Vol. 64 January 1988 No. 1

THE PAN-PACIFIC ENTOMOLOGIST

SAN FRANCISCO, CALIFORNIA • 1988

***Published by the* PACIFIC COAST ENTOMOLOGICAL SOCIETY**
***in cooperation with* THE CALIFORNIA ACADEMY OF SCIENCES**

The Pan-Pacific Entomologist

Published quarterly in January, April, July, and October with Society Proceedings appearing in the October number. All communications regarding nonreceipt of numbers, requests for sample copies, and financial communications should be addressed to the Treasurer, Dr. Wojciech J. Pulawski, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-9961.

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THE PAN-PACIFIC ENTOMOLOGIST (ISSN 0031-0603) is published quarterly (January, April, July, and October) for $20.00 per year by the Pacific Coast Entomological Society, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118-9961. Second-class postage paid at San Francisco, California, and at additional mailing offices. POSTMASTER: Send address changes to THE PAN-PACIFIC ENTOMOLOGIST, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118-9961.

This issue mailed March 18, 1988

The Pan-Pacific Entomologist (ISSN 0031-0603)
PRODUCED BY A-R EDITIONS, INC., MADISON, WI 53703, U.S.A.

PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 1–7

Nesting Biology of Two North American Species of *Chelostoma* (Hymenoptera: Megachilidae)

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Abstract.—Nests of *Chelostoma phaceliae* Michener and *C. minutum* Crawford are described for the first time. *C. phaceliae* nested in abandoned burrows that other insects bored in stems of elderberry (*Sambucus*). *C. minutum* nests were recovered from 2 mm diameter borings in trap blocks. Both species separated their cells and plugged the nest entrance with soil. Data on next architecture, provisions, cocoons, sex ratio, and nest associates are presented. Chalkbrood, a fungal disease of bees, killed 4.7% of the *C. minutum* larvae.

Bees in the genus *Chelostoma* Latreille occur in both the old and new worlds, and their zoogeographical distribution includes the Holarctic and Oriental regions (Griswold 1985). Adults are small, non-metallic, and slender. Information on nesting biology is limited. Parker and Bohart (1966) noted *C. phaceliae* Michener was reared from trap-stems, Stephen et al. (1969) gave information on cell linings and material used in nest construction by *C. minutum* Crawford, and Eickwort (1981) discussed the biology of two adventive species now established in New York. In Europe, both of these latter species utilized beetle borings and one was reared from trap-stems (Bonelli 1967). Hurd (1979) reported that native North American *Chelostoma* were oligoleges of Hydrophyllaceae because of the numerous collections made from *Phacelia* and *Eriodictyon* flowers. This study presents more detailed data on the nesting biology of *C. phaceliae* and *C. minutum,* including nest architecture, factors affecting mortality of immatures, sex ratios, and identity of pollen used to provision cells.

METHODS AND MATERIALS

Nests of *C. phaceliae* were obtained from stems removed from live plants of elderberry (*Sambucus*) that grew near the banks of the Truckee River north of Verdi, Nevada (Washoe Co.). The stems were collected during the winters of 1961–1964. Nest contents from such stems were recorded and individually placed in gelatin capsules and reared after a 2-month cold treatment at 5°C. In these earlier studies, placement of sexes within the nest and weight of the adults were not recorded.

Nests of *C. minutum* were recovered from trap blocks placed at several sites in the mountains near Logan, Utah. At each site, 10 trap blocks (Fig. 1) with 5 layers of drilled wood (each layer had 10 holes, 2 each with diameter of 2, 4, 6, 8, and 10 mm

Figure 1. Trap nest utilized in this study.

for a total of 50 holes/trap) were individually attached to wood stakes placed 50 m apart. The stakes were driven into the ground and traps were held about 1 m above the soil. The experiment began in May and the traps were removed in early October. Methods of recording data and rearing contents from traps were described earlier (Parker 1985).

Data on adult weight (separated by sex) from each site were analyzed by analysis of variance. If $P < 0.05$, Fisher's LSD multiple comparison test was used.

Chelostoma minutum

Nesting Sites.—In Logan Canyon, 10 sites were established and numbered from the entrance to the summit of the canyon. Elevation differed by about 100 m between adjacent sites. At sites 3, 4, and 8, nests of *C. minutum* were recovered; at the lower sites (1876 to 1976 m), the dominant trees were juniper, scrub maple, and box elder. At site #8 (2134 m), the dominate trees were fir, aspen, and mountain mahogany. Two other sites on the west side of Cache Valley in the Wellsville Mountains (1982 m), where the dominant trees were aspen, maple and box elder, also had numerous *Chelostoma* nests.

Nest Construction.—All nests were obtained exclusively from 2 mm wide borings. A total of 90 nests was recovered from all the sites. A total of 509 cells was produced and the average number of cells/nest was 5.65 (range of 1–14, SD = 3.6). The percentage of 2 mm borings utilized at sites where *C. minutum* nested ranged from 3 to 62.

Females of *Chelostoma* rarely used the rear section of the 100 mm deep borings. Instead, nests were begun an average of 46.2 mm (SD = 29.6 mm, n = 57) above the inner end. The partitions separating the cells and forming the base of the first cell were made from thin discs of soil which averaged 0.7 mm thick (SD = 0.2 mm, n = 172). The average length of cells (by emergent sexes) was: female = 6.2 mm

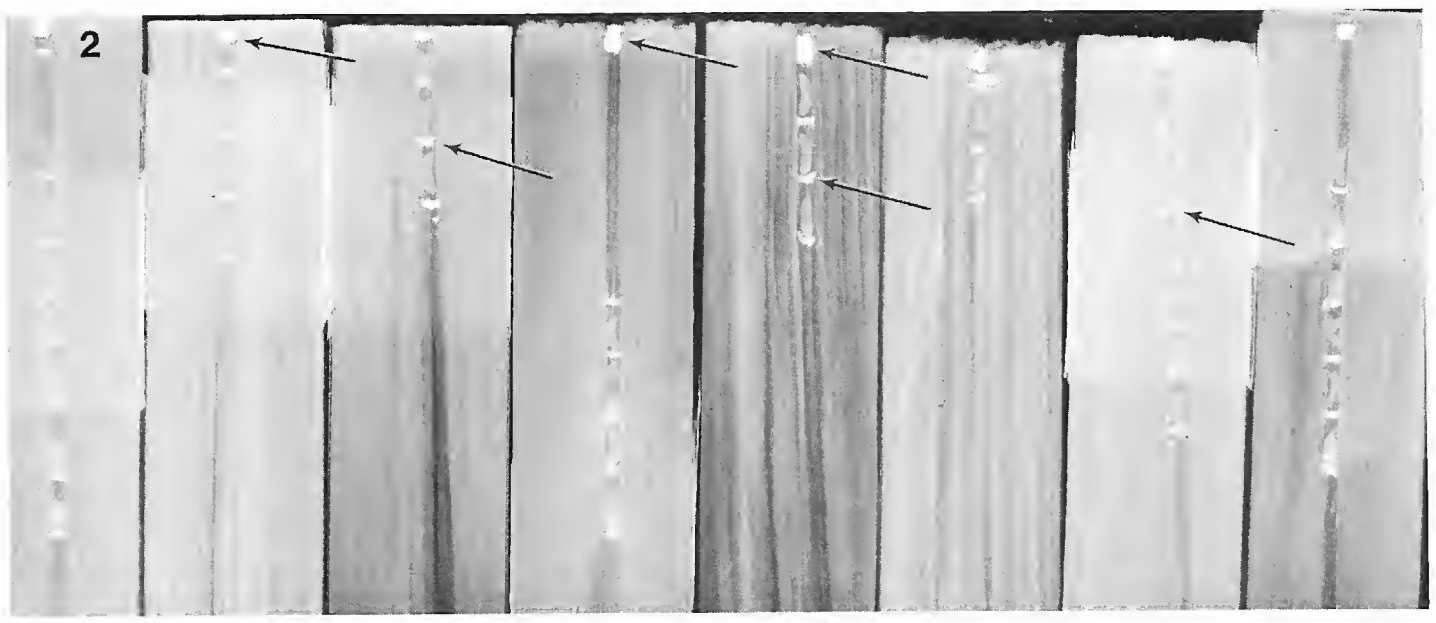

Figure 2. X-radiograph of nests of *C. minutum*. White areas (arrows) indicate nest plugs and cell partitions.

long, (SD = 1.0 mm, n = 56), male = 6.1 mm long (SD = 1.1 mm, n = 56). Often, the last cell in a nest series was longer than cells below it because the entrance plug served as the top of the cell. Average length of these long cells was 36.3 mm (SD = 21.5 mm, n = 26). A vestibular cell was made in some (13%) of the nests; average length of these cells was 15.7 mm (SD = 19.5). The entrance to the boring was usually closed (83% of the nests) with a thicker (2.6 mm, SD = 1.1 mm, n = 75) plug of soil (Fig. 2). Often, the entrance plug had several larger pieces of gravel stuck together with sand and probably a salivary secretion. Some plugs also contained small amounts of organic matter.

Provisions.—The moist pollen-nectar provisions were packed into the lower 3/4 of the cell. The top of the provision was slanted and formed a shelf on which the egg was deposited. *Allium* pollen grains made up the majority of the provisions and ranged from 97.5 to 100% of the plant species used by *C. minutum* at all but one location. At two sites in Logan Canyon, the provisions were exclusively pollen from *Allium*. At the highest elevation in Logan Canyon, no *Allium* pollen was found in the nests; only *Phacelia* and *Sedum* (?) pollens were identified.

Feces.—The shape of the fecal pellets formed by *C. minutum* larvae was variable; some were globular and others elongate. Most pellets were deposited beneath the partition at the top and along the sides of the cell (Fig. 3).

Cocoon.—The cell walls below the partition were closely lined with a thin, transluscent layer of white silk that held the fecal pellets against the side and beneath the cell partition. This first layer formed a hood over the actual barrel-shaped cocoon. Cocoons were made from a single layer of silk, were very thin, and often ripped apart when the boring was split open.

Overwintering.—The overwintering stage was a prepupal larva. A few larvae (0.8%) failed to develop further the first year, but all died during the second year and before they reached the adult stage.

Sex Ratio and Adult Weights.—Combined sex ratio from all sites was 1.05 males: 1 female. However, the sex ratio differed among sites. For example, at one site in

Figure 3. Cocoons formed by *C. phaceliae* larvae.

Logan Canyon, the sex ratio was 2.0 males: 1 female, but across the valley there were more females than males—0.88 males: 1 female. Average weight of adults differed among sites and between sexes. At site #4 in Logan Canyon, males averaged 3.06 mg and females weighed an average of 3.75 mg. These differences were significant ($P < 0.05$, male n = 44, female n = 22, ANOVA). At the Wellsville site across the valley, males also weighed less (average of 2.69 mg) than females (3.19 mg, $P < 0.05$, male n = 53, female n = 78, ANOVA). The weight of the respective sexes differed significantly between these sites ($P < 0.05$, ANOVA). Thus, individuals from nests made at higher elevations weighed less than those from nests at lower elevations. There were no significant differences in the expected sex ratio calculated from data on adult weights (see Torchio and Tepedino, 1980, for methods). The expected ratio was 1.2 males: 1 female at Logan Canyon and Wellsville, which was similar to the actual sex ratio based on combined data (see above). Placement of the sexes within the nest was typical of most bees that nest in linear series; females were in the first cells constructed and males were in cells constructed later (Table 1). In unusually long nests (13–14 cells), some females were in the outer cells. Placement of the sexes in long nests may have resulted from supersedure.

