil. Ventrally, puparium generally flat longitudinally but well rounded transversely. Spiracular plates retain characteristics of third instar larva.

LIFE HISTORY AND HABITS. *S. vitripennis* usually has two generations per year at higher elevations, although the first generation is sometimes absent. In lowland areas, *S. vitripennis* has only a single spring generation. The reason for one rather than two or more generations is not known precisely, although it appears that as the season progresses into summer, the soil becomes too dry to allow a second emergence. Mature larvae drop to the ground for pupation, but on dry soil go into aestivation and will not develop further. Laboratory tests showed substrate must be quite moist before pupation will occur.

Specific life history information is meager, owing to early difficulty in rearing. Field observations revealed the oviposition period lasting at least 15 days. Eggs were laid singly and conspicuously on the bark surface of infested trees, seldom secluded within aphid-wax masses. After 3 to 4 days of warm weather, the egg hatches. The resulting three larval instars feed from outside the wax masses and prey on all aphid stages except the neosistentes. Duration of the larval stages is not known. Late in the third instar, larvae began to work down the stem in preparation for pupation. Puparia are usually formed within a day or two after reaching the soil, although laboratory rearings revealed some larvae resting as long as 17 days before pupating. The period between puparium formation and adult emergence is 8 to 10 days.

DISCUSSION. Synchronization of the predator with the host for maximum effectiveness is good. Chief fault is that the predator generally occurs in small numbers. Also, its distribution between trees is erratic; *S. vitripennis* may be abundant on one tree, while on an adjacent tree with a similar prey density it may be very scarce.

Syrphus opinator (Diptera: Syrphidae)

S. opinator is found at all elevation zones throughout the zone of aphid infestation in the Pacific Northwest. Some years it is the most important native predator affecting the balsam woolly aphid; in others it is extremely scarce. Figure 6 presents the four insect stages of *S. opinator*.

DESCRIPTIONS OF IMMATURE STAGES. The adult *S. opinator* is described by Fluke (1933).

Egg (Figure 6A). Length, 1.12 to 1.36 mm.; width, 0.38 to 0.39 mm. Color greyish-white. Shape subcylindrical; tapering slightly towards smaller and blunter micropylar end. Entire surface covered with conspicuous, longitudinally oriented, minutely ramose carinae; carinae loosely arranged in alternating courses.

First instar larva. Length, 1.90 to 3.08 mm.; width, 0.40 to 0.65 mm. Mean length of mouth-hooks, 0.27 mm. Color mostly white when first hatched, becoming greyish-white to light green after feeding. Larval outline similar to third instar larva shown in Figure 7A. Dorsally, larva somewhat flattened and moderately rugose transversely. Venter distinguished by seven pairs of fleshy pseudopods, as shown for Instar III in Figure 7B. Integument densely covered with small, inconspicuous papillae; each papilla surmounted with 1 to 23 black, well sclerotized spherules, usually loosely arranged in circular patterns; spherules most evident in dorsal and pleural regions. Except for last abdominal segment which has no spines, number and arrangement of segmental spines identical to previously described first instar syrphids. Rudiments of spines on ventral surface of metathorax as previous first instars. Shape of segmental spines differs from previous species by being distinctly capitate; knob usually simple but on some specimens bilobed or even trilobed. Insect metapneustic as previous first instar larvae; spiracular plates well separated, sessile, and only slightly sclerotized; plates subcircular in outline, characterized by two narrowly elliptical spiracular openings.

Second instar larva. Length, 3.0 to 7.0 mm.; width, 0.71 to 1.15 mm. Mean length of mouth-hooks, 0.52 mm. Color mostly pale green in pleural and dorsal regions, becoming increasingly paler cephalad. Dorsally, green broken by two incomplete, white, mid-dorsal lines which broaden posteriorly to form cuneate patterns on each of the last six abdominal segments. Small yellowish patches sometimes present immediately posterior to broad part of wedge. Black diagonal patches lateral to cuneate designs form six conspicuous chevron-shaped patterns. Lateral margins of dorsum with thin white lines extending brokenly from thorax to caudal segment. Larval shape similar to first instar larva except more rugose dorsally and laterally. Ventral surface with conspicuous pseudopods. Integument densely spinose; numerous minute black spinules around mouth opening and on ventral surface; spinules becoming larger and more distinct dorsally. Most dorsal spinules translucent brown, but in certain definitely arranged dorsal groups spinules are black forming distinctive chevron-shaped patterns (as shown for third instar larva in Figure 7A). Number and arrangement of segmental spines nearly identical to previously described second instar larva; exceptions are on third thoracic segment and first abdominal segment which have 18 and 16

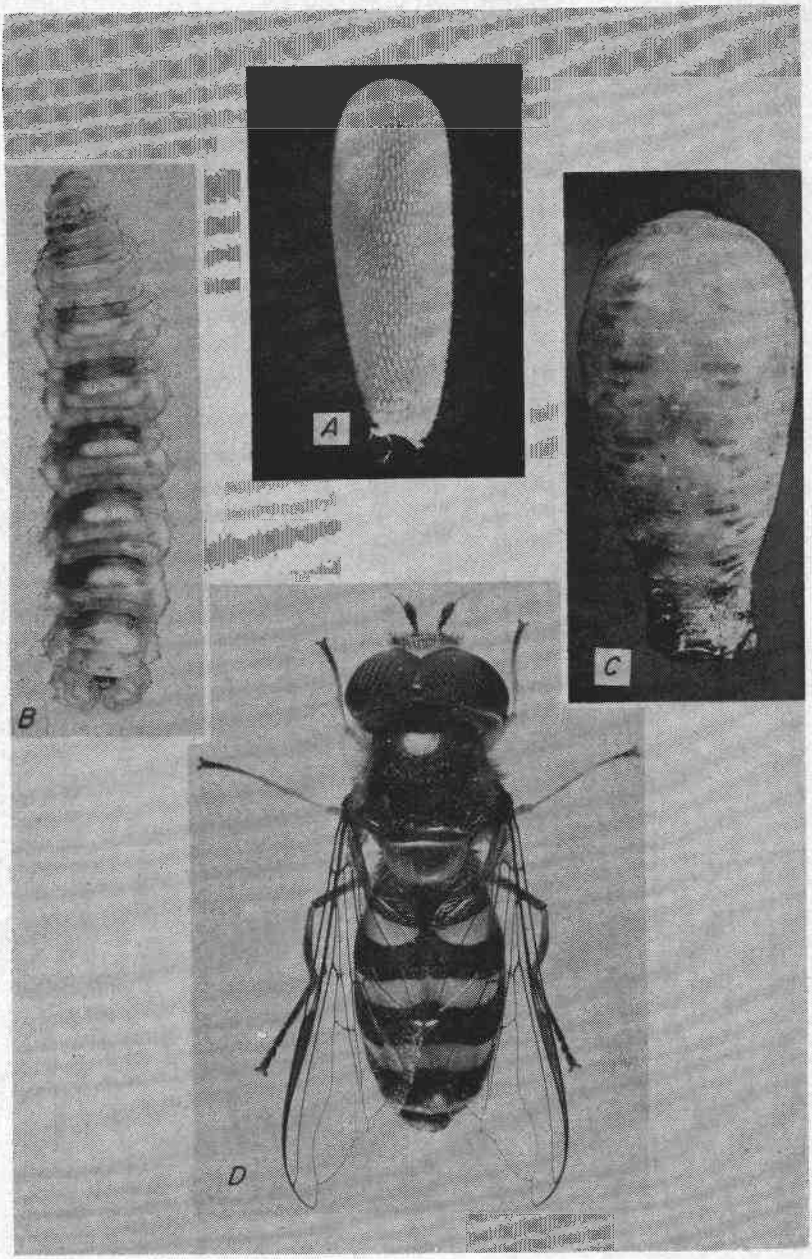

FIGURE 6. *Syrphus opinator* O. S.: A, hatched egg; B, third instar larva; C, puparium; and D, male adult.

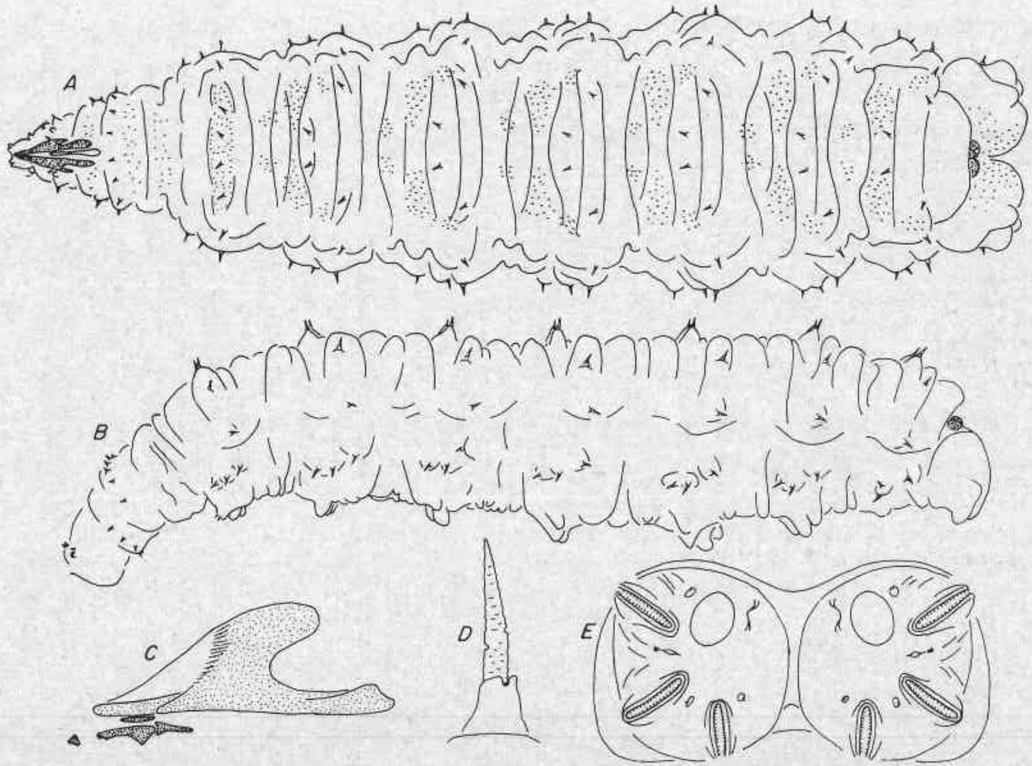

FIGURE 7. Drawings of third instar *Syrphus opinator* O. S. larvae: A, dorsal view; B, lateral view; C, mouth hooks; D, segmental spine; and E, spiracular plate.

spines, respectively. Spines on metathorax: two pair dorsal, one pair dorsolateral, one pair lateral, and, one annulet anterior, one pair lateral, one pair lateroventral, three pair ventral. Spines on first abdominal segment: two pair dorsal, one pair dorsolateral, one pair lateral, two pair lateroventral, and, on the outermost pseudopods, two pair ventral. Individual segmental spines two-segmented, distal portion twice as long as basal portion; distal part wrinkled and crenate, occasionally with a secondary spine branching off. Larva amphipneustic as previous second and third instar syrphids; posterior process only slightly raised. Plates distinctly sclerotized and completely separate; each plate terminating with a circular spiracular scar, four minute setae, and three slit-like, cirrose, spiracular openings.

Third instar larva (Figures 6B and 7). Length, 7.2 to 13.1 mm.; width, 1.3 to 2.9 mm. Mean length of mouth-hooks, 0.77 mm. Color same as second instar except green becomes darker and dorsal area light brown between the black chevron areas just prior to pupation. Shape as shown in Figures 7A and 7B; transverse wrinkles quite deep. Integument more distinctly spinose than second instar larva; black spinules forming chevron designs particularly conspicuous. Arrangement and number of segmental spines as second instar. Posterior respiratory processes completely fused, sessile, recessed in a triangular-shaped concavity. Spiracular plates terminating with a small dorsal spur, subcircular spiracular scar, four small setae, and three cirrose, slit-like, spiracular openings (Figure 7E); combined width of both plates, 0.35 to 0.43 mm.

Puparium (Figure 6C). Length, 5.9 to 6.9 mm.; width, 2.3 to 3.0 mm. Color light tan to pink; surface exhibiting spinule pattern of the third instar larva. Abdominal color pattern of adult outwardly visible a few days prior to emergence. Dorsum broadly convex at the anterior end, sharply arcuate and concave before posterior spiracular process. Venter gently concave longitudinally; caudal end laterally arcuate when pupation occurs in the soil, flat when pupating on the tree. Posterior respiratory process more conspicuous than on third instar larva.

LIFE HISTORY AND BEHAVIOR. *S. opinator* has one generation per year when preying on *C. piceae*. Eggs are laid conspicuously on the bark surface of infested trees about mid-March at Corvallis and May 1 at Willamette Pass. Tiny larvae emerge from the eggs in 2 to 3 days and immediately begin to feed. Duration of the feeding larval period is 20 to 30 days in the laboratory and 50 to 60 days in the field. The syrphid is a very active feeder and preys on all stages of the balsam woolly aphid except the resting first instar.

Puparia are easily obtained in the laboratory, but adults do not readily emerge unless conditions are moist. Puparia placed in a humid environment at room temperature produced adults in 10 days. Under dry conditions at the same temperature, emergence was delayed as long as 2 months. In nature, pupation usually occurs in the soil, but occasionally on trees. When pupating in the soil, the insect does not drop directly from the tree, but migrates down the stem and away from the tree. Laboratory observations showed the migratory period lasting 12 to 36 hours.

Caged adults feeding on honey, sugar, powdered milk, and water lived 18 to 24 days; females survived a few days longer than males. Attempts to propagate this species by caging males and females with aphid-infested log bolts failed. Mating was not achieved.

NATURAL ENEMIES. The following hymenopterous parasites have been reared from *S. opinator:*

Ichneumonidae: *Syrphoctonus* spp. (two species)

Ichneumonidae: *Diplazon orbitalis* Cress

Chalcidoidea: Pteromalidae—*Pachyneuron allograptae* Ashm.

The two species of *Syrphoctonus* were the most abundant parasites. Both attack the larval stage. The second two species were reared from predators that pupated on the tree. *P. allograptae* emerged from several collections while *D. orbitalis* was reared only once.

Amount of parasitism suffered by *S. opinator* was quite variable. It was about 15% in 1958 at Corvallis. In 1959 at Willamette Pass, parasitism before the July 16 collection was less than 5%; thereafter, the two *Syrphoctonus* parasites were reared from more than 90% of the syrphids collected.

Predation was noted on several occasions but did not appear significant. Chief predators were ants removing *S. opinator* eggs from the bark of aphid-infested trees. Occasionally, however, small larvae were attacked by other predators, mainly neuropterons.

DISCUSSION. When abundant, *S. opinator* proved effective in reducing prey population. Chief shortcoming was timing; the heaviest predation did not occur until the first aphid generation reached or passed its peak. By then a large number of eggs had hatched and sistentes constituting the next generation had already settled.

When abundant, there seemed to be a linear relationship between the population of *S. opinator* and host density. Counts at Corvallis in 1958 on the relation of predator number to prey density revealed the following:

Number of prey per square inch	Number of *S. opinator* per 100 square inches
42.0	5.72
21.0	1.93
7.4	0.21

A confusing feature about the life history of *S. opinator* is that there is only one generation that preys on balsam woolly aphid annually. Adults are known to emerge shortly after pupation, and collections by the writer and a check of specimens in the insect collection at Oregon State University has revealed that adults are in flight well into October. It appears, therefore, that *S. opinator* hibernates as an adult or changes hosts in mid-season. The latter seems more probable. The writer observed the predator feeding on an unknown species of *Cinara,* and Campbell and Davidson (1924) recorded *S. opinator* preying on seven different species of aphids which are pests of farm crops.

Metasyrphus lapponicus (Diptera: Syrphidae)

M. lapponicus is a holarctic species that has been observed attacking *C. piceae* in southeastern Canada (Balch, 1952) and Sweden (Pschorn-Walcher and Zwölfer, 1956). In Oregon and Washington, *M. lapponicus* adults were reared from all collection localities. The species generally occurs in association with *Syrphus opinator* and *S. vitripennis,* although generally in much smaller numbers than either of the two associates. Three stages of *M. lapponicus* are shown in Figure 8.

DESCRIPTIONS OF IMMATURE STAGES. A minimum of description is given the egg and first two larval instars of *M. lapponicus,* since they are very similar to the same stages of *S. opinator.* The adult is described by Fluke (1933).

Egg. Length, 1.05 to 1.29 mm.; width, 0.38 to 0.41 mm. Color, shape, and surface configuration indistinguishable from *S. opinator.*

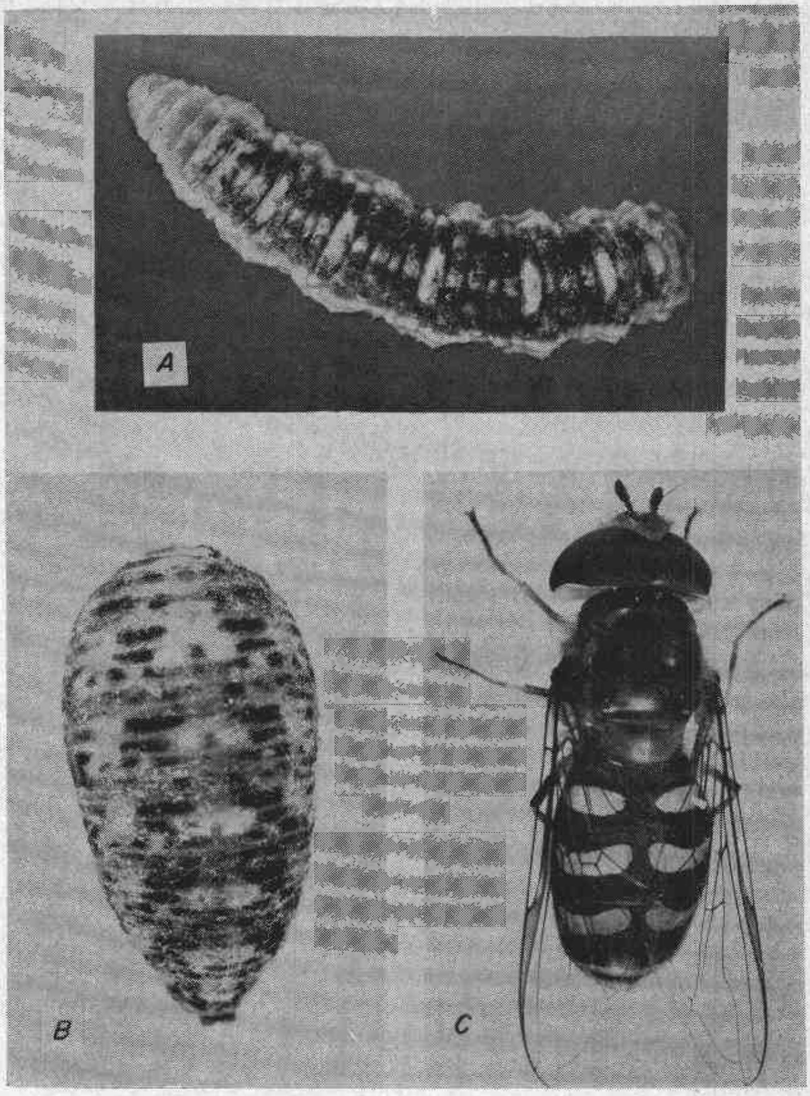

FIGURE 8. *Metasyrphus lapponicus* Zett: **A**, third instar larva; B, puparium; and **C**, male adult.

First instar larva (Figure 9A). Length, 1.90 to 3.30 mm.; width, 0.32 to 0.67 mm. Mean length of mouth-hooks, 0.28 mm. Identical to *S. opinator* in all other respects.

Second instar larva (Figure 9B). Length, 4.74 to 7.20 mm.; width, 1.15 to 1.67 mm. Mean length of mouth-hooks, 0.50 mm. Color dark to light brown in pleural areas, becoming increasingly paler cephalad. Brown color in dorsal area broken by white mid-dorsal line as described for *S. opinator*. Chevron patterns also similar to *S. opinator* except darker. Dorsal spinules much the same as *S. opinator* except those in the chevron areas much blacker and more numerous. Larva indistinguishable from *S. opinator* in all other respects.

Third instar larva (Figures 8A and 9C). Length, 8.27 to 12.21 mm.; width, 1.80 to 3.44 mm. Mean length of mouth-hooks, 0.93 mm. Color as in second instar larva. Form as *S. opinator*. Characteristic designs formed by black, closely set spinules even more apparent than in second instar. Segmental spines as *S. opinator* except ordinarily not as crenate. Posterior spiracular plates similar to *S. opinator* except dorsal spur longer, spiracular carinae more pronounced, and spiracular scar oriented laterad rather than mesad (Figure 9E); combined width of spiracular plates also slightly greater than *S. opinator*, 0.41 to 0.51 mm.

Puparium (Figure 8B). Length, 5.5 to 6.9 mm.; width, 2.3 to 3.0 mm. Color dark orange-brown, with surface spinule pattern of third instar larva distinct. In outline, puparium appears inflated; dorsum distinctly and entirely convex; venter only slightly concave longitudinally and gently rounded transversely. Posterior respiratory process retains characteristic of third instar larva.

LIFE HISTORY AND BEHAVIOR. *M. lapponicus* has one distinct spring generation and may also have a small summer generation. Because only a few puparia of what appears to be the summer form were obtained, and because all were parasitized, the presence of a second generation was not definitely established. Spring oviposition starts near May 1 at high elevations and about mid-March in the Willamette Valley. Eggs are laid singly and conspicuously on the bark of the aphid-infested trees.