Mortality.—Death from unknown causes averaged 36.3% of the immature stages. The pine wood used to construct the nests may have been an important factor in this unusually high larval mortality. Resins from the wood surrounding the small boring seeped often into the nest and soaked into the provisions. Bee cells in such nests contained provisions with dead eggs or dead young larvae. Within-nest temperatures may have also affected larval mortality. In some nests, the provisions lost their shape and flowed the length of the cell, thus submerging eggs and/or young bee larva.

Nest Associates.—No parasites were found in any cells of *C. minutum,* but the common nest-destroying larvae of the beetle, *Trichodes ornatus* Say, consumed

Table 1. Contents of *Chelostoma minutum* cells from trap blocks placed in the vicinity of Logan, Utah 1984.

Cell Position	*Females*	*Males*	*Dead*	*Ascosphaera*	*Trichodes*	*Misc.**
a	33	5	33	7	4	8
b	25	19	30	8	3	4
c	22	33	24	4	2	3
d	10	18	18	4	2	2
e	7	18	16	1	1	3
f	10	9	19	0	1	0
g	7	14	13	0	1	0
h	6	12	8	0	0	0
i	3	8	11	0	0	0
j	3	8	5	0	0	0
k	2	7	3	0	0	0
l	0	4	2	0	0	2
m	1	2	0	0	0	0
n	1	0	0	0	0	0
Total	137	130	182	24	14	22

*Cells partially finished, missing data, or larvae injured during rearing.

2.8% of the cells. An important disease organism, the fungus *Ascosphaera* which causes chalkbrood in leafcutting bees (McManus, 1983), was found in 4.7% of the cells. Parasitism in the first cells constructed was higher than in cells constructed later (Table 1).

Chelostoma phaceliae

Nesting Site.—Nests of *C. phaceliae* were found only in borings in stems attached to living elderberry plants. The bees appropriated the burrows of other aculeates (*Ceratina* and *Ectemnius*). *C. phaceliae* did not nest in elderberry trap stems at many localities near Verdi (unpublished data from another experiment). These traps were placed vertically in the ground.

Nest Construction.—Only six nests of *C. phaceliae* were found during these studies although thousands of nests of other aculeates were recovered from borings in elderberry stems (Parker and Bohart, 1966). The number of cells/nest ranged from 2 to 10 and averaged 4.3 (SD = 3.0). Most of the nest material was lost subsequent to these studies, and complete data on nest measurements were not available. The length of cells containing males averaged 6 mm and those containing females averaged 7 mm. In one nest made in a 3 mm wide boring, the entrance plug was 4 mm thick. This nest was initiated above the bottom of the boring. The cell partitions and the entrance plug were made from small grains of sand that had been stuck together with a salivary secretion.

Feces and Cocoons.—There were no discernible differences in the shape of the fecal pellets and the construction of the cocoon between *C. phaceliae* and *C. minutum*. The irregular shaped fecal pellets of *C. phaceliae* are shown in Fig. 2.

Provisions.—The single nest sampled had 100% *Phacelia* pollen in the provisions.

Sex Ratio.—No data were recorded on sex ratio and adult weight.

Discussion

Griswold (1985), in a revision of the systematics of bees in the tribe Osmiini, suggested that *Prochelostoma* should be synonymized with *Chelostoma*. Biological data also support this suggestion since nesting characteristics, i.e. material used for nest construction, occurrence of natural nests in beetle burrows, formation of the cocoons (Krombein, 1967), are very similar in these genera. The gross morphology of *Chelostoma* prepupae (Fig. 2) is similar to those of *Hoplitis*; prepupae of both are linear rather than the curled or c-shape typical of *Heriades* and *Ashmeadiella* prepupae. Cocoons formed by larvae of both *Hoplitis* and *Chelostoma* had a hood that holds the fecal pellets against the upper cell walls and cell partition.

Hurd (1979) reported *Chelostoma* females were oligoleges of Hydrophyllaceae, but in light of this study and data referenced by Eickwort (1980) on adventive species, the range of floral resources utilized by *Chelostoma* for nest provisions is broader than was previously believed. In Europe, Kapyla (1978) reported that *C. campanularum* Kirby and *C. fulginosum* were oligoleges of *Campanula* (Campanulaceae). In New York, these inventive populations also were associated with *Campanulum* (Eickwort, 1981). The range of floral resources used by *C. minutum* appears to be made on the basis of availability rather than specialization as previously believed (Hurd, 1979), since provisions at nesting sites in Utah contained Liliaceae pollen.

Nesting sites chosen by species of *Chelostoma* appear to be specialized, both in location and in size of the boring. The great number of traps with larger borings set out each year by researchers in our laboratory, in which no *Chelostoma* were captured (unpublished data), indicates that hole size is an important factor in choice of nesting sites. Hole sizes larger than 2 mm were never used by *Chelostoma*. In Utah, it was not uncommon to locate natural nests of *C. minutum* made in old beetle exit holes in standing dead trees. Traps placed on such trees were readily accepted by *Chelostoma* (unpublished data). Trap stems, however, placed at the same sites where *Chelostoma* nested in block traps during an eight-year study (unpublished data), were not utilized by *Chelostoma*.

Stephen et al. (1969) reported that *C. minutum* lined its cells with pitch and gravel and "lines its burrow with a transparent varnish that appears to be secreted." None of the nests examined in this study contained resin and the transparent burrow linings were not apparent.

The presence of the fungus, *Ascosphaera,* in cells of *Chelostoma* is noteworthy. *Ascosphaera* spp. causes chalkbrood, a general term for such diseases of both honey bees and leafcutting bees. A modern classification of these fungi is urgently needed because many species or forms have been associated recently with solitary bees (unpublished data) and little information concerning identification or host susceptibility is available. At this point, it is difficult to determine whether these diseases are spreading from infected populations of the alfalfa leafcutting bee, which are produced in enormous numbers each summer throughout the western portion of the United States, or if the fungi associated with *Chelostoma* and other solitary bees are new species. Little research has concerned the cross-infectivity or the influence of hosts on morphological and biological characteristics used to distinguish species of *Ascosphaera*.

Acknowledgments

Thanks are due D. Veirs, R. Butler, R. Griswold, and V. Rhea for constructing the trap nests, recording the data, and curating the specimens. G. Eickwort (Cornell) and V. Tepedino of this Laboratory reviewed the manuscript.

This is a contribution from the Utah Agricultural Experiment Station, Utah State University, Logan, Utah 84322-4810, Journal Paper No. 3347, and USDA-Agricultural Research Service-Bee Biology and Systematics Laboratory, Utah State University, Logan, Utah 84322-5310.

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Scientific Note

Arctophyto marginalis Curran (Diptera: Tachinidae): Parasite of a *Cephaloon tenuicornis* LeConte Larva (Coleoptera: Cephaloidae) in Northern Idaho

Parasites of Cephaloidae have apparently not been previously reported. Here, we record the occurrence of the tachinid fly *Arctophyto marginalis* Curran as a larval parasite of *Cephaloon tenuicornis* LeConte. This also appears to be the first report of a host for *A. marginalis*.

Three prepupal larvae of *C. tenuicornis* were collected at: IDAHO, Clearwater County, Isabella Landing, 43km NNE Headquarters, Clearwater National Forest, T41N R7E s.31 NESW, el. 518m, 8.V.1985, from the rhizoid layer of a thick, loose mat of the moss *Rhytidiadelphus triquestris* (Hedw.) Warnst. The moss was growing on a well-rotted conifer stump in a mesic grove of western red cedar (*Thuja plicata* Donn.). This is a rather typical habitat for *C. tenuicornis* in northern Idaho as larvae are generally found deep inside barkless, rotted conifer stumps and logs, usually Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco or grand fir (*Abies grandis* (Dougl.) Forbes. In these hosts, they burrow through the delignified, blocky wood, nearing the surface in spring and pupating in moss rhizoids or lower portions of the gametophyte.

Larvae were returned to the laboratory alive and stored for several days in a moss-filled salve tin at ca. 4°C. Upon checking the specimens prior to intended preservation, one specimen was noted to have died, and there was a dipteran puparium nearby. Remaining beetle larvae were examined revealing no apparent evidence of parasitism. They were left for several days without further mortality, and subsequently preserved. The puparium was left in the salve tin and transferred to a small environmental chamber at ca. 15°C, with a 12 hr light/dark photoperiod. A recently eclosed adult fly was observed on 12.VI.1985, 35 days after field collection.

Determination of the fly was made by B. E. Cooper through the assistance of D. M. Wood (Agriculture Canada, Ottawa) and P. H. Arnaud, Jr. (California Academy of Sciences, San Francisco); our thanks are expressed for their assistance. The adult and puparium of *A. marginalis* are deposited in the collection of the California Academy of Sciences. Larval specimens of *C. tenuicornis* have been deposited in the William F. Barr Entomological Museum, University of Idaho, and the collection of P. J. Johnson.

Our thanks to W. J. Turner and J. P. McCaffrey for reading the manuscript. This paper is published with permission of the director of the University of Idaho Agricultural Experiment Station as research paper number 87710.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 9–15

Immature Stages of *Tachytrechus auratus* (Diptera: Dolichopodidae)[1]

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Abstract.—Tachytrechus auratus (Aldrich) is a dolichopodid which inhabits freshet seeps and mud flats in east-central Washington. Development time from first instar to adult was 23 to 32 days. Pupal development was 4 to 7 days and maximum adult life span was 7 days. The third larval instar, larval mouth parts, pupa, and several different cocoons utilized by the pupae are illustrated with line drawings and photographs.

The dolichopodid genus *Tachytrechus* is one of 27 genera in the large subfamily Dolichopodinae (Ulrich 1980) and is represented in North America by 33 species (Robinson and Vockeroth 1981). Most of the biological and morphological information available about the genus is derived from data concerning several Palearctic species. These include *T. insignis* Stannius and *T. planitarsis* Becker (Vaillant 1951), and *T. notatus* Stannius (Vaillant 1949). To date, the only biological information for any Nearctic *Tachytrechus* is that presented by Kuenzel and Wiegert (1977) in their study of the energetics of *T. angustipennis* Loew.

MATERIALS AND METHODS

Tachytrechus auratus adults and larvae were collected from Boyer Seep and Crum Seep, 44.9 and 37.6 km respectively, SW of Pullman, Whitman County, Washington. The characteristics of these sites were detailed by Corpus (1983, 1986). Mud samples from these two sites were sieved through a series of brass screens, and the subsequent detritus was submerged in saline solution to extract active larvae. Individual larvae were set into separate dishes of fresh mud for further development. Dishes were kept under a 16L:8D photoperiod regime and checked daily. Newly emerged adults were collected and identified. Larval and pupal exuviae as well as intact pupae were also collected and preserved for description. Pupal cocoons were extracted after adult emergence, air dried, and sprayed with hair spray to preserve their structure. Descriptions and terminologies follow those of Dyte (1967), Smith (1952), and Beaver (1966).

LIFE HISTORY OBSERVATIONS

Adults of *T. auratus* are active from late April to mid-September. Under laboratory conditions the development time from first instar to emergent adult was

23 to 32 days (n = 7; $\bar{x}$ = 27.5). Larvae remained within the mud substrate to feed and complete development. Precise developmental periods for each instar were not determined since molting occurred within the mud, and larval exuviae were extracted only by sieve screening.

Tachytrechus auratus pupal development varied from 4 to 7 days (n = 7; $\bar{x}$ = 5.3). Pupae were detected by daily viewing of the mud surface in each dish under a dissecting scope and noting where respiratory horns protruded above the mud. The tips extended approximately 1–2 mm beyond the mud and moved in a scissoring motion when touched. After adult emergence, pupal exuviae remained wedged into the cocoon exit hole, although on occasion they were discarded on the surface of the mud.