In 1959, an ovipositing adult was captured at Corvallis. It was then released in a cage with three species of *Chermes: C. piceae, C. cooleyi* Gill., and *C. tsugae* Ann. The female lived 25 days and laid 41 eggs, most of them by the end of the third day. Of the 41 eggs, 35 were deposited on *C. tsugae*, 2 on *C. cooleyi*, none on *C. piceae*,

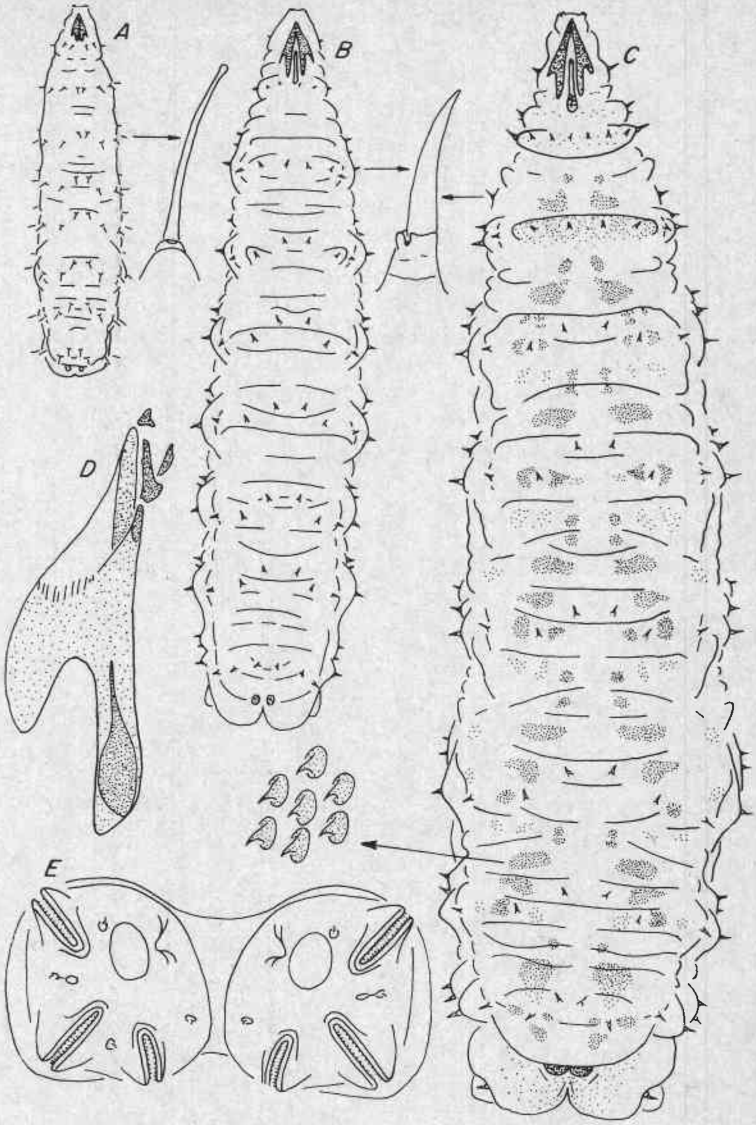

FIGURE 9. Drawings of *Metasyrphus lapponicus* Zett. larvae: A, first instar larva; B, second instar larva; C, third instar larva; D, third instar mouth-hooks; and E, third instar spiracular plate.

and 4 on the sides of the cage. Progeny were then reared in the laboratory on *C. tsugae*. A breakdown of the resulting 40-day rearing period from egg to adult showed the following:

Egg stage	3 to 4 days
First larval stadium	5 to 6 days
Second larval stadium	8 to 9 days
Third larval stadium (one larva)	14 days
Pupal stage	9 days

In the field, the same development took 60 to 70 days.

This insect also has a 1- to 2-day migratory period before pupation. Normally it pupates in the soil, although it is not unusual for *M. lapponicus* to remain on the tree. As with *S. opinator,* adult emergence is delayed considerably in a dry environment.

Except for *Diplazon orbitalis,* which was not encountered, *M. lapponicus* had the same parasite complex as *S. opinator*.

DISCUSSION. Since *M. lapponicus* is usually a minor member of a larger predator complex, it is difficult to estimate the significance of its role in reducing balsam woolly aphid populations. Observations indicate that individually the larva is quite efficient. Its chief fault is a late arrival and low density.

Metasyrphus attenuatus (Diptera: Syrphidae)

Little is known about this species other than that it will prey on balsam woolly aphid. Two third instar larvae were collected feeding on *C. piceae* at Corvallis on May 1, 1959. Both larvae were placed in rearing, and one adult was obtained.

Superficially, larvae and puparia are indistinguishable from *M. lapponicus,* thus leading to possible difficulty in future field determinations. However, the problem will be unimportant if *M. attenuatus* remains as rare on *C. piceae* as it appears at present.

Leucopis sp. I (Diptera: Chamaemyiidae)[1]

This is an undescribed species in the subgenus *Neoleucopis,* near *L. atrifacies* Ald. It was found only at lower elevations, particularly in the Willamette Valley of Oregon. Populations were usually light, although heavier than those of other *Leucopis* species found associ-

[1] Three undetermined species of *Leucopis* are discussed in this bulletin. For distinction, they are called species I, II, and III.

ated with *C. piceae*. Extremely heavy populations were also seen preying on an unknown *Pineus* species at Corvallis. The four life stages of *Leucopis* I are presented in Figure 10.

DESCRIPTIONS OF IMMATURE STAGES. This section describes the egg, third instar larva, and puparium of *Leucopis* I. First and second instar larvae were not observed.

Egg: (Figure 10A). Length, 0.45 to 0.48 mm.; width, 0.17 to 0.18 mm. Color pearl white. Shape oblong-ovate; smallest at micropylar end. Surface entirely covered with numerous undulating, branching, longitudinal carinae; carinae incompletely broken at regular and alternate intervals in adjacent rows, suggesting rows of bricks.

Third instar larva (Figures 10B and 11C). Length, 2.0 to 3.9 mm.; width, 0.62 to 1.08 mm. Mean length of mouth-hooks, 0.28 mm. Color varies from light grey to pale yellow. Form faintly cymbiform in outline; widest portion near but somewhat posterior to mid-portion of body. Dorsum moderately arched longitudinally; venter concave, made more conspicuous by a broad cone-like protrusion on the posterior segment. Segmentation moderately distinct; most obscure in posterior region. Integument densely covered with small to large recurved, hyaline spines; spines loosely arranged in transverse rows on anterior segments, becoming more scattered caudally. Buccal armature distinguished by a sclerotized collar-like arrangement at anterior end, the open end of which faces diagonally ventral and caudad where it connects with the rest of the mouth-parts; anterior end of collar with two short, conical antennae. Larva amphipneustic; spiracles at juncture of first and second visible somites and on antepenultimate segment. Anterior respiratory processes on lateral sides of dorsum; branched into three and occasionally four arms. Posterior processes widely separated, densely spinose, darkly sclerotized, and terminating with a short truncated spur and three conspicuous spiracular arms. Length of respiratory processes, 0.055 to 0.073 mm.; width at base, 0.059 to 0.073 mm.

Puparium (Figure 10C). Length, 2.1 to 2.3 mm.; width, 0.69 to 0.76 mm. Color velvet-like tan or light brown. Fusiform in outline; ends broadly rounded. Dorsum moderately convex, the highest portion in the middle. Anterior end flattened dorsally into a duck bill-like shelf. Dorsolateral regions with weakly developed longitudinal sulcus extending from anterior shelf to posterior respiratory processes. Ventral surface flat. Posterior processes conspicuously echinate.

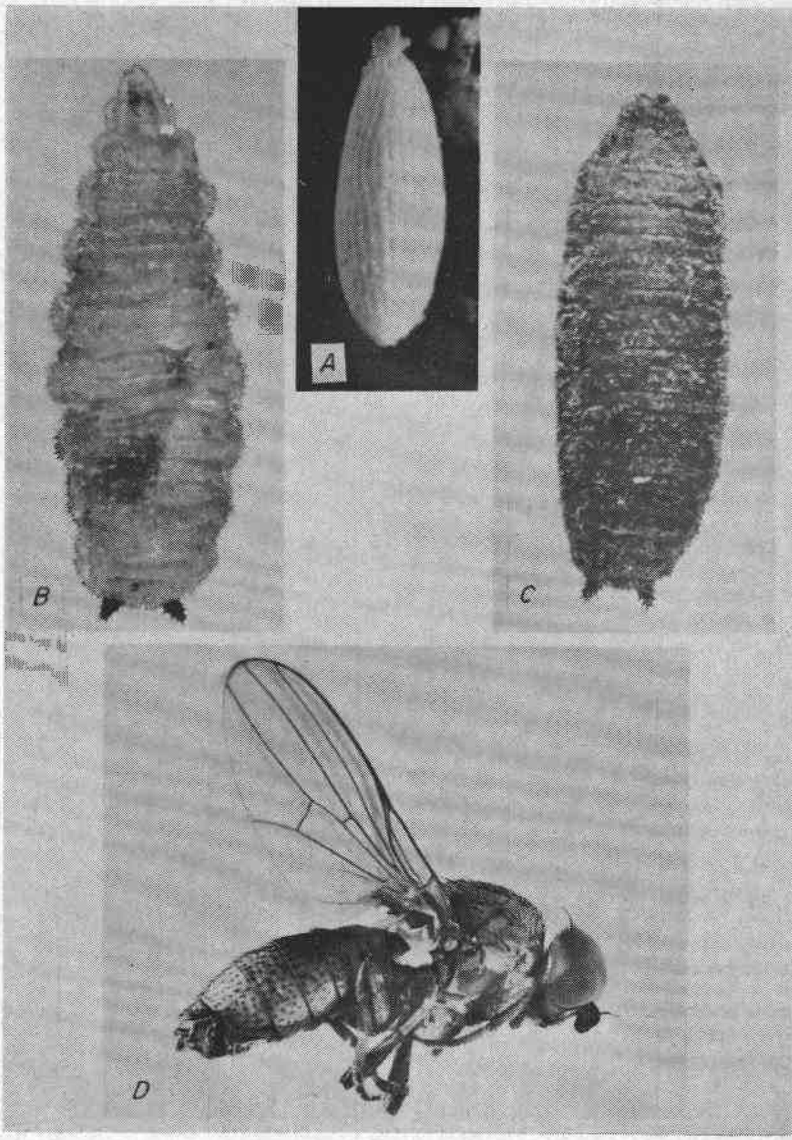

FIGURE 10. *Leucopis* sp. I: A, hatched egg; B, third instar larva; C, puparium; and D, adult female.

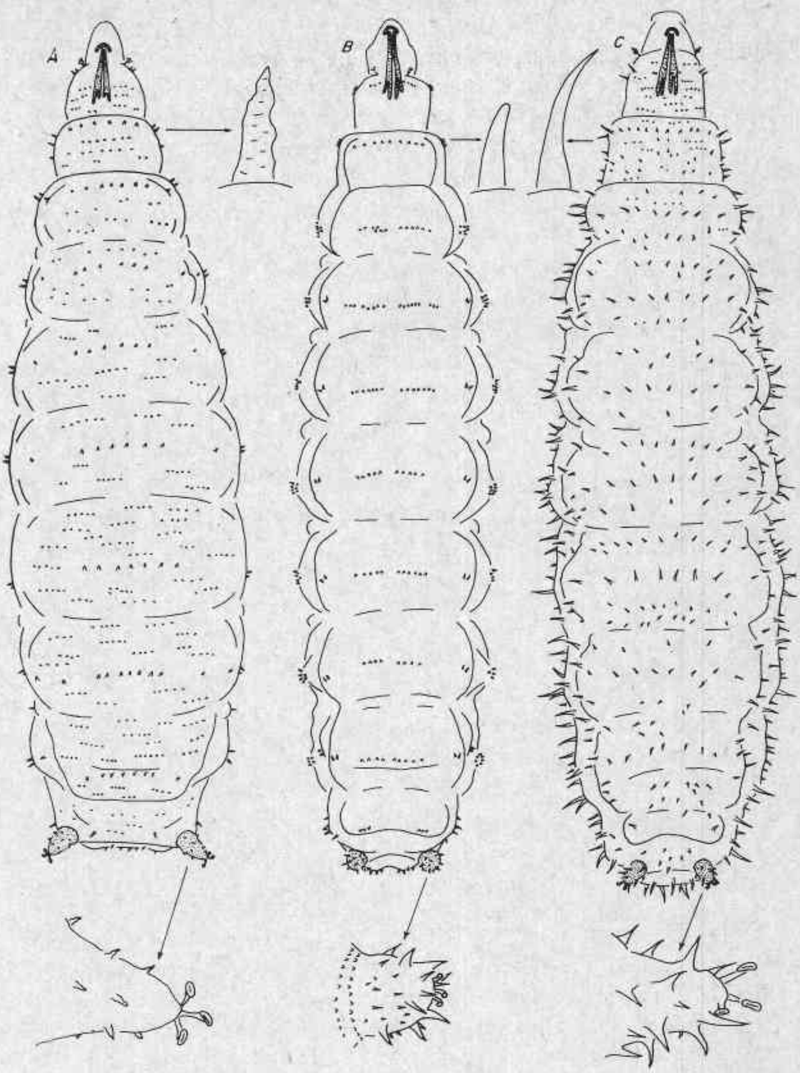

FIGURE 11. Drawings of three mature larvae in the genus *Leucopis:* A, *Leucopis* sp. II; B, *Leucopis* sp. III; and C, *Leucopis* sp. I.

LIFE HISTORY AND BEHAVIOR. *Leucopis* I has two generations per year. Eggs are laid singly on *Chermes*-infested trees—on the bark surface, in wax masses, and under lichen. They are usually very difficult to find, even when populations are heavy. Mature larvae are equally difficult to detect because of their habit of feeding completely within the wax masses, and because the chermid wool clings tenaciously to the numerous larval spines.

Pupation occurs on the tree, usually in some hidden area under lichen, around bark fissures, or within mats of chermid wool. If the predator population is heavy and hiding places scarce, pupating larvae become quite gregarious. Ten to fifteen larvae may congregate under one small piece of lichen.

Winter is passed in the larval and pupal stages. All three larval stages will over-winter on the tree, although most of the hibernating population consists of puparia. Puparia collected in the fall need an extended cold treatment at near-freezing temperatures before adults will emerge. Treatment must last at least 30 days.

Two parasitic chalcids were reared from puparia of *Leucopis* I—*Pachyneuron* sp. and *Lygocerus* sp. Aggregate parasitism by these two chalcids varied but was usually near 25%.

DISCUSSION. Control of *Chermes piceae* by *Leucopis* I appears to be negligible, largely because of its low numbers. Rarely are more than 10 larvae per 5-foot section found on an aphid-infested tree. In contrast, as many as 17 larvae have been found on less than 3 square inches of *Pineus*-infested bark.

Leucopis sp. II (Diptera: Chamaemyiidae)

This species (subgenus *Leucopina*) apparently is undescribed. According to Dr. J. F. McAlpine,[1] Entomology Research Institute, Canada Department of Agriculture, *Leucopis* II is the same as the *L. americana* Mall. found by Brown and Clark (1956a) preying on the balsam woolly aphid in the maritime provinces of Canada, but not the true *L. americana* described by Malloch (1921). In Oregon and Washington, populations of *Leucopis* II associated with balsam woolly aphid are usually quite small, seldom exceeding 9 to 10 larvae per 5-foot bole section. Occasionally, however, predator density is greater, and usually is found associated with heavy, long established aphid infestations.

[1] Correspondence in the fall of 1960.

DESCRIPTION OF IMMATURE STAGES. This section describes the third instar larva and puparium. Egg and first two larval instars were not observed.

Third instar larva (Figure 11A). Length, 2.57 to 4.01 mm.; width, 0.64 to 1.38 mm. Mean length of mouth-hooks, 0.30 mm. Color pale, light grey. Subcuneiform in outline; strongly arched dorsally; conspicuously concave ventrally, pronounced by a conical swelling on last abdominal segment. Buccal armature with collar-like apparatus as in *Leucopis* I. Segmentation somewhat obscure. Body spines of two distinct sizes: large segmental spines, distinctly sinuate, irregular in number, and arranged in eight transverse rows dorsally; smaller spines spinule-like and arranged in numerous short, transverse rows over the entire body. Integument smooth between spines. Larva amphipneustic as *Leucopis* I. Anterior respiratory processes branched into four and sometimes five spiracular arms. Posterior processes well separated, slightly spinose, and heavily sclerotized; distal end of process split on three sides, making an opening from which emerge three spiracular arms. Length of respiratory processes, 0.12 to 0.15 mm.; width at base, 0.08 to 0.10 mm.

Puparium. Length, 2.4 to 2.8 mm.; width, 0.9 to 1.1 mm. Color silky dark brown to reddish brown. Shape broadly fusiform in outline, constricting abruptly at dorsally flattened anterior end. Dorsum convex; highest point in posterior third, sloping gradually forward to anterior depression and abruptly posteriorly and laterally. Each pleuron with distinct longitudinal sulcus extending from anterior flattened area to posterior respiratory process. Ventral surface level longitudinally, gently rounded transversely. Posterior spiracular processes distinctive as in larva.

SEASONAL HISTORY AND BEHAVIOR. Seasonal history of *Leucopis* II is very similar to *Leucopis* I, both having two generations per year. Larvae feed within the chermid-wax masses, but are easier to detect than *Leucopis* I because of their larger size and absence of wool-gathering spines. Pupation usually occurs on the bark, although a collection of several larvae and puparia in a tray at Black Rock suggests that some may pupate in the soil. Winter is passed in the larval and pupal stages. A cold period is needed to break diapause in fall-collected puparia.

Leucopis II is attacked by the same two parasitic chalcids reared from *Leucopis* I—*Pachyneuron* sp. and *Lygocerus* sp.

Leucopis sp. III (Diptera: Chamaemyiidae)

This is another undescribed species (subgenus *Leucopis*). It was encountered throughout the region but was generally rare. One exception was an eastside collection at the south boundary of the Yakima Indian Reservation near Goldendale, Washington. There, this species presented the heaviest predator population ever seen associated with the balsam woolly aphid. It appears that there is but one generation per year in that locality. There was no indication of an early generation, and larvae collected in August pupated on the stem and went into diapause. Diapause could be broken only by subjecting the puparia to an extended cold period at temperatures near freezing.

Mature larvae of this species are conspicuously different from those of *Leucopis* I and II. A larval drawing of this species is presented in Figure 11B. Mature larvae range from 1.64 to 3.22 mm. in length and 0.64 to 0.90 mm. in width. Mean length of mouth-hooks is 0.26 mm. Color is bright yellow. Shape narrowly fusiform in outline, tapering gradually from a point slightly anterior to mid-body. Dorsum only slightly arched, dropping abruptly laterally to shelf-like, crispate margins. Venter faintly concave longitudinally and generally flat transversely. Segmentation very distinct. Collar arrangement and short conical antennae conspicuous at anterior end of buccal armature as in *Leucopis* I and II. Integument densely covered with conspicuous, conical, hyaline papillae. Each somite with an irregular number of spines. Spines well rounded distally; arranged in 9 medially interrupted, transverse rows dorsally and clustered in 10 small groups in pleural areas. Larva metapneustic as in previously described *Leucopis*. Anterior spiracles branched into three arms. Posterior processes subspherical in outline, well separated, heavily sclerotized, and echinate. Processes terminating with three branched arms, so short they are nearly lost in the mass of spines; truncated spiracular spur arises immediately dorsal to origin of the three spiracular arms.

Puparium length, 2.1 to 2.3 mm.; width, 0.69 to 0.76 mm. Color granular light brown. Shape narrowly cymbiform; pointed at anterior end and blunt caudally. Dorsum generally convex, except anterior end which is dorsally flattened as *Leucopis* I and II; venter flattened. Lateral margins steep and lacking longitudinal sulci. Posterior respiratory processes less conspicuous than those on the two previous *Leucopis* species.

Lestodiplosis sp. (Diptera: Itonididae)

This insect was found at nearly every collection point in the balsam woolly aphid infestation area. It occurred in very small numbers and, for that reason, appeared to be of little value in controlling *C. piceae*. Adults were not reared, although the larvae are easily assigned to genus from the description by Peterson (1951). A drawing of a mature larva is presented in Figure 12A.

Lestodiplosis sp. has two generations per year—the first complete generation appearing in midsummer, the second in late fall. Winter is passed in various stages of larval development. The small larvae feed completely within aphid egg masses and are very difficult to detect. The pupal stage is unknown. A similar predator—perhaps the same species—attacking *Pineus* sp. at Corvallis was found pupating in loosely spun cocoons under lichen growing on the tree stem.

Length of mature larvae ranges from 1.92 to 2.25 mm.; width, 0.35 to 0.44 mm. Color dark pink with an iridescent shagreened texture. Larva cylindrical, slender; widest just posterior to mid-portion of body and gradually tapered toward the ends. Dorsal surface level and somewhat flat transversely. Ventral surface slightly arcuate longitudinally and with conspicuous pseudopods on 10 segments: meso- and metathorax each with two pseudopods, abdominal segments I through VII and abdominal segment IX with three pseudopods. Small, brown, capsule-like head with a pair of long, two-segmented antennae; distal segment about 10 times the length of basal segment. Breast plate on ventral surface of thorax with anterior end heavily sclerotized and retuse; posterior portion not sclerotized and largely obscure. Integument densely covered with minute, hyaline papillae. Body encircled by 12 transverse rows of conspicuous, alternately large and small setae: 16 setae on each of the thoracic segments, 12 on each of the first 7 abdominal segments, and 6 each on the last 2 segments; lateral setae on the first 7 abdominal segments always close to the spiracles and somewhat anterior to the dorsal and ventral setae. Nine pairs of spiracles are located on the prothorax and the first eight abdominal segments; those of the prothorax and eighth abdominal segment more dorsad. Caudal end of larva blunt, lacking ornamentation.

The long, conspicuous setae; the blunt, simple cauda; and the distinctive, ventral pseudopods easily distinguish *Lestodiplosis* larvae from the introduced itonidid, *Aphidoletes thompsoni* (Figure 12C).

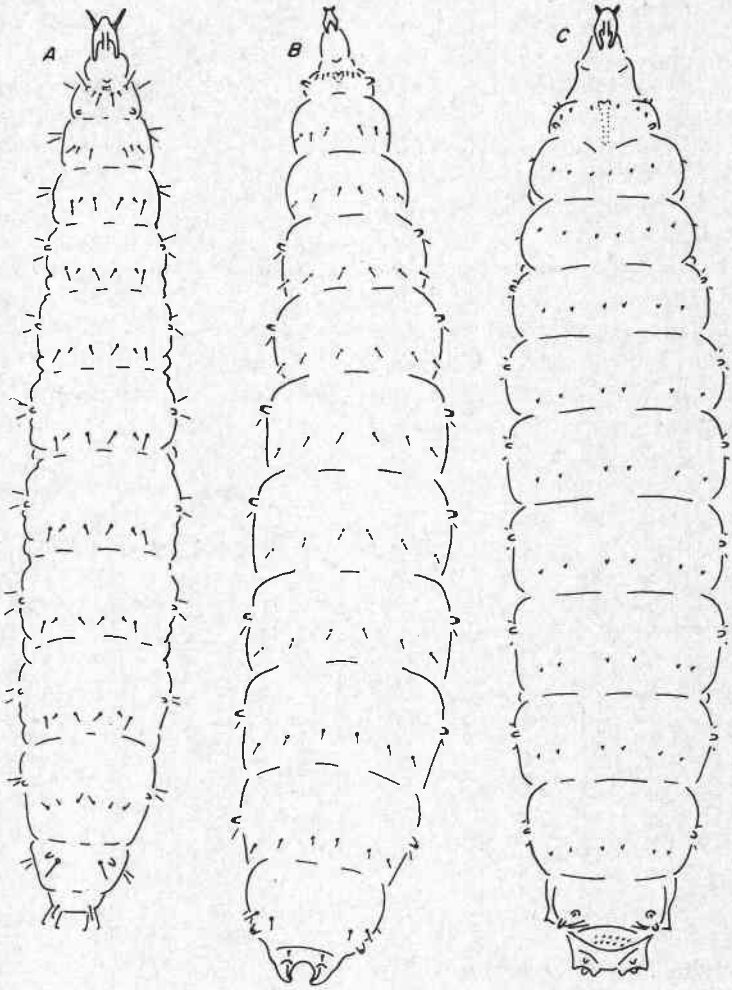

FIGURE 12. Drawings of three mature itonidid larvae: A, the native *Lestodiplosis* sp.; B, a native unknown species; and C, the introduced *Aphidoletes thompsoni* Mohn.