Adult *Tachytrechus* fed readily upon small chironomid and muscid larvae placed into the rearing containers. Adult flies held prey against the substrate and rasped the prey integument until body fluids seeped out. They then fed on the exudate. When freshly killed cockroach nymphs were opened and placed into the rearing containers, several adult dolichopodids converged and commenced feeding on the body exudates. Adult longevity of *T. auratus,* in the laboratory, varied from 5–7 days (n = 7; $\bar{x}$ = 5.9).

Several other dolichopodids were reared from the same mud as *T. auratus*. These included *T. olympiae* (Aldrich), *Calyxochaetus sobrinus* (Wheeler), *Chrysotus argentatus* Van Duzee, *C. arcuatus* Van Duzee, and *Pelastoneurus vagans* Loew. In addition, a number of unidentified stratiomyid, tipulid, tabanid, ceratopogonid, chironomid, and sciarid larvae were extracted.

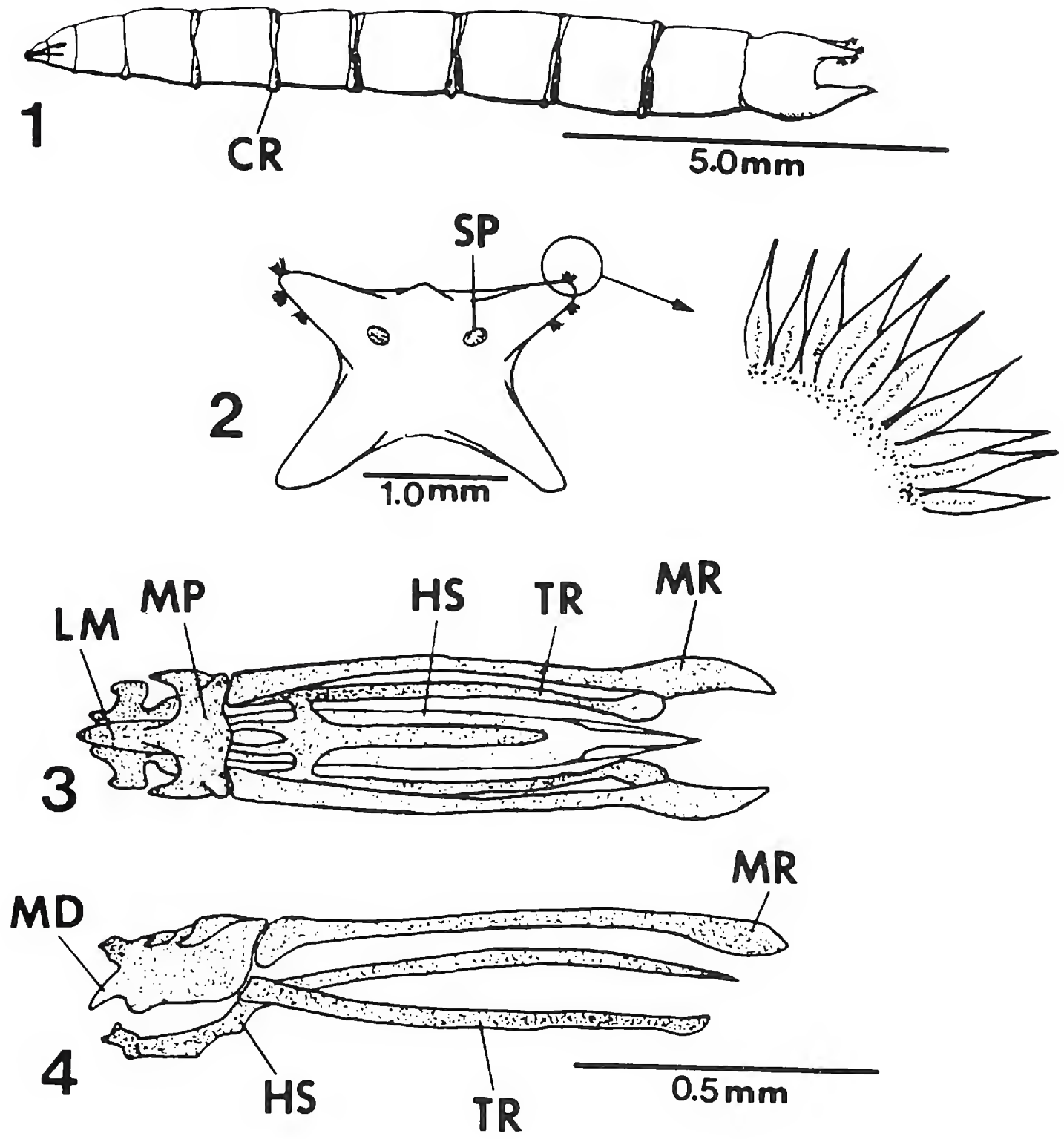
Descriptions of Immature Stages

Egg.—Length 0.8–0.9 mm; width 0.40–0.45 mm; elliptical; white; chorion finely sculptured. (Based on 27 eggs, dissected from 4 females having 6, 6, 7, and 8 eggs, respectively.)

First larval instar.—Length 1.0–1.6 mm; maximum width 0.29–0.31 mm; 12-segmented; translucent to white; mouth parts black; caudal dorsolateral and ventrolateral lobes short, nearly equal in length; metapneustic; posterior spiracles indistinct, borne near tips of dorsoventral lobes. (Based on 3 larvae and 3 larval exuviae.)

Second larval instar.—Length 3.2–6.1 mm; maximum width 0.60–0.71 mm; 12-segmented; white; mouth parts black; ventrolateral lobes longer than dorsolateral lobes; amphipneustic; anterior spiracles on segment 2, minute; posterior spiracles black, minute, located near bases of dorsolateral lobes. (Based on 3 larvae and 3 larval exuviae.)

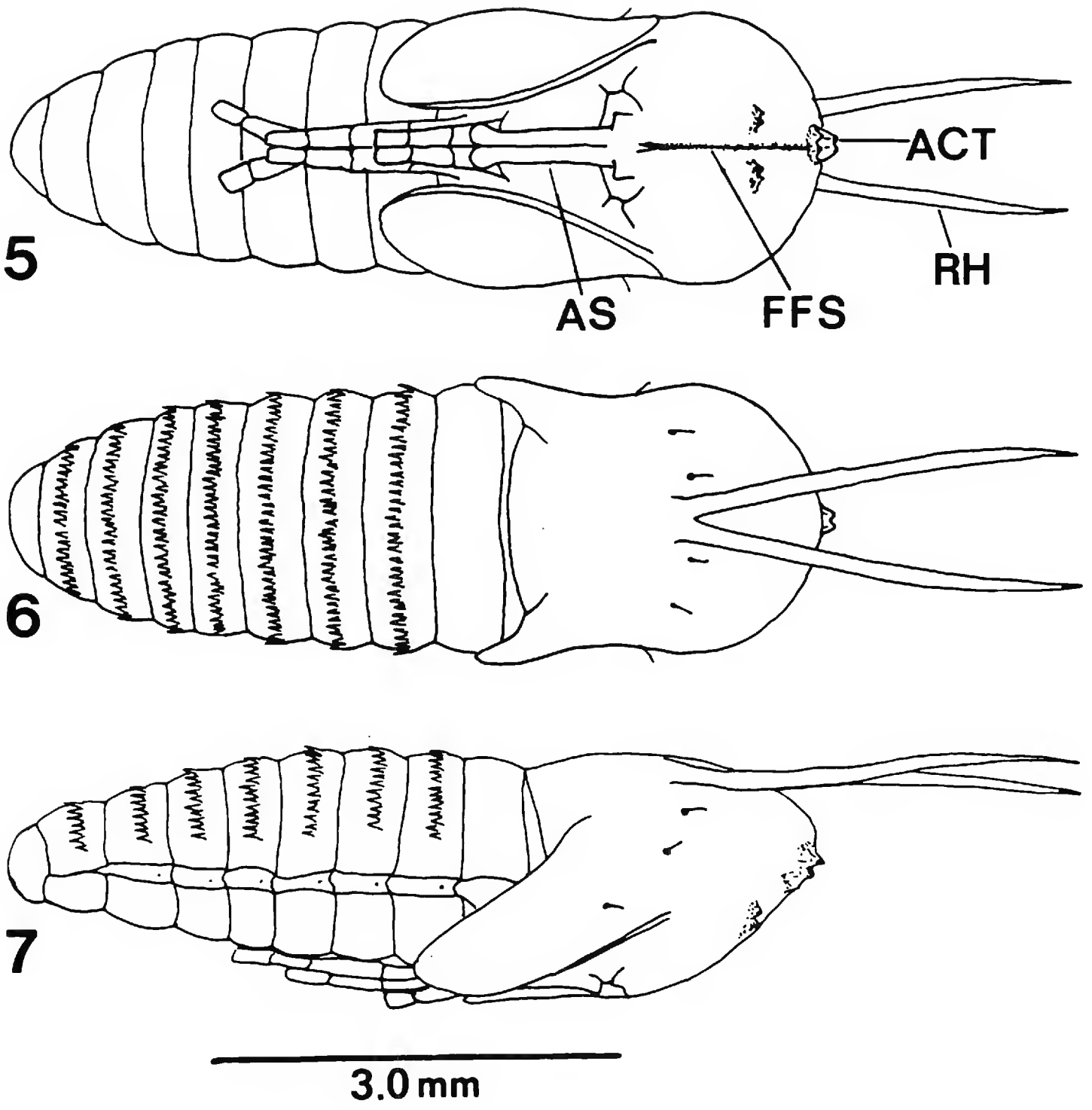
Third larval instar (Fig. 1).—Length 10.5–11.1 mm; maximum width 1.4–1.5 mm; 12-segmented; white to pale yellow; amphipneustic; mouth parts and posterior spiracles dark brown to black; body tapered anteriorly; truncate posteriorly; lateral body surface with fine, longitudinal striae; anterior spiracles 0.04 mm long, short-stalked; segments 4–11 with ventral crawling ridges composed of transverse rows of tiny, brown setulae and fleshy protuberances. Segment 12 with 6 caudally-directed lobes (Fig. 2); 2 dorsolateral lobes each bearing 3 hair tufts, tuft at apex of lobe comprised of 20–25 black, flattened hairs; lateral tufts each comprised of 20–30 hairs; Each ventrolateral lobe with 2 hair tufts; tuft at apex comprised of 20–25 hairs; tuft near lobe base comprised of 15–20 hairs. Lateral lobes small,



Figures 1–4. *Tachytrechus auratus*. 1. Larva, lateral view. 2. Posterior spiracular disc of segment 12 with enlarged hair tuft. 3. Larval mouth parts, dorsal view. 4. Same, lateral view. Abbreviations: (HS) hypopharyngeal sclerite. (LM) labrum. (MD) mandible. (MP) median plate. (MR) metacephalic rod. (TR) tentorial rod.