Undetermined Itonididae (Diptera)

The significance of this insect in the balsam woolly aphid predator complex is probably nil. Larvae were seen in only three areas (Black Rock and Corvallis, Oregon, and Toutle River, Washington) and always at extremely low densities. Ten larvae represented the largest collection ever made. One adult female was reared from that collection, but the species was not identified since only males are useful in taxonomic determination.

Habits of this predator are similar to those of the introduced predator, *Aphidoletes thompsoni*. Both species feed entirely concealed by chermid wool and are found only by disturbing them with a probe or removing their cover. Both pupate in the soil and make the same type of pupal chamber from silk and soil particles.

A drawing of the mature larva of this species is presented in Figure 12B. A description follows: Length, 2.61 to 3.76 mm.; width, 0.54 to 0.82 mm. Color pale pink. Narrowly cuneiform in outline; widest at fifth abdominal segment. Dorsum well rounded transversely, level longitudinally. Venter arcuate; thickest in posterior third. Tiny, brown head capsule diamond-shaped in outline; antennae inconspicuous. Breast plate with anterior end sclerotized and heart-shaped; posterior portion narrow and weakly or not at all sclerotized. Integument covered with hyaline projections similar to fish scales. Body encircled by 12 transverse rows of evenly spaced, uniformly long setae; 12 setae on each segment except the last 2 segments which have 6 setae each. Spiracles as *Lestodiplosis* sp. except slightly larger and more sclerotized. Two well-sclerotized, recurved horns on caudal segment; each horn with a small seta on the outside lateral margin near the base. Caudal horns easily distinguish this species from *Lestodiplosis* sp. and *A. thompsoni*.

Hemerobius neadelphus (Neuroptera: Hemerobiidae)

This species was one of the most abundant native predators attacking the balsam woolly aphid, although occasionally quite rare. It was found throughout the entire infested zone, but usually was more abundant at higher elevations. The four life stages of *H. neadelphus* are presented in Figure 13.

DESCRIPTIONS OF THE IMMATURE STAGES. This section describes the egg, three larval instars, and pupa of *H. neadelphus*. The adult is described by Gurney (1948).

Egg (Figure 13A). Length, 0.45 to 0.52 mm.; width, 0.19 to 0.22 mm. Color light tan when first laid, becoming pinkish later; abdominal segments of developing larva outwardly visible about one day before hatching. Egg barrel-shaped in outline with conspicuous button on micropylar end. Surface completely covered with short, longitudinal, microscopic carinae.

First instar larva. Length, 1.33 to 3.20 mm.; width at third thoracic segment, 0.26 to 0.51 mm. Mean width of head capsule, 0.29 mm. Very similar to second and third larvae except lacking cervical segment and having trumpet-shaped empodium (Figure 14F).

Second instar larva. Length, 3.02 to 4.96 mm.; width at third thoracic segment, 0.51 to 0.79 mm. Mean width of head capsule, 0.38 mm. Identical in all other respects to the third instar larva described below.

Third instar larva (Figures 13B and 14A, B, C, D, and G). Length, 5.7 to 9.2 mm.; width at third thoracic segment, 0.82 to 1.54 mm. Mean width of head capsule, 0.49 mm. Head and thorax light tan with two parallel brown stripes laterodorsally; meso- and metathorax and first four abdominal segments blue dorsally and tan mottled with brown in pleural regions. Last six abdominal segments pink with two parallel brown stripes. Head prognathous, depressed, and subcircular in outline. Three ocelli positioned immediately behind and to the outside of the antennal bases (Figure 14A). Antennae conspicuous, five-segmented; last two segments very short; distal segment bristle-like. Jaws consisting of mandible and maxilla. Mandible falcate and minutely shagreened; grooved ventrally and with 3 to 4 horizontal barb-like serrations distally on inner margin and 10 to 15 minute vertical barbs farther back (Figure 14C). Maxilla broadly falcate with 14 large setae mostly along outer margin and 2 to 3 inconspicuous distal setae; surface shagreened as mandible and grooved dorsally to form sucking duct when united with mandible; distal end blunt, terminating with 10 to 12 microscopic sensory pegs (Figure 14D). Labium reduced to a pair of conspicuous, four-segmented palpi (proximal two segments obscured in drawing); internal margin of last segment with distinct distal concavity; outer margins of concavity ringed with a single row of 40 to 50 sensory pegs. Integument with numerous multilength setae; surface between setae covered with numerous, black, microscopic spinules. Prothorax as shown in Figure 14B with three annulets; first annulet (or cervical segment) with 18 setae; second annulet with 24 setae; third annulet with 26 setae and 2 large sclerotized plates dorsally. Mesothorax with 2 annulets—anterior annulet with a pair of annular spiracles and 14 setae; posterior annulet with 44 setae and 2 sclerotized plates. Metathorax with

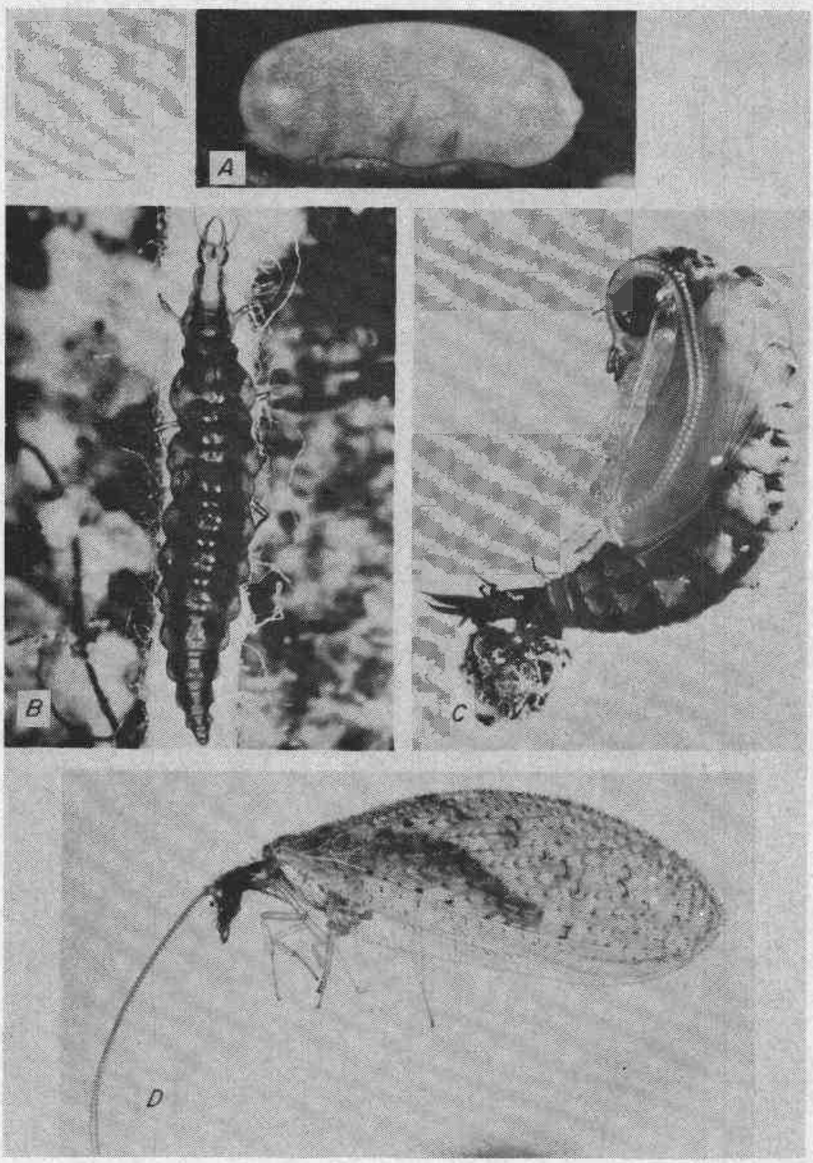

FIGURE 13. *Hemerobius neadelphus* Gurney: A, egg; B, third instar larva; C, pupa; and D, adult.

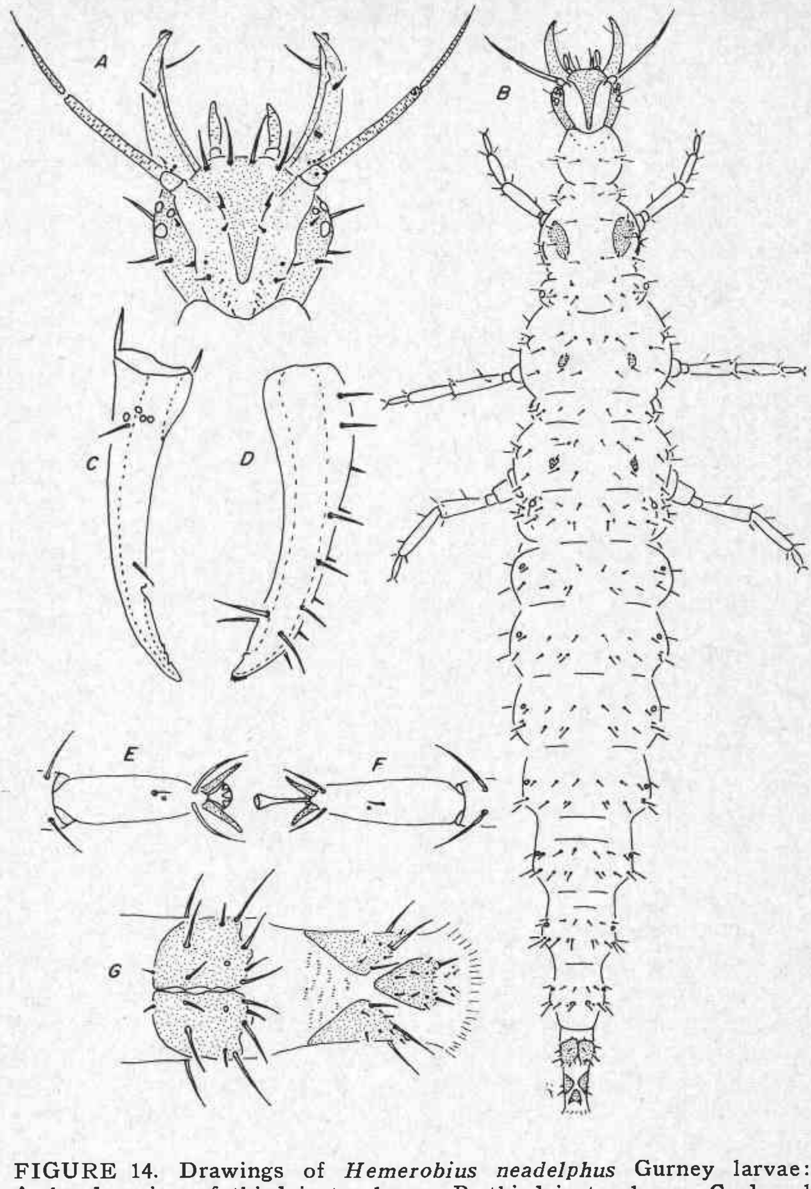

FIGURE 14. Drawings of *Hemerobius neadelphus* Gurney larvae: A, head region of third instar larva; B, third instar larva; C, dorsal view of third instar right mandible; D, ventral view of third instar right maxilla; E, tarsus of third instar; F, tarsus of first instar; and G, dorsal view of last two abdominal segments.

2 annulets—12 setae anteriorly; 38 setae and 2 small sclerotized plates posteriorly. Legs five-segmented; empodium abbreviated (Figure 14E). Abdomen composed of 10 segments; first 8 segments with lateral pairs of annular spiracles, the circular openings becoming progressively smaller with each succeeding segment. Last two abdominal segments eversible and with distinct triangular sclerotized plates as shown in Figure 14G. Abdominal segments I through VIII each with two transverse rows of setae; anterior row with 14 setae on first 4 segments, 12 on the next 4; posterior row with 20 setae except for segment I which has 12 setae.

Pupa (Figure 13C). Length, 4.0 to 4.7 mm. Enclosed in loosely spun white cocoon. Body largely brown, mottled with light tan; developing wings, antennae, and legs uniformly translucent tan; eyes glossy black. Shape strongly arcuate dorsally. Segmentation distinct. Conspicuous humps on dorsum of second and third abdominal segments; each hump surmounted by two pairs of recurved, sclerotized hooks—anterior pair bending cephalad and posterior pair bending caudad. Terminal abdominal segment blunt, usually covered by exuvium of the last larval instar, as in Figure 13C.

LIFE HISTORY AND BEHAVIOR. *H. neadelphus* has at least two and possibly three generations per year at high elevations. Oddly enough, there is only one generation in the Willamette Valley. It occurs in late summer. Oviposition at Willamette Pass starts in mid- or late-June and continues to mid-July. Eggs are laid singly, directly on the bark of the aphid-infested tree or on lichen growing on the stem. The majority are attached to lichen, where as many as five eggs may be deposited on one small, thread-like thallus branch. The first hatched larvae of the group sometimes attack and destroy remaining unhatched eggs.

All three larval stages feed from outside the wax mass and are easily detected. Larvae are extremely cannibalistic in laboratory rearings and moderately so in their natural habitat. Duration of the three larval instars in the laboratory is about 20 days. The pupal period lasts 9 or 10 days. Pupation occurs in the soil or under lichen on the tree. *H. neadelphus* may overwinter in either larval or pupal stage; there is no diapause period.

H. neadelphus seems to have few natural enemies. One parasite, *Anacharis punctatifrons* Kieffer (Cynipoidea: Figitidae), was recovered, but seldom encountered. Chief enemy was a syrphid, *Metasyrphus amalopsis*. All three larval stages of *H. neadelphus* were preyed upon by this fly.

DISCUSSION. *H. neadelphus* does not contribute greatly to the reduction of balsam woolly aphid populations; predation begins too late in the season and is confined largely to trees with heavy aphid populations. Also, this predator does not maintain a significant population throughout the year. Initially, numbers are large, but density drops sharply after the end of the first generation. In 1959 at Willamette Pass, the first generation was more than 10 times the size of the second.

Chrysopa sp. (Neuroptera: Chrysopidae)

A few *Chrysopa* larvae were found feeding on *C. piceae* at almost all collection points, mostly in late summer. All appeared to be the same species, although this was not proved. Because chrysopid eggs were found only in the upper crowns, associated with free-living aphids (*Cinara* spp.), it is suspected that feeding on the balsam woolly aphid was incidental. A larva and adult are illustrated in Figure 15.

Mature larvae are easily detected when feeding on the balsam woolly aphid. They feed completely exposed and are relatively large; 8 to 11 mm. long. Color is dark grey on lateral margins and conspicuously red and pink along dorsal midline. Lateral wart-like protuberances and conspicuous long hairs also are distinguishing features.

Chrysopa quadrimaculata Burm. (Neuroptera: Chrysopidae)

Larvae of this species were observed only a few times, at three areas—Corvallis and Benton-Lane Park, Oregon, and Goldendale, Washington. The insect is very interesting because of its habit of piling *C. piceae* wool, sistentes, and eggs on its back. In its early stages, when small, the predator gives the appearance of a moving balsam woolly aphid wax mass.

The insect apparently has but one generation per year, beginning in late July and ending in late August. Pupae are easily obtained by caging the insect on the tree, but adult emergence will not occur unless the insect is cold-treated. A dorsal view of the larva with the wool removed and a ventral view with the wool in place are illustrated in Figure 16.

Larvae are quite distinct from those of the chrysopid listed above. Mature larvae are about 4 mm. long and colored a nondescript grey and black. The most distinctive features are the extremely long hairs and the dorsally humped abdomen.

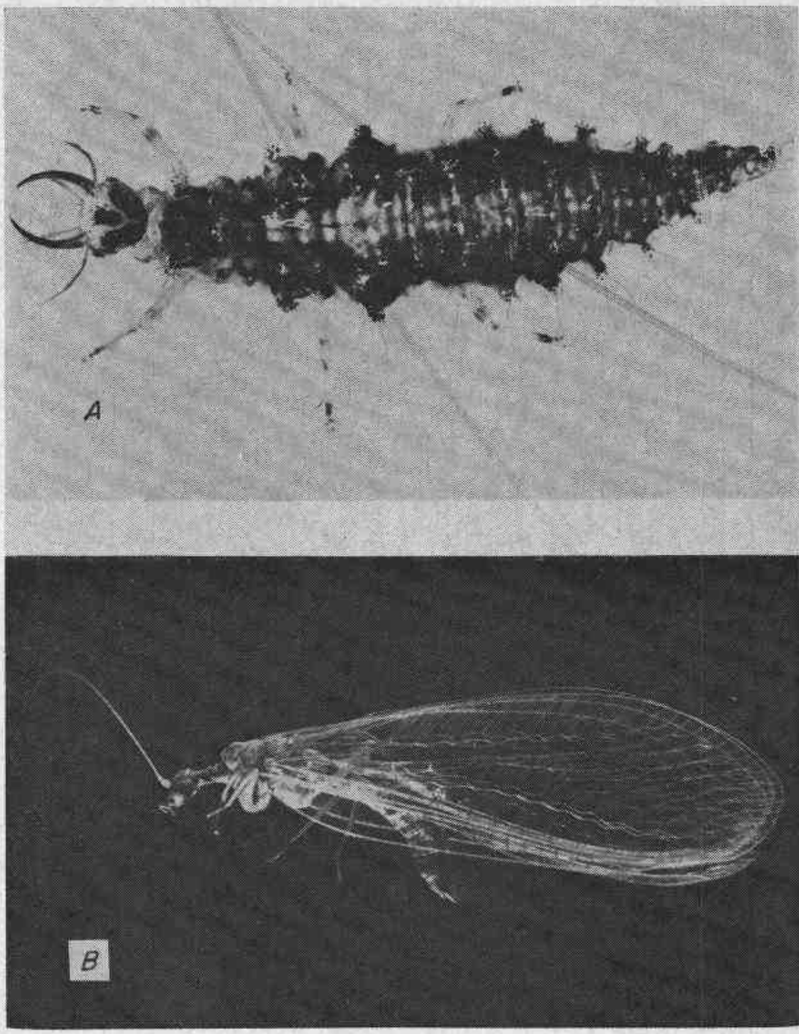

FIGURE 15. *Chrysopa* sp.: A, mature larva; and B, adult.

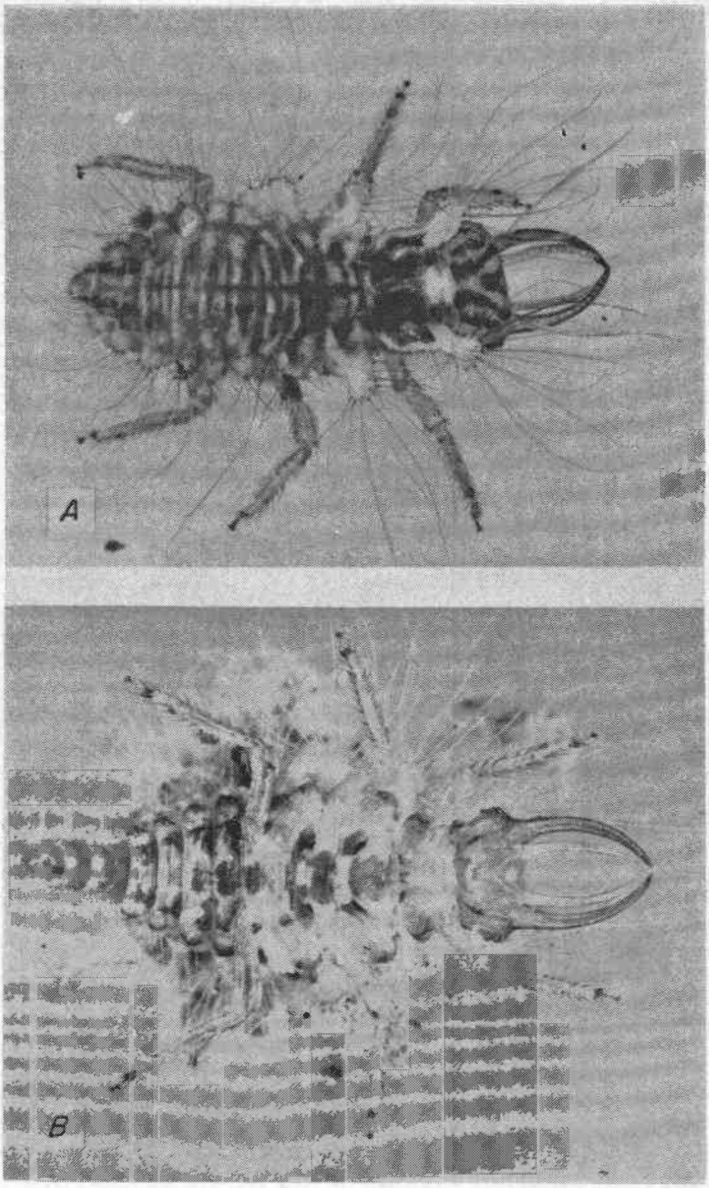

FIGURE 16. *Chrysopa quadrimaculata* (Burm.): A, dorsal view with trash removed; and B, ventral view with trash in place.

Mulsantina picta (Coleoptera: Coccinellidae)

This beetle is often encountered preying on native chermids in the lowland areas of the Pacific Northwest, but is seldom seen associated with *C. piceae.* It is also a predator of chermids in New Brunswick province, Canada (Balch, 1952). Eggs, larva, pupa, and adult of *M. picta* are shown in Figure 17.

M. picta has two generations per year. Eggs are laid in mid-May and again in early July. They are deposited in groups of four to eight, attached on end directly to the bark or needles of the infested tree. Eggs are bright yellow and about 1 mm. long. Newly hatched larvae prey on all aphid stages except the neosistentes. Most predation occurs high on the tree, in association with *Cinara* sp. as well as with the balsam woolly aphid. Pupation occurs on the bark, usually in fissures or pitch pockets. Emerging adults occasionally remain associated with the chermid infestation, but usually go elsewhere.

Larvae are about 7 mm. long and are mostly black, with white margins and a white mid-dorsal line. The black areas are heavily sclerotized, rough textured, and quite spinose. Pupae are mostly white to pink with conspicuous black areas on the dorsum; length is about 5 mm.

Laricobius nigrinus (Coleoptera: Derodontidae)

L. nigrinus was found preying on balsam woolly aphid in only one area—Portland, Oregon. Although rarely associated with *C. piceae,* it is a common predator of native chermids, at least in Oregon's Willamette Valley. The insect has one generation per year. Adults appear in March and larvae become abundant in April. About the first of May, larvae begin dropping from the trees and enter the soil. Laboratory tests suggest that larvae begin pupation a few days after leaving the tree. It is not known if the predator emerges the same year. However, observations suggest that the adult does not emerge until the following spring. Larva and adult are illustrated in Figure 18.