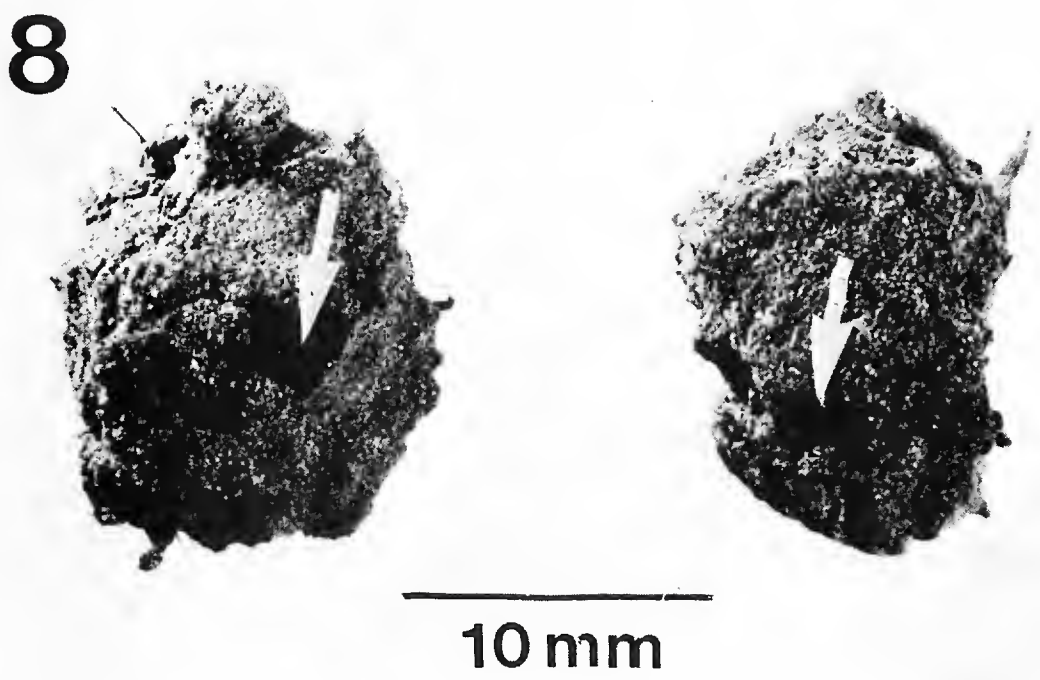
triangular, asetose. Perianal pad on venter of segment 12 elliptical, swollen; posterior spiracles located near bases of dorsolateral lobes, 0.54–0.60 mm apart; diameter of each spiracle 0.15–0.17 mm. (Based on 7 larvae.)

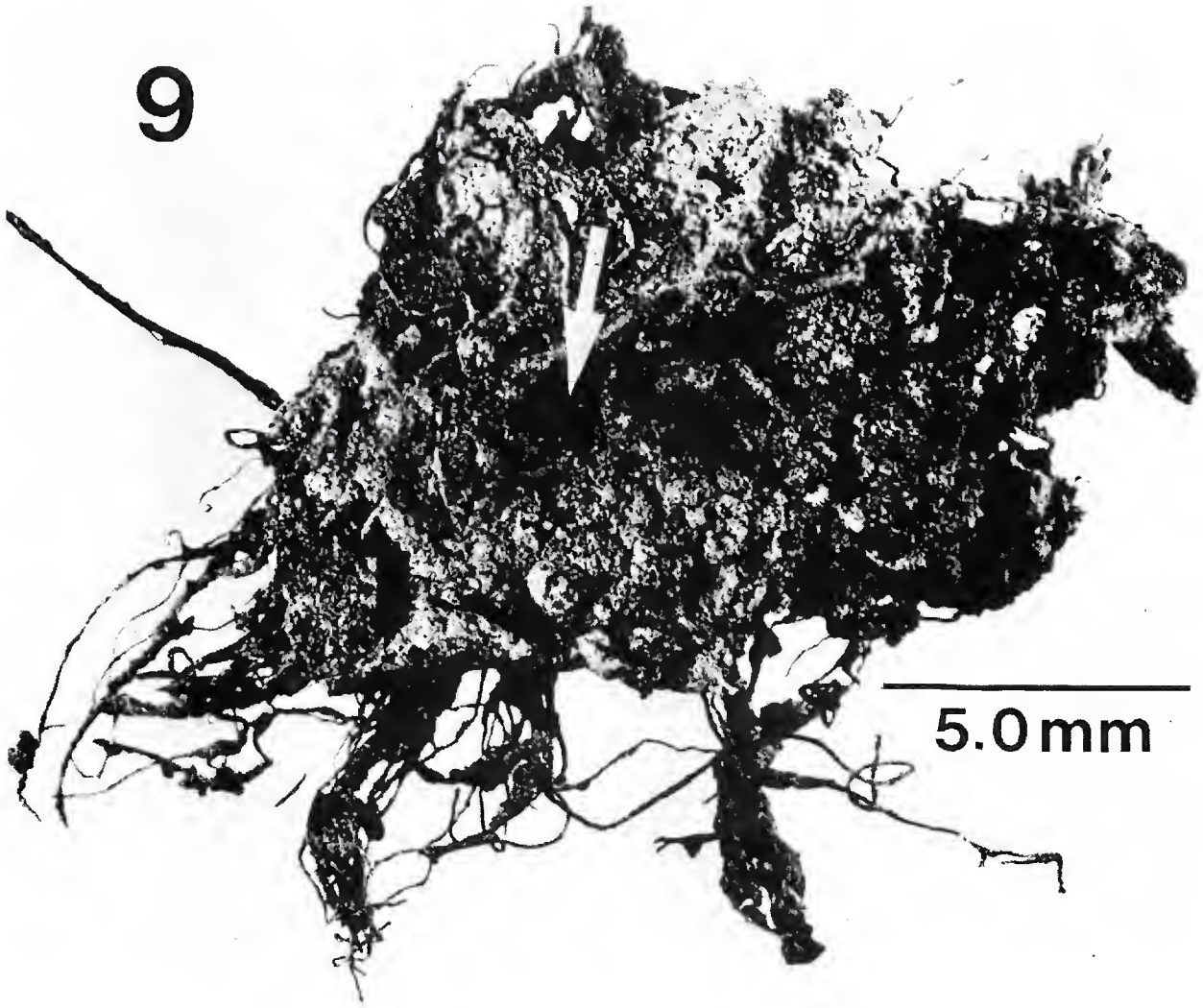
Larval mouth parts (Figs. 3, 4).—Labrum with acute tip; lateral arms of median piece with acute tips, projecting laterally and curving forward; hypopharyngeal sclerite 0.65–0.70 mm long, caudal tip acute, amber colored; metacephalic rods 0.75–0.81 mm long, black, caudal tips enlarged, acutely pointed toward meson; tentorial rods 0.70–0.74 mm long, black, caudal tips broad, spatulate, curved mesally. (Based on 5 third instar head capsules.)



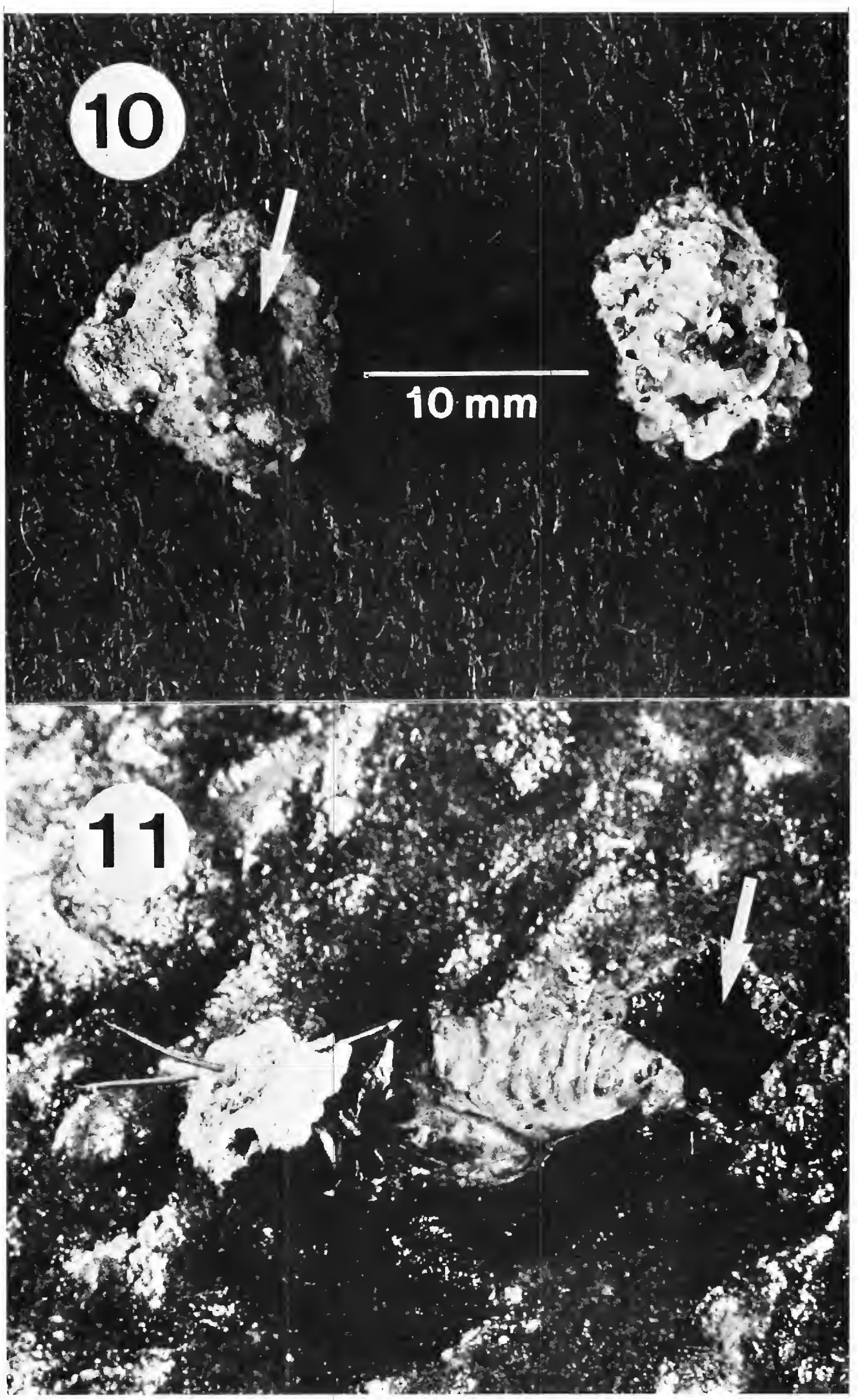
Figures 5–7. *Tachytrechus auratus*. 5. Pupa, ventral view. 6. Same, lateral view. 7. Same, dorsal view. Abbreviations: (ACT) apical cephalic tubercle. (AS) antennal sheath. (FFS) frontal facial suture. (RH) respiratory horn.

Pupa (Figs. 5, 6, 7).—Total length 6.4–6.8 mm from abdominal tip to apical cephalic tubercle; thorax in dorsal view 1.5–1.9 mm wide; body amber; sutures, tubercles, and respiratory horn bases dark brown; prothoracic respiratory horns 2.0–2.3 mm long, directed forward, slightly curved, unsegmented, terminating in sharp points, distal tip of each horn appears to bear minute pores. Frontal region swollen; frontofacial sutures straight; apical cephalic tubercle large, comprised of 4 blunt points. Male pupa with antennal sheaths free and movable, 1.4–1.5 mm long; reaching to pedothecae 1, enlarged at tips to accommodate apical lamellae of adult male antennae. Dorsal surface of thorax with 3 setae on each side of midline; pterothecae smooth, asetose. Pedothecae 1 extend to posterior edge of abdominal segment 2; pedothecae 2 extend to abdominal segment 4; pedothecae 3 extend to





Figures 8–9. *Tachytrechus auratus*. 8. Pupal cocoons of soil. 9. Same, composed of soil and plant roots. Arrows indicate emergence holes.



Figures 10–11. *Tachytrechus auratus*. 10. Pupal cocoons of sand grains. 11. Pupal exuvium with cocoon cap surrounding respiratory horns. Arrows indicate emergence holes.

abdominal segment 5, tips slightly separated. Abdomen 9-segmented, curved, tapered and blunt posteriorly; transverse spiniferous bands on dorsal surfaces of segments 2–8, spines increasing in size mesally. (Based on 2 pupae and 8 pupal exuviae.)

Cocoon (Figs. 8, 9, 10).—Length 10.5–15.3 mm; width 8.2–12 mm; irregularly shaped, composed of either fine soil particles, plant roots, or sand grains from substrate; color variable, but generally gray; inner surfaces glassy and smooth when fresh; outer surface often textured. Cocoon tightly encapsulates pupa, leaving only respiratory horns exposed; opening in cocoon for adult emergence 1.6–2.3 mm diam.; cap from exit hole often left on respiratory horns of pupal exuvium (Fig. 11). (Based on 23 cocoons.)

Acknowledgments

I would like to acknowledge the assistance and suggestions provided by R. D. Akre, E. P. Catts, J. W. Crane, and R. S. Zack during this study. I also thank R. D. Akre and E. C. Klostermeyer for providing funding for this project.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 17–22

Larval Development and Leafmining Activity of *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae)

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Abstract.—The larval development of *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) was investigated using chrysanthemum (*Dendranthema grandiflora* Tzvelev, cultivar 'Hurricane') as the host. With a mean temperature of 28.4°C, median duration was 0.85, 1.23, and 1.42 days, respectively, for first, second, and third instars. Third instars mined the greatest area, ca. 4- and 30-fold that of second and first instars, respectively. Measurements (length) of the cephalopharyngeal skeleton followed the Brooks-Dyar rule of geometric growth, with a growth ratio of 2.03, and mean skeletal lengths (mm) were 0.10 (firsts), 0.17 (seconds), and 0.27 (thirds). Both serpentine and blotchlike mines were observed. Mean mine lengths of serpentine mines (mm) from the point of egg hatch to larval location were 5.28, 9.85, and 21.57 for first, second, and third instars, respectively. Third instars mined at a rate that was ca. 9.4-fold that of first instars and 4.5-fold that of seconds; the mining rate of second instars more than doubled that of firsts.

A serpentine leafminer, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) has been the focus of considerable research during the past 5 years (Parrella and Robb, 1985) as a consequence of its sudden rise to major world-wide pest status on numerous ornamental and vegetable crops (Lindquist, 1983). Several recent studies have reported selected aspects of the biology of *L. trifolii* (Charlton and Allen, 1981; Parrella et al., 1983; Mora and Mosquera, 1984; Bodri and Oetting, 1985; see Parrella [1987] for a thorough review). However, few of these studies examined the larval development of this leafminer in detail. Often no discrimination of larval instars has been made; many studies report larval development as if there were only one instar, and sometimes even combine egg and larval development.

Accurate larval development data are necessary for a more thorough understanding of the biology of *L. trifolii* on chrysanthemum and other hosts. Furthermore, our studies and others have emphasized the use of parasites for control of this leafminer on ornamentals (Jones et al., 1986; Woets and van der Linden, 1985; see Minkenberg and van Lenteren [1986] for a thorough review). Corollary studies with these parasites (i.e., searching behavior, instar preference with respect to oviposition and host feeding, factors influencing sex ratio, etc.) necessitate detailed data on larval development of *L. trifolii.*

This study was undertaken to evaluate the larval development and leafmining activity of these leafminers in chrysanthemum. In particular, we were interested in documenting instar size, stadial duration (Jones, 1978), and the amount of leaf area mined by each instar.

Materials and Methods

Eighty rooted chrysanthemum plants (cultivar 'Hurricane') were grown in 9.67 cm^2 pots on raised benches in the greenhouses at the University of California, Riverside. Standardized chrysanthemum plants (same age and size) were used to avoid the bias that may be associated with larval development on leaves of different ages on the same plant. The soil mix used consisted of 1 part vermiculite, 1 part peat, and 2 parts soil and the plants were given Osmocote® (14-14-14) (2.5 g/pot) ca. 4 days after planting. Supplemental lighting maintained a 13:11 photoperiod. Plants were grown for 5 weeks, then pinched to 10 leaves before exposure to colonies of *L. trifolii*. This colony is maintained on chrysanthemum (cultivar 'Hurricane,' 'Florida Marble,' 'Blue Chip') and wild flies from commercial chrysanthemum greenhouses in California were added at approximately monthly intervals. Details of colony maintenance are provided elsewhere (Parrella, 1983; Parrella et al., 1983).

Plants were exposed to a leafminer colony (ca. 2,000 flies) for 1/2 hour at 12 Noon on 18 November. All subsequent larvae hatched from eggs laid during this period. After exposure plants were placed in an environmental chamber of 28.4 ± 0.06°C ($\bar{x}$ ± SE), 13:11 L:D photoperiod and 60% RH. Plants were observed for egg hatching and larval development at 6-h intervals (1/4 days) beginning on day 2.5. At each 6-h interval, through 12 Noon, 24 November (6 days), 10 leaves with nonintersecting mines were removed from plants and one mine per leaf was selected and photographed, using a Wild® photomacroscope at 8× or 16×. Although larvae of *L. trifolii* prefer to mine the upper palisade misophyll of a chrysanthemum leaf (Parrella et al. 1985), they occasionally mine the spongy mesophyll. Only larvae mining the upper palisade meosphyll were used. Large third-instar mines sometimes required several photographs to encompass the entire mine. These photographs were joined together for analysis.

After photographing, larvae were removed from the leaves and placed in dilute alcohol for later mounting on microscopic slides in Hoyer's mounting media. The cephalopharyngeal skeleton of each larva was then measured using a microscope fitted with an ocular micrometer. From the photographs, serpentine mine length was calculated as was the width of each mine at the location of the larva. Mine area was determined using a TRS® 80 computer with High Pad® digitizing software; as the area encompassing a mine is outlined, the area is calculated.

Statistical Analysis

The Brooks-Dyar rule of geometric growth (Hutchinson and Tongring, 1984; Daly, 1985) was used to determine the number of larval instars. The Ln (cephalopharyngeal skeletal length) [dependent variable] was regressed against the presumed instar number (independent variable) (Ray, 1982).

Because larvae were killed for instar determination at 6-h intervals, the total development time of and area mined by any one larva from egg hatch to pupation was not recorded. Duration of each larval stadia was determined by linear regression of the proportion of successive instars (dependent variable) against time (independent variable), thus providing the median (e.g. 50% firsts—50% seconds) time of transition between instars. At such time the preceding instar population will also have mined its maximum before transition. Therefore, by linear regression of log (area mined) against time and selecting the area mined at time of first instar

Table 1. Duration, area mined, and size of the cephalopharyngeal skeleton for the instars of *L. trifolii*.

Instar	*Stadial duration*[1] *(days)*	*Area mined* [2] *(cm^2)*	*$\bar{x}$ cephalopharyngeal size (mm) (± SE)*
First[1] N = 28	0.85	0.07	0.100 ± 0.0
Second N = 48	1.23	0.29	0.172 ± 0.0
Third N = 50	1.42	1.36	0.267 ± 0.0

[1]Calculations were initiated after an egg stage of 2.5 days.
[2]Method of calculation explained in text.

transition, the approximate area mined during the first larval stadium was obtained. A similar procedure was followed with each instar. At this point, subtracting the area mined by first instars from seconds and second instars from thirds, an approximate area mined per instar was calculated.

To determine rates of mining between instars, regression analysis was used where mean mine area of each instar (dependent variable) was regressed against time (dependent variable). The slope of the lines gives the rate at which instar mined a leaf.

Results and Discussion

The presence of 3 larval instars within the leaf was confirmed. Regression of the natural log of mean cephalopharyngeal skeletal lengths against presumed instar number was represented by $Y = 5.64 + 2.03\times$, $R^2 = 0.99$. Mean cephalopharyngeal skeletal lengths (mn) were 0.10, 0.17, and 0.26 for first, second, and third instars, respectively (Table 1). These are pictured in Mora and Mosquera (1984). Cephalopharyngeal skeletal size increased by a constant factor (slope = 2.03) which follows the Brooks-Dyar rule of geometric growth (Hutchinson and Tongring, 1984; Daly, 1985).

The duration of the first larval stadia was less than one day while second and third stadia required greater than one day (Table 1). The area mined increased with each instar, with the third instar mining ca. 4- and 20-fold the area mined by the second and first instars, respectively. This is considerably different from data reported by Fagoonee and Tory (1984). Differences in host plant as well as temperature could possibly explain this discrepancy. In addition, Fagoonee and Tory (1984) did not report how instar determination was made nor how often larval development was checked.

In the chrysanthemums and other hosts (Suss et al., 1984), *L. trifolii* does not always made serpentine mines; occasionally blotchlike mines are observed. The length of the mine and, in particular, mine width, are affected by the type of mine created. Blotch mines are generally shorter than serpentine mines (i.e., the larva moves a smaller distance in the leaf over the same time period); however, they are usually much wider (Table 2). The distance traveled by a larva approximately doubled with each successive instar. The amount of leaf area mined per day for each

Table 2. Selected measurements ($\bar{x} \pm$ SE mm) of the larval mining behavior of *L. trifolii*.

Instar	*Serpentine mine width*[1]	*Serpentine mine length*[1]	*Widest point of a blotch mine*	*Blotch mine length*
First	0.264 ± 0.012 (17)[b]	5.28 ± 0.36 (28)	1.017 ± 0.090 (14)	0.746 ± 0.097 (9)
Second	0.492 ± 0.030 (27)	9.85 ± 0.74 (46)	1.676 ± 0.144 (35)	0.852 ± 0.084 (15)
Third	1.126 ± 0.056 (37)	21.57 ± 1.28 (43)	3.78 ± 0.28 (28)	3.049 ± 0.244 (12)

[1]Measured at the location of the larva.
[2](N).

instar (Fig. 1) clearly shows that the third instar develops the most rapidly and consumes the greatest amount of leaf material compared to the other instars. Linear regression of mine area of each instar against time (Fig. 1) produced $Y = 0.0074 + 0.0385\times$, $R^2 = 0.96$ for first instars, $Y = -0.0033 + 0.08\times$ for second instars, $R^2 = 0.89$ and $Y = -0.0319 + 0.365\times$ for third instars, $R^2 = 0.64$. Based on the slopes of the regressions, the third instar creates a mine ca. 9.4-fold the rate of a first instar and ca. 4.5-fold that of a second instar. The second instar approximately doubled the mining rate of a first instar.

The ability of a parasite to find the larva of a leafminer may be related to the distance between its antennae among other factors (Sugimoto, 1977); adult females continually tap a leaf with their antennae in search of a mine. Parasites may be able to locate mines that have a diameter smaller than the width between their antennae by coming upon a mine perpendicularly. However, they may be unable to orient along this narrow mine when initiating a search for the leafmining larva. Thus, size of the mine created by leafmining larvae may influence the degree of susceptibility of each instar. Knowledge of the area mined by each instar may be a useful predictor (together with detailed studies on parasite searching, and other behaviors) of whether a particular instar will be attacked. Such information (together with intrinsic rate of increase, overall searching efficacy, ease of mass rearing, etc.) may be important in making decisions as to what parasite species may be the best to use for biological control of *L. trifolii*. Those parasites attacking younger instars would be preferred in both ornamental and vegetable crops. In ornamental crops they would stop mine development at an early stage thus reducing aesthetic injury and in vegetable crops small mines are likely to make less of an impact on plant yield compared to larger mines.

Acknowledgments

The critical review of John Sanderson (Dept. of Entomology, Cornell University) was greatly appreciated. This research was supported in part by the American Florists Endowment. The generous donation of chrysanthemums from Yoder Brothers of Florida, Inc. and the California Plant Corporation is gratefully acknowledged.