The value of this species as an effective predator of the balsam woolly aphid is probably nil, except, perhaps, in isolated cases. Its significance in the predator complex lies in its similarity in the larval stage with *L. erichsonii* Rohn., an introduced predator from Europe. The two species are nearly identical, anatomically as well as in their yellowish green color. Mature larvae of the native predator are only slightly longer in length, ranging from 4.0 to 5.0 mm., while *L. erichsonii* is 4.0 to 4.5 mm. long. Field separation of the two species is

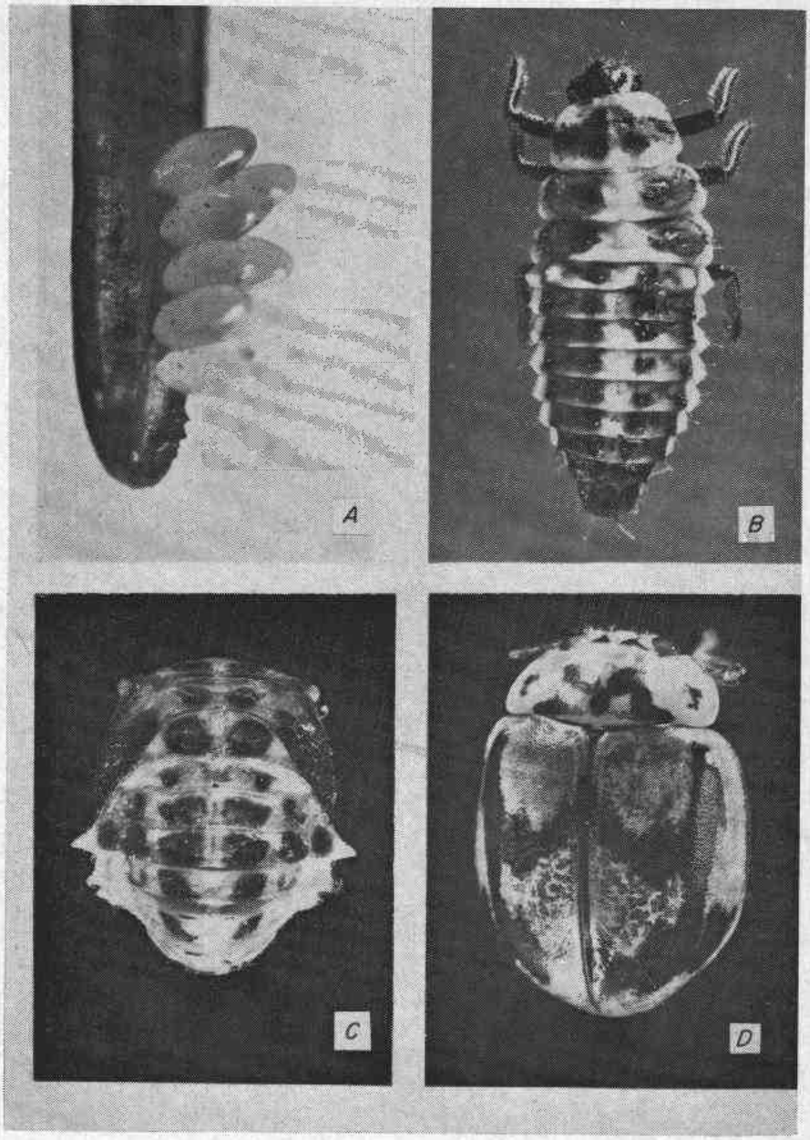

FIGURE 17. *Mulsantina picta* (Rand.): A, eggs; B, mature larva; C, pupa; and D, adult.

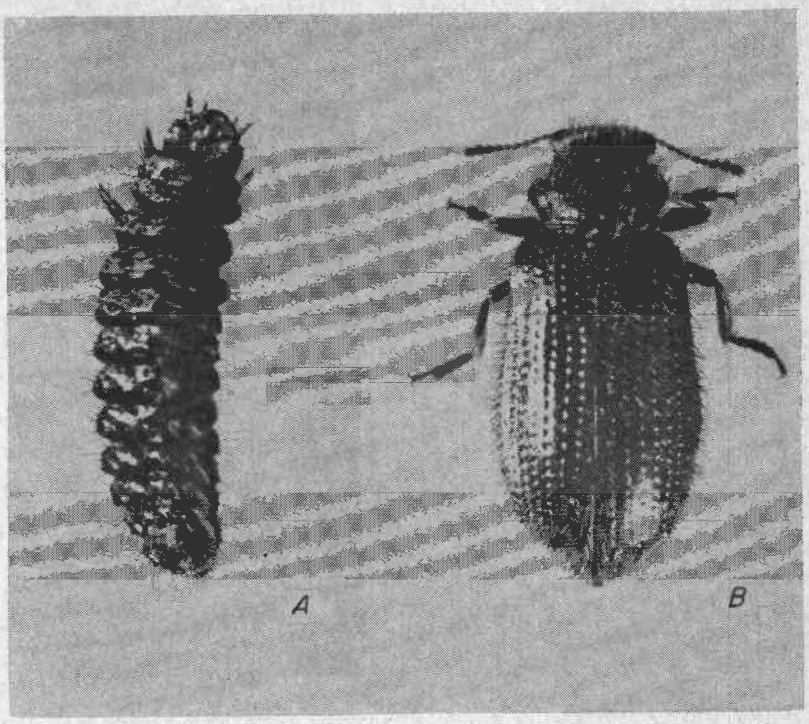

Figure 18. *Laricobius nigrinus* Fender: A, mature larva; and B, adult,

therefore impossible, and distinction between slide-mounted specimens almost as difficult. Thus far, the only means of separation in the laboratory is to compare widths of last instar head capsules—widths for the native predator varying from 0.46 to 0.53 mm. as compared to a range of 0.38 to 0.47 mm. for *L. erichsonii.*

Acompocoris lepidus (Hemiptera: Anthocoridae)

This interesting anthocorid was observed on two occasions in 1961, 2 miles east of Santiam Pass, Oregon. On June 26, the population was composed entirely of nymphs. Density ranged from 20 to 30 predators per square inch of aphid-infested bark surface. Two weeks later, on July 10, the insects had all developed to the adult stage and decreased in density to about half that seen previously. Bi-weekly inspections were continued throughout the rest of the summer, but the predator was not seen again; nor was it ever seen anywhere else except for the one small, isolated area.

A. lepidus preys on all stages of the balsam woolly aphid except neosistentes and appears to be an effective predator when present. Nymphs and adults are quite active and completely exposed when feeding. Adults range from 2.8 to 3.1 mm. in length; nymphs may be as small as 1 mm. Their color is a dark, glossy maroon.

Anystis sp. (Trombiformes: Anystidae) and *Allothrombium* sp. (Trombidiformes: Trombidiidae)

Neither of these mites appeared particularly significant as predators of the balsam woolly aphid. *Anystis* was found on nearly all aphid-infested trees in the region, but was seldom abundant on any one tree. It appeared that the principal host was other mites. *Anystis* is small, 0.39 to 0.59 mm. long, bright red, and extremely active.

Allothrombium, a much larger mite, 2.1 to 3.2 mm. long, is bright red, covered with a velvet-like pile, and not nearly as active as *Anystis*. The writer observed *Allothrombium* only once—in early May at Black Rock, Oregon. N. E. Johnson, entomologist for Weyerhaeuser Company, reports the mite to be more common in the Toutle and Green River drainages of Washington, but not particularly abundant.[1] Again, the primary host is probably other mites.

Notes on Possible Predators of Chermes piceae

None of the eight arthropods discussed in this section have been observed feeding on the balsam woolly aphid. The possibility of their being predators is suggested by the fact that all were found in association with *C. piceae* and that all belong to groups known to be predaceous on insects. In general, the purpose of this section is to report briefly what was learned about these possible predators.

Insects

Metasyrphus amalopsis (Diptera: Syrphidae)

This dipteron was found throughout the aphid infestation zone but was not abundant. Although *M. amalopsis* was occasionally found preying on free living aphids, particularly *Cinara* spp., it is quite possible that the insect primarily feeds on other predators associated with the balsam woolly aphid. Several times it was observed preying on *Hemerobius neadelphus*, and once it was seen attacking *Cnemodon rita*.

[1] Private correspondence.

M. amalopsis larvae do not search for their food, but rather let the prey come to them. Resting on the bark surface with its anal end adhering firmly to the substrate, the larva does not move until contacted by some wandering arthropod. It then rears back and strikes out at the prey. When caught, the prey is held in the air until consumed. Mature larvae are 8 to 11 mm. long, quite spinose, and strikingly colored in various shades of pink, blue, green, and black. The mature larva and adult are illustrated in Figure 19.

Hemerobius conjunctus var. *conjunctus* (Neuroptera: Hemerobiidae)

One adult was reared from a pupa found on the bark of a balsam woolly aphid-infested tree in June 1957, at Toutle River, Washington. The species was not collected again and nothing further is known about it.

Agulla sp. near *adnixa* (Neuroptera: Raphidiidae)

One adult was collected on the bark of an aphid-infested tree at Willamette Pass in 1957. In 1958 and 1959, several snakefly larvae were found in other areas as well as Willamette Pass; however, none were observed feeding naturally, nor could they be reared on the balsam woolly aphid after starvation. Accordingly, it was not determined whether the larvae were of the same species as the adult collected in 1957.

Cycloneda polita (Coleoptera: Coccinellidae)

In 1958, two adults were collected in association with *C. piceae*—one in May at Corvallis, Oregon, and the other in June at Wind River, Washington. Both appeared to be merely resting on the bark of aphid-infested trees; neither was observed feeding. On June 17, 1959, at Benton-Lane Park, several *C. polita* were observed pupating on the bark around the base of an aphid-infested tree. Larvae were not seen; therefore, predation habits were not learned.

Mites

Very little is known about the four mites found associated with balsam woolly aphid. One, *Biscirus uncinatus,* was found associated with *C. piceae* in almost every area. Although the species had had

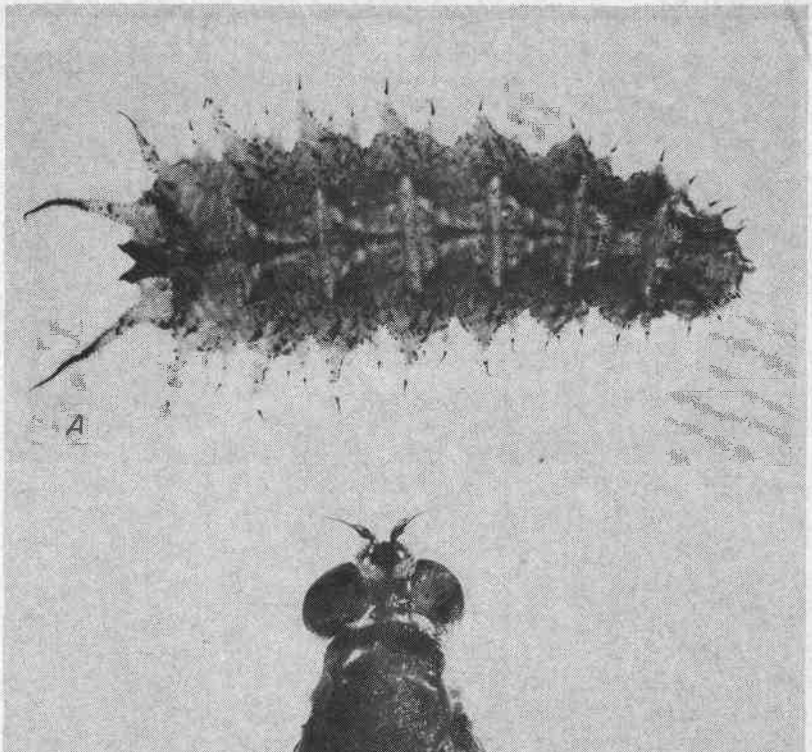

FIGURE 19. *Metasyrphus amalopsis* O. S.: A, third instar larva; and B, adult.

ample opportunity to prey on the balsam woolly aphid, close observations failed to detect it doing so. At Corvallis, it was seen once feeding on an undescribed phytophagous mite in the genus *Brevipalpus,* which is abundant on grand fir. It is possible that *Brevipalpus* is the primary host.

A second mite, *Anystis agilis,* was observed in great numbers on two occasions at Black Rock. Both times it was seen on *C. piceae*-infested trees during a short period in late July. At neither time was the mite observed feeding.