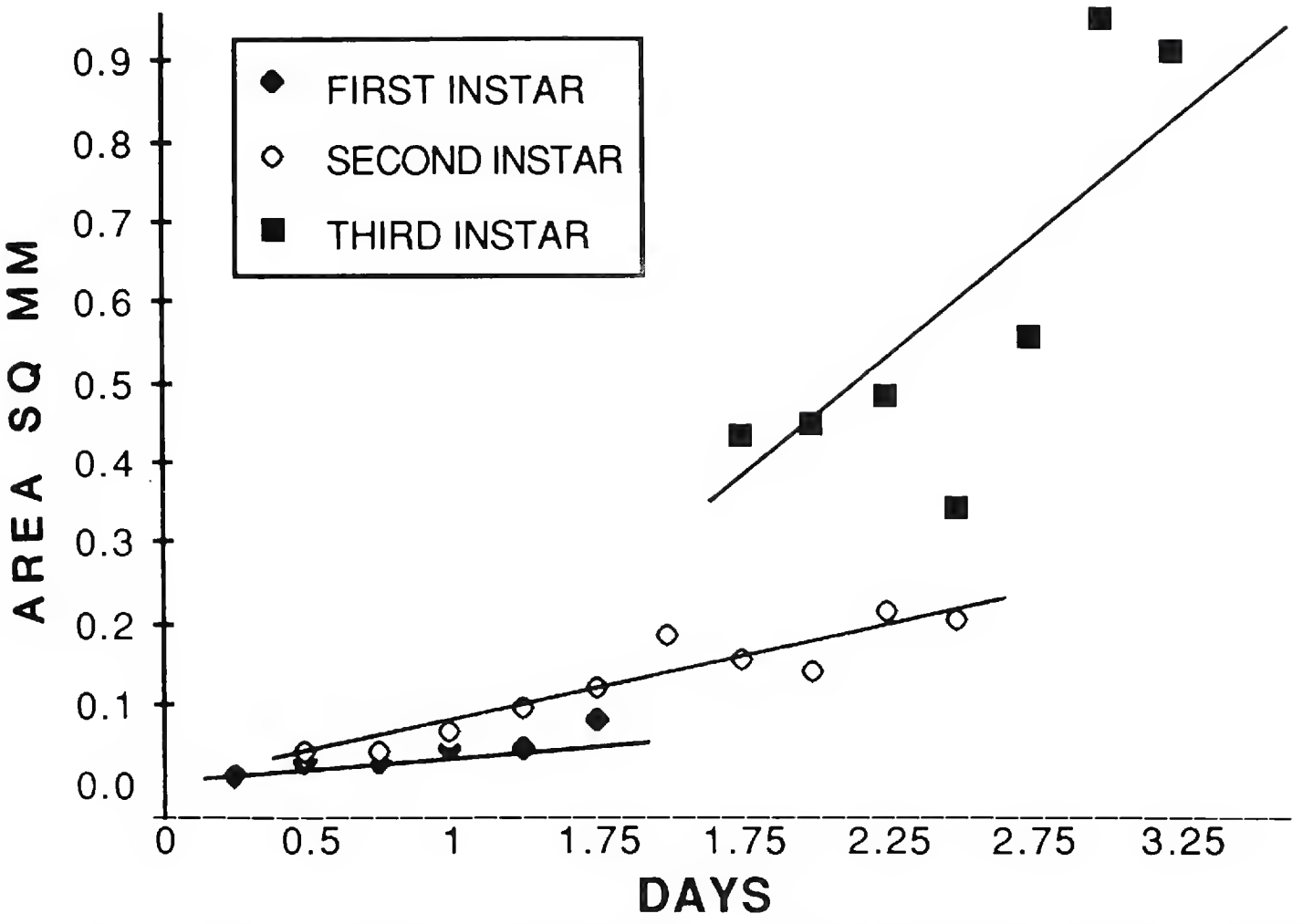

Figure 1. Amount of chrysanthemum leaf area mined and mining rate through time for each larval instar of *L. trifolii* at 28.4°C. Solid lines represent least squares linear regression between areas mined and time for each instar (see text).

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 23–27

A New Ant Mimetic Mirid From the Colorado Tundra (Hemiptera: Miridae)

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In 1980, while examining a lot of ant mimetic Miridae kindly loaned to us by Dr. Joseph C. Schaffner of Texas A&M University we came across two female specimens of an unusual *Coquillettia* species taken by Dr. Schaffner near Rollins Pass, Colorado. These females possessed small wing pads, a character state found in no other *Coquillettia* species except *C. numata* Bliven from California. Having no males at hand we hesitated to describe this new species, but the knowledge of its existence caused us to collect more carefully on the high tundra grasslands above timberline. In 1982 one of us (DAP) discovered this insect at over 3600 meters (approx. 12,000 ft.) on Mt. Goliath, a spur of the Mt. Evans massif west of Denver. Subsequent collecting at this locality produced a good series of both males and females, from which the species may now be described.

We thank Dr. Schaffner for the generous loan of material held in the collections of Texas A&M University, College Station (TAM). Types are deposited in the United States National Museum of Natural History, Washington, D.C. (USNM). Paratypes are held in the above collections and in the J. T. Polhemus collection, Englewood, Colorado (JTPC). All measurements are in millimeters.

Coquillettia (Procoquillettia) alpina n. subg. & n. sp.

Description—Macropterous male: Of moderate size, form elongate (fig. 2), length 6.24 mm; width across base of pronotum 1.44 mm. General coloration black; hemelytra brown with scattered white markings.

Head black, eyes dark reddish, frons and vertex set with scattered short pallid setae; tylus produced, vertical; frons convex, with oblique striations to either side of midline; width of vertex 0.43, subequal to 1.5 times the dorsal width of an eye; eyes protruberant, bulging, bearing scattered very short pale setae; antennae dark brown, clothed with very short recumbent pale setae intermixed with longer partially recumbent bristly black setae, lengths of segments I–IV:0.41; 1.80; 1.35; 0.77; segment two gradually enlarged apically, distal diameter equal to that of segment I.

Pronotum black, surface finely rugose with irregular transverse striae, bearing fine short recumbent pale setae; width of anterior collar subequal to diameter of antennal segment I; calli indistinct; lateral margins weakly concave, posterior margin weakly convex, posterolateral angles acute. Scutellum black, bearing short recumbent pale setae; mesoscutum broadly exposed, raised, bearing two shallow circular depressions to either side of midline basally.

Hemelytra brown, darker basally, bearing scattered short black bristly setae; yellowish white areas present on basal half of corium between clavus and costal

margin, on basal third of cuneus, and at extreme basal tip of membrane; remainder of membrane fumate.

Ventral surface black, abdomen bearing short recumbent pale setae; rostrum length 2.02 mm, attaining middle coxae; ostiolar peritreme black, narrow, vertical. Legs long, slender, dark brown, covered with short recumbent stout black setae intermixed with scattered erect black spines on tibiae and tarsi, length of tibial spines equal to diameter of middle tibia; claws slender, gently curving, parempodia hair-like, weakly convergent apically, pulvilli large, triangular, attached only at base of claw and reaching to tip.

Male genitalia typical phyline type, twisted to left in capsule as viewed from above; right paramere cup-like, with acuminate process (fig. 3); left paramere leaf-like, with small point at tip (fig. 4); vesica sclerotized, U-shaped, tip bearing small pointed process (fig. 5).

Micropterous female: Of moderate size, ant-like (fig. 1), length 4.13 mm; width across pronotum 0.77 mm; width across abdomen 1.44 mm. General coloration dull black.

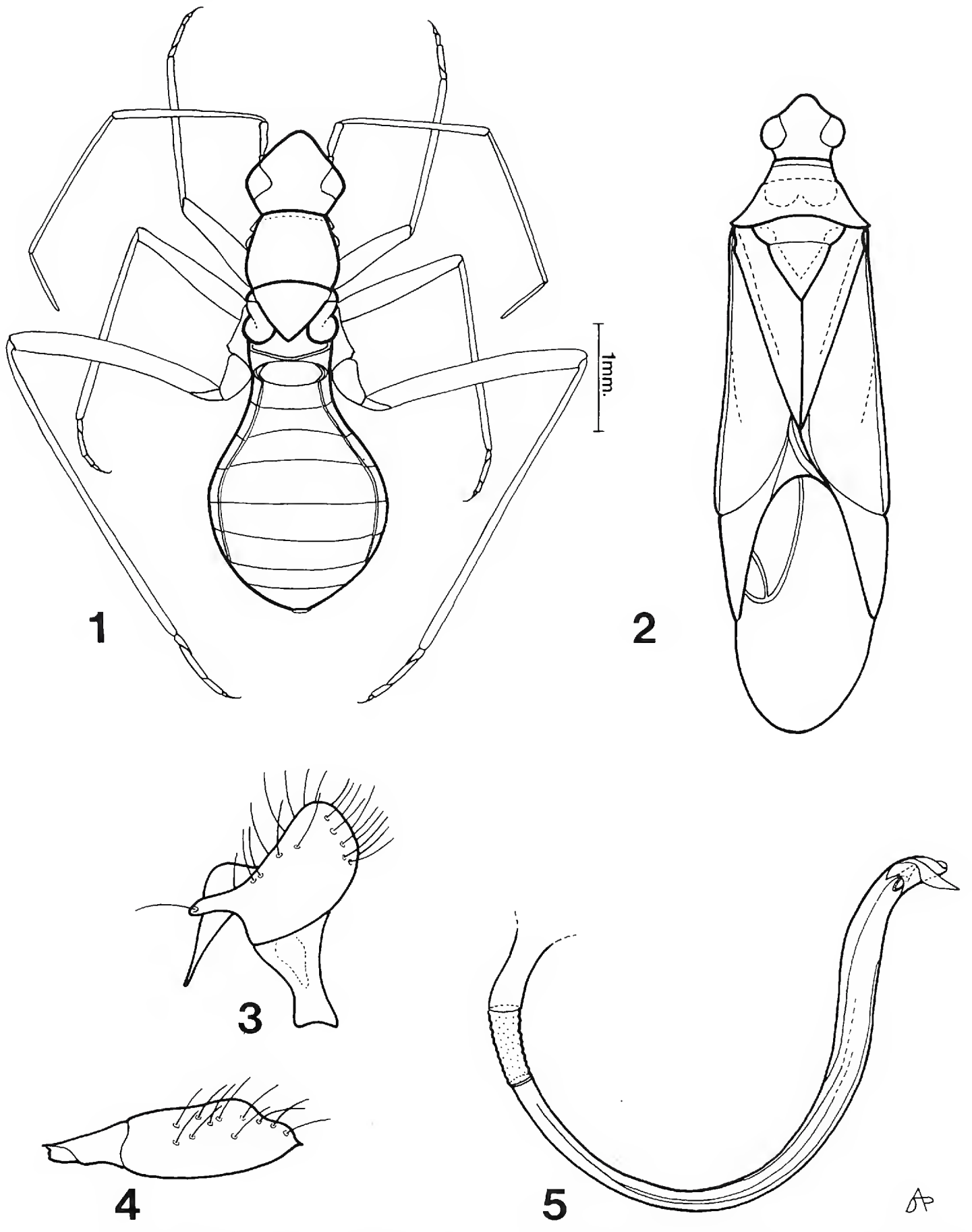
Head black, vertex and frons bearing short pale setae; tylus produced, oriented vertically; frons convex, elongate, with oblique striations; vertex width .50, over 1.8 times the dorsal width of an eye; eyes not as protrusive as in male, not bulging beyond general outline of head, bearing a few minute pale setae; antennae brown, segments III and IV darker, all segments clothed with short pale setae intermixed with slightly longer semirecumbent black bristly setae, lengths of segments I–IV:0.32; 1.39; 1.06; 0.72; segment II slightly enlarged apically, distal diameter equal to that of segment I.

Pronotum black, finely rugose, bearing short pale setae, shape roughly quadrate, convex dorsally and on lateral margins; anterior collar present but weakly defined; calli obscure; posterior margin weakly concave. Scutellum black, bearing short recumbent pale setae, convex, rising anteriorly to meet pronotum. Metanotum plate-like, posterior margin raised to a narrow lip, light brown, anterior margin reflexed downward beneath scutellum. Wing pads small, brown, rounded, bearing short pale setae, central portions weakly depressed; arising under lateral edges of scutellum and extending onto flattened metanotum.

Abdomen globose, constricted basally, black, connexival margins and posterior margin of tergite I white, surface bearing recumbent pale setae; tergites I and II forming pedicel, tergite I narrow with conspicuous transverse medial fold, broadly convex on anterior portion, tergite II narrow anteriorly, broadly expanded posteriorly, shape trapezoidal; tergites III–VIII arched convexly to form globose structure; conspicuous pleural fold present along lateral margins of tergites I–VII.

Ventral surface black, abdomen bearing pale recumbent setae; rostrum length 2.16, reaching nearly to base of ovipositor sheath; ostiolar peritreme brownish, narrow, vertical; ovipositor sheath beginning at posterior margin of abdominal ventrite V and extending to tip of abdomen. Legs brown, coxae blackish, all segments covered with short recumbent stout black setae; short erect bristly black setae present distally on femora; scattered erect black spines present on tibiae and tarsi.

Discussion.—Coquillettia (Procoquillettia) alpina n. sp. stands apart in the genus *Coquillettia* on the basis of several unusual morphological characters that we consider plesiomorphic, e.g. the short stout antennae, short abdomen, and differently formed female basal abdominal segments. It does not settle comfortably



Figures 1–5. *Coquillettia (Procoquillettia) alpina* n. sp. 1. Female, dorsal habitus. 2. Male, dorsal habitus, legs and antennae omitted. 3. Male right paramere. 4. Male left paramere. 5. Male vesica.

into the genus in spite of the similarities in general facies and structures of the head, pronotum and genitalia. The presence of wing pads is reminiscent of the closely related genus *Orectoderus,* but in that genus the wing pads are sharply reflexed upward and pointed at their apices while in *C. alpina* they are rounded and unreflexed. The vesica of *C. alpina* is typical of *Coquillettia,* being U-shaped with a

small hooked tip and a poorly developed gonopore located near the apex, and the claws are also of the *Coquillettia* type, with the long triangular pulvilli being attached to the claw only at the base, while in *Orectoderus* they are attached for a considerable distance along the inner edge of the claw. A few other *Coquillettia* species have relatively short antennae (e.g. *granulata, jessiana*) and females of *numata* have wing pads that are larger and better developed than those of *C. alpina*. The morphology of the basal abdominal segments is also somewhat plastic in the genus, since in females of *C. ajo* the anterior portion of segment I is produced sharply upward into an acute conical projection. *C. alpina,* however, differs sufficiently from these and all other *Coquillettia* species that we propose the subgenus *Procoquillettia* to hold it, with *alpina* as the type and only included species. The following will separate the two subgenera:

Character	*Coquillettia*	*Procoquillettia*
Length of abdominal tergites I–II combined	longer than pronotum	much shorter than pronotum
Abrupt widening of female abdomen (dorsal view)	commences with segment III	commences with segment II
Rostrum reaching:		
Female	between mid coxae	onto base of abdomen
Male	middle of mesosternum	between mid coxae
Male abdomen; ratio narrowest/widest	0.60 max.	0.75
Ratio; length antennal segment II/pronotum	male, 1.75 min. female, 2.0 min.	male & female, 1.7

In many respects *Coquillettia (Procoquillettia) alpina* would seem to be annectant between *Coquillettia* and *Orectoderus*, and would clearly be placed basally on any cladogram of *Coquillettia* species. The only other *Coquillettia* to show such marked annectant trends is *C. nicholi* from Wyoming, which has a campanulate pronotum quite similar to that of many *Orectoderus* species. This latter species, however, is known from but a single male type, thus an analysis of female characters to clarify its position within *Coquillettia* is at present impossible.

Coquillettia alpina occurs among tundra grasses and sedges in the cold and windswept areas above timberline on the Colorado mountains. The habitat is extremely inhospitable and the growing season very short, so that in many years there appears to be only a brief span of time during which the insects may be found. In 1982 we were able to collect the species from mid-July through mid-August, but during the same time period in 1984 and 1986 we found no sign of it. Like the flowering plants of the alpine tundra, *C. alpina* is probably adapted to opportunistically exploit whatever short and unpredictable summer season occurs at these very high elevations.

Several other mirids were found on the tundra, including *Chlamydatus wilkinsoni* Douglas and Scott, *Labops burmeisteri* Stal, and an unidentified *Hadronema* species. The former two taxa are palearctic species that have been previously recorded in North America only from the northern regions of the continent, indicating that the

high peaks of the Rockies have provided refugia for cold adapted taxa that formerly had more southerly ranges during the Pleistocene glaciations.

Etymology.—The name "alpina" refers to the high mountain habitat of this species.

Materials examined.—Holotype, male, and allotype, female: COLORADO, Clear Creek Co., Mt. Goliath nature area on Mt. Evans rd., 3658 m (12,000 ft.), VIII–21–82, D. A. and J. T. Polhemus (USNM). Paratypes: 1 male, 21 females, same data as types (USNM, JTPC); 4 males, 7 females, same locality as types, VII–14–82, D. A. and J. T. Polhemus (JTPC); 2 females, Gilpin Co., 1 mi. E. of Rollins Pass, VIII–16–69, J. C. Schaffner (TAM).

PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 29–31

A New Species of *Isonychia* From China (Ephemeroptera: Oligoneuriidae)

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Abstract.—A new species, *Isonychia hainanensis,* is described and illustrated from specimens collected in Hainan Island, Guangdong Province, China.

Presently three species of *Isonychia* are known from China (Gui 1985). During studies of the mayflies of Hainan Island, a distinctive undescribed species was collected.

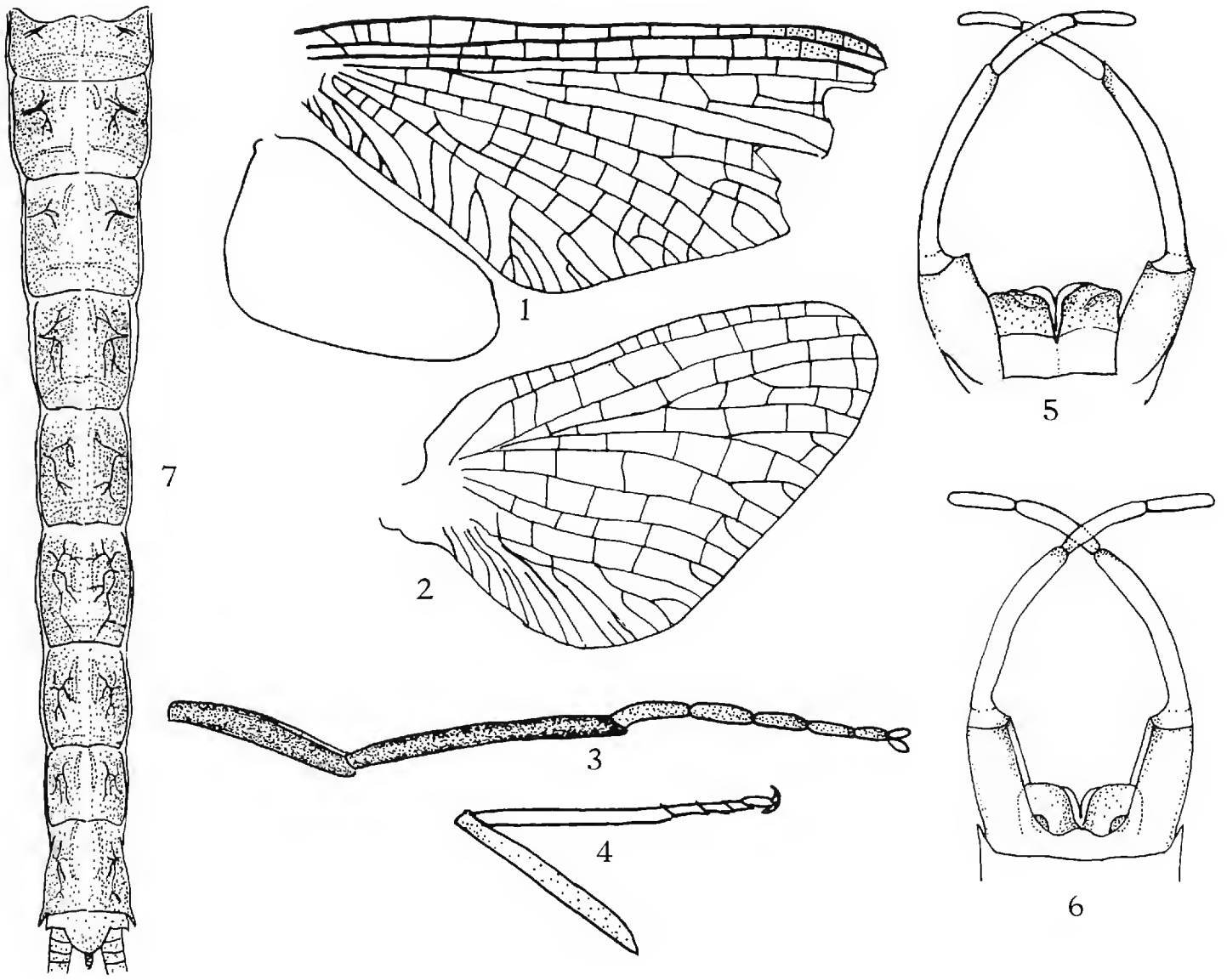
***Isonychia hainanensis,* n. sp.**
Figs. 1–11

Male Imago (in alcohol): Length of body 14 mm, forewing length 13 mm, hindwing length 5 mm. *Head*: Base of ocelli dark brown; scape and flagellum light brown. *Thorax*: Pronotum brown, bordered with white anteriorly and laterally; mesonotum and metanotum dark reddish-brown; thoracic pleura and coxae marked with contrasting areas of dark reddish-brown and white. Fore femora and tibia brown, tarsi light brown (Fig. 3). Femur of meso and meta-thoracic legs yellowish, tarsi paler (Fig. 4). Tarsal ratio: 0.8: 0.7: 0.6: 0:5: 0.4. Gill remnants present at bases of forecoxae. Forewings (Fig. 1) hyaline, veins light brown and stigmatic area dull white. MA forked beyond middle. CuA 3 branched and two unbranched veins to the margin. Vein MP of hind wing forked near margin, stem longer than fork (Fig. 2). *Abdomen*. Reddish-brown with white lateral margins. A pale middorsal stripe on terga 1–9 (Fig. 7); terga 2–9 with a pair of small submedian streaks, Pleural fold pale. Cerci reddish-brown basally, becoming paler distally. *Genitalia*. Light brown. Subgenital plate with a deep posteromedian emargination (Fig. 5 and 6). Basal joint of forceps enlarged, segment 2 longer than segment 3, segments 2 and 3 subequal to segment 1. Penis lobes truncate and apically separate (Fig. 5 and 6). In ventral aspect a small projection at base of penis lobe (Fig. 6).

Female Imago (in alcohol): Length of body 13–14 mm, forewing length 13.5–14 mm hindwing length 6 mm. Marking similar to male, but paler. Subanal plate with deep posteromedian emargination (Fig. 11). Caudal filaments marked as male. Legs as colored as male (Figs. 8–10).

Nymph.—Unknown.

Holotype: Male Imago, Allotype, female imago, Maoyang, Qongzhong County (19°N, 109°36′E), 2 June 1986.



Figures 1–7. *Isonychia hainanensis* n. sp., male imago. 1. Forewing; 2. hindwing; 3. foreleg; 4. metathoracic leg; 5. genitalia, dorsal; 6. genitalia, ventral; 7. abdomen, dorsal.