The last two mites, *Tydeus* sp. and *Typhlodromus bakeri,* were found at Black Rock in late December, 1957. They were not observed feeding, and no other collections have been made since that time.

Evaluation of Predator Effectiveness

In a previous section, some qualitative estimates were made on efficiency of individual predator species in reducing *C. piceae* populations. The following section presents procedures and results of attempts in two study areas to quantitatively evaluate the combined effectiveness of all predators present. Information presented is based on work done in 1959. A similar, more ambitious evaluation program was pursued in 1958 but was a failure, largely because of inadequate sampling.

Methods and procedures of evaluation

Two trees, a Pacific silver fir at Black Rock, Oregon, and a subalpine fir at Willamette Pass, Oregon, were used for sampling predator effectiveness. Both trees had heavy balsam woolly aphid stem infestations, but survived the one season of study. A selection requirement was that the trees have aphid infestations extending close to the ground.

The method used for evaluating predator effectiveness was a modification of a system designed in Canada by Clark and Brown (1958). On each of two study trees, beginning just above ground level, a 5-foot trunk section was delineated with string lines as a sampling area. The number, stage, and species of predators were recorded over the entire 5-foot area. Prey populations were tallied on 10 1-inch-square "sub-plots" within the area. These 10 plots were grouped into two vertical rows of five each, one row on the north and the other on the south side of the tree. Vertical distance between plots was 1 foot. A variation from the method used by Clark and

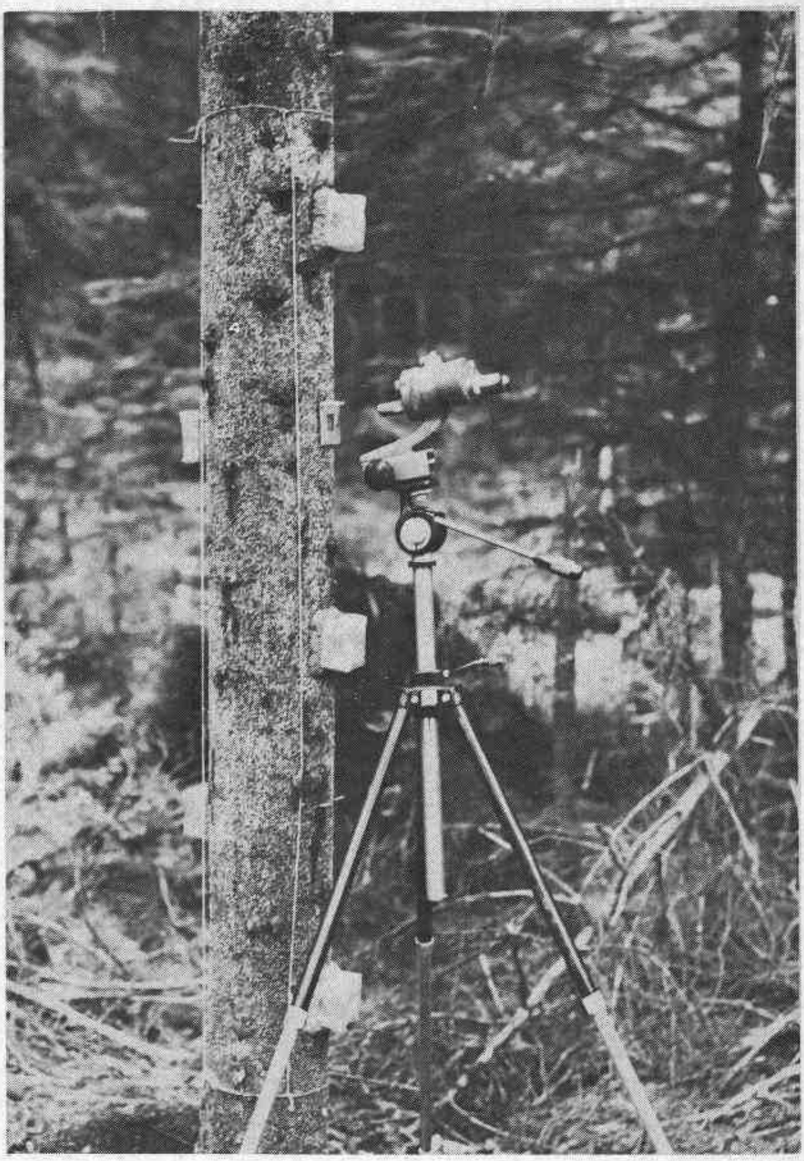

FIGURE 20. Predator evaluation tree at Black Rock, Oregon, and microscope arrangement for population study.

Brown was to protect five of the 1-inch plots from predation. This was done by covering alternate plots with small screen cages. A sample tree is shown in Figure 20.

A metal, window-like template hung from two aluminum nails was used to delineate the 1-inch-square sampling units. The aphid population within these plots was counted, using a microscope mounted on an elevator-type camera tripod (Figure 20). Counts of predator population were made with an ordinary reading glass. Records were taken every 2 weeks and kept on a standardized form.

From this sampling scheme, predator population was calculated as to the number of larvae per 1,000 square inches of bark surface; aphid populations were computed on the basis of "acceptable prey" (2nd, 3rd, and 4th instars) per square inch. The trends of the two populations were then plotted on graph paper. From these plottings, comparisons were made between the protected and unprotected prey densities and the predator population.

For both areas, the differences between the aphid population exposed to predation and the aphid population protected from predation were subjected to statistical analysis. Two methods were used: One was a split-plot analysis of variance of the accumulative difference between the two populations over the entire season; the second was a simple T-test of the populations present at each sampling date.

Results of evaluation

Statistical analysis showed that native predators did not significantly reduce balsam woolly aphid populations in either area. This was expected for the Willamette Pass data. But, the nonsignificance of data collected at Black Rock was surprising; the differences between nonprotected and protected prey populations were quite large. Mean population differences for both areas at different times of the year are shown in Figure 21.

Examination of raw data collected in 1959 revealed a fair amount of unexplained variation between plots. Presumably some stemmed from observational error, although great care was taken to keep recording variation at a minimum. Regardless of the source, however, variation was not so great that it would have masked a truly notable host population reduction by predators. Even without statistical analysis, Figure 21 shows that the effectiveness of the predator complex in 1959 was not great. At both Black Rock and Willamette Pass, the exposed prey population at the peak of the second generation was much greater than at the first generation peak. To be truly effective, predators must reduce their prey density, or at least keep it static, over the period of seasonal activity.

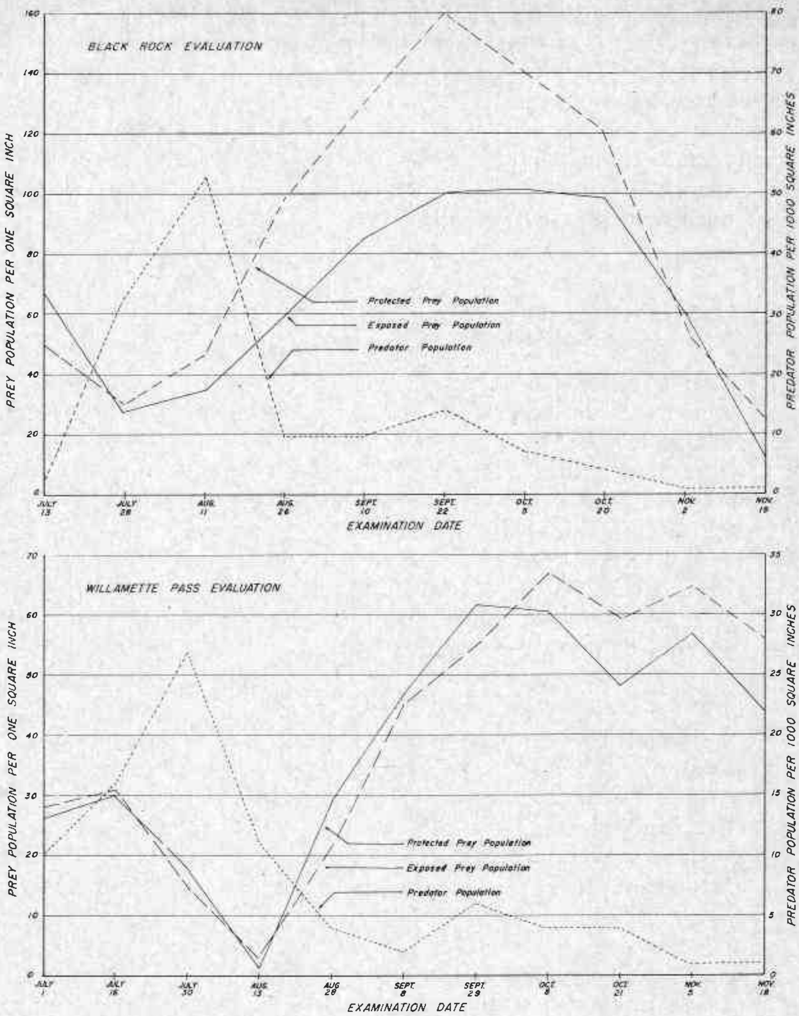

FIGURE 21. Native predator effectiveness in reducing balsam woolly aphid stem populations at two locations in Oregon. (Each point on the graph represents an average of population counts on five plots.)

Conclusions drawn from the above data should not be that native predators offered no control benefits; they fed on some aphids, and therefore were of value. Because the chermid population settling on the tree was not reduced, it must be assumed that there was some reduction in the number of dispersing aphids. Probably, however, such reduction was slight. The predators were too late to catch the peak dispersal period in the first aphid generation, and too few to give much reduction in the second.

Summary and Conclusions

In 1957, the Department of Entomology, Oregon State University, joined with the Pacific Northwest Forest and Range Experiment Station, United States Forest Service, in a cooperative study to explore the possibilities of biological control of the balsam woolly aphid, *Chermes piceae* Ratz., (Hemiptera: Chermidae). Objectives of one ramification of the biological control project were to: (1) Collect and identify the native predators of the balsam woolly aphid, (2) learn as much as possible about the life history and behavior of significant predator species, and (3) evaluate predator effectiveness in controlling aphid populations. This bulletin presents results of investigation on the above objectives.

Three years of study revealed 26 species of arthropods associated with the balsam woolly aphid in the Pacific Northwest. Sixteen insects and two mites were found to be definitely predaceous; four insects and four mites were found which may be predaceous. Of the predators in Insecta, 10 were in the order Diptera, 3 were in Neuroptera, 2 were in Coleoptera, and 1 was in Hemiptera. The most important predators were four syrphids: *Cnemodon rita* Curran, *Syrphus vitripennis* Mg., *S. opinator* O. S., and *Metasyrphus lapponicus* Zett. One hemerobiid, *Hemerobius neadelphus* Gurney, was also moderately abundant.

Descriptions of the immature stages, including drawings, photographs, and a field key, are presented for most insects. Life history and behavior information are also given where available.

Evaluation studies on the effectiveness of native predators in controlling the balsam woolly aphid showed no significant predation by the aggregate predator complex. These data, coupled with general observations, suggest that native predators observed in this study are general feeders; they showed no particular preference for the balsam woolly aphid and were noted feeding on a wide variety of other homopterons. Hence, significant control from native predators is unlikely.

Finally, it is admitted that the predator evaluation data presented are limited. Ideally, assessments should be continued for several more years, in many different areas, and at a variety of prey densities. However, the advisability of giving high priority to such work at this time appears questionable. It would seem that sufficient information has been secured to conclude that native predators are of little value as controlling agents, and that future research could be spent more profitably in exploring other avenues of control. At present, the most promising areas of applied research on *Chermes piceae* seem to lie in studies of (1) silvicultural control and (2) introduction and manipulation of chermid predators from foreign lands.

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