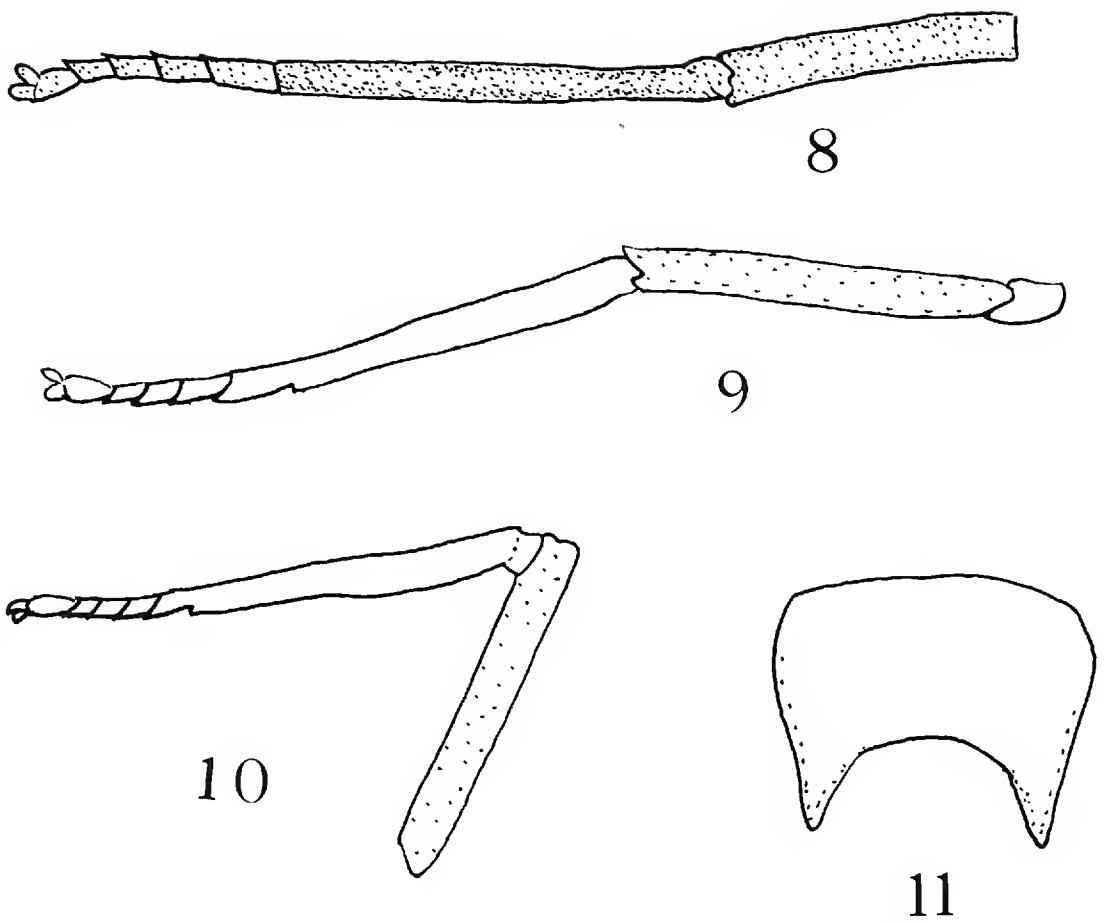
Paratypes: 1 male imago, Diaoluo Mountains, Linshui County, (18°40′N, 109°45′E), 26 May 1986, 3 male and 7 female imagoes, same data as holotype; 34 subimagoes, Jianfeng, Luodong County (18°45′N, 108°40′E) 24–27 April 1986; 1 male subimago, Bawanglin, Baisha County (19°06′N 109°05′E) 1 May 1986.

All specimens were collected by the first author and Mr. Zhang Jun and are deposited in the collection of the Department of Biology, Nanjing Teachers University.

Biology.—All specimens were collected as subimagoes, which were attracted to a gas light. These specimens were allowed to transform to adults in special subimago boxes.

The type locality, Maoyang River is a clear and slow moving stream approximately 70 m wide. The substrata is sand and small stones. The river is bordered by forests and farmland.

Diagnosis.—*Isonychia hainanensis* apparently belongs to the subgenus *Isonychia* (Kondratieff and Voshell, 1983) and may be easily distinguished from other *Isonychia* known from China (*I. formosana* (Ulmer), *I. japonica* Ulmer, and *I.*



Figures 8–11. *Ionychia hainanensis,* n. sp., female imago. 8. foreleg; 9. mesothoracic leg; 10. metathoracic leg; 11. subanal plate.

kiangsiensis Hsu) by the following combination of characters: ventral base of each penis lobe with a small projection and abdomen reddish-brown with a pale middorsal stripe and pair of submedian curved streaks.

Acknowledgments

We are greatly indebted to B. C. Kondratieff, Department of Entomology, Colorado State University, Fort Collins, Colorado, who has kindly provided us with some literature for reference, and who offered some suggestions and corrections to our manuscript. I also wish to thank Mr. Noah S. Brannen for his assistance in checking the manuscript for linguistic accuracy.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 33–38

Observations on *Eupelmus inyoensis* Girault (Hymenoptera: Eupelmidae)

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Abstract.—Eupelmus inyoensis Girault is a native, facultative secondary ectoparasite which has been reared from eight host species, representing six families and three orders of insects. This species is generally associated with the gall midge *Rhopalomyia californica* Felt on *Baccharis pilularis* DC in California; however, it is relatively rare and probably does not have a major impact on population dynamics of the midge. Analysis of galls containing *E. inyoensis* from the Jasper Ridge Biological Preserve and adjacent areas revealed that most contained only one individual of this species, regardless of the number of available hosts per gall. The evidence suggests that *E. inyoensis* has a relatively low reproductive capability; however, its broad host range and intrinsic competitive ability presumably enable it to persist in nature. Despite its rareness, this species appears well suited for coexistence in competitive parasite guilds.

Eupelmus inyoensis was described by Girault (1916) from specimens reared by Koebele from a dipterous gall on *Artemesia* at Inyo, California (Smith and Compere, 1928).[1] This native eupelmid is a solitary ectoparasite of various insect species and can develop as either a primary or secondary parasite, presumably depending on the host encountered. According to Burks (1979), it is known only from Utah and California. The literature on *E. inyoensis* is somewhat anecdotal and there is very little information on its field ecology. In the course of our investigations on the parasites of *Rhopalomyia californica* Felt in northern California, we accumulated a considerable amount of field data on *E. inyoensis.* The purpose of the present paper is to summarize this information. We also speculate on how this rather unusual parasitic species is able to persist in nature and coexist in competitive parasite guilds.

Host Range

Eupelmus inyoensis has been reared from eight host species, representing six families and three orders of insects (Table 1). These hosts represent both nonparasitic (phytophagous) and parasitic species, affirming that *E. inyoensis* is a

[1]According to G. A. P. Gibson (personal communication), current generic concepts in the Eupelmidae are unsatisfactory and most genera are in need of revision. When *Eupelmus* Dalman is revised, *E. inyoensis* Girault will be transferred to the genus *Brasema* Cameron. In view of this, we have deposited voucher specimens of our material at the following locations: Bohart Museum, University of California, Davis; U.S. National Museum, Washington, D.C.; and Biosystematics Research Center, Agriculture Canada, Ottawa.

Table 1. Hosts of *Eupelmus inyoensis*.

Order	*Family*	*Genus, species and authority*	*Reference*
Coleoptera	Bruchidae	*Bruchus* sp.	Smith and Compere (1928)
Diptera	Cecidomyiidae	*Rhopalomyia californica* Felt	Doutt (1961), Present paper
		Asphondylia adenostema Felt	Smith and Compere (1928)
Hymenoptera	Ichneumonidae	*Pimplopterus* sp.	Tilden (1951b, 1951c)
	Torymidae	*Torymus koebelei* (Huber)	Present paper
	Encyrtidae	*Metaphycus lounsburyi* (Howard)	Armitage (1923), Compere (1925), Smith and Compere (1928)
		Diversinervus smithi Compere[a]	Flanders (1952)
	Platygastridae	*Platygaster californica* (Ashmead)	Present paper

[a]Apparently not established in California.

facultative secondary parasite. The nonparasitic hosts include a bruchid and two cecidomyiids, and it is likely that other nonparasitic hosts exist in nature. The primary parasites exploited by *E. inyoensis* are associated with three host species: *Gnorimoschema baccharisella* Busck., a gall-forming gelechiid on *B. pilularis,* parasitized by *Pimplopterus* sp.; *R. californica,* parasitized by *T. koebelei* and *P. californica*; and *Saissetia oleae* (Olivier) (black scale), parasitized by *M. helvolus* and *D. smithi.* Black scale and its respective parasites are introduced and thus have no coevolutionary history with *E. inyoensis.* This is probably a conservative estimate of the host range because *E. inyoensis* may very well exploit other species in the respective guilds. For example, our records of secondary parasitization by *E. inyoensis* in the parasite guild associated with *R. californica* consist of those cases where the primary parasite could be identified with some degree of certainty; in many cases, *E. inyoensis* was observed parasitizing an immature parasite (of another species) whose identity could not be ascertained. It is also likely that *E. inyoensis* can parasitize other species in the parasite guild associated with black scale.

These findings suggest that facultative secondary parasites might be divided into two broad categories. There are species such as *E. inyoensis* which exploit more than one parasite guild (including nonparasitic hosts in some cases). Because black scale also occurs on *B. pilularis* (Kennett, 1986), *E. inyoensis* is capable of exploiting three different guilds, all on the same host plant. (Whether or not it parasitizes black scale and *G. baccharisella* has not been determined.) In contrast, other facultative species may be relatively "guild specific," exploiting only one phytophagous host and some or all of its primary parasites. *Zatropis capitis* Burks, a pteromalid ectoparasite in the guild associated with *R. californica,* may be an example.

Table 2. Frequency of *Eupelmus inyoensis* in dissected galls of *Rhopalomyia californica*.

Site	County	Date of collection	Subspecies of host	Galls Dissected Total	Galls Dissected With Eupelmus	Chambers Dissected Total	Chambers Dissected With Eupelmus
1	Yolo	24 Apr. 86	*consanguinea*	9	0	76	0
2	Solano	24 Apr. 86	*consanguinea*	10	0	123	0
3	Solano	21 May 86	*consanguinea*	12	6	143	14
4	Solano	28 July 86	*consanguinea*	13	9	151	34
5	Solano	7 Apr. 86	*pilularis*	19	0	209	0
6	Yolo	14 Apr. 86	*pilularis*	8	0	70	0
7	Yolo	6 Aug. 86	*pilularis*	10	1	128	1
				81	16	900	49

Frequency in Dissected Calls

Larvae of *R. californica* develop in terminal galls on both subspecies of *Baccharis pilularis* DC. The galls are usually multichambered, and can contain over 100 chambers per gall. Each chamber houses a single midge larva, along with whatever parasite progeny have been deposited therein. Additional aspects of the natural history and population ecology of the midge were given by Tilden (1951a), Doutt (1961), Force (1974), and Ehler (1982, 1987). In order to determine the frequency of occurrence for *E. inyoensis,* we collected galls from seven field sites during spring and summer of 1986. Four sites contained naturally occurring stands of ssp. *consanguinea* whereas the remaining three were urban plantings of ssp. *pilularis*. The sites containing ssp. *consanguinea* represented "endemic" midge populations (i.e., less than one gall per 100 terminals); the three urban sites displayed midge outbreaks (i.e., more than ten galls per 100 terminals). Overall, 81 galls were dissected. Of these, 16 (19.8%) contained at least one *E. inyoensis*; however, this species was present in only 49 of the 900 dissected chambers (Table 2). About 5% of the chambers were empty. Although parasitization by *E. inyoensis* was relatively high at site 4, the overall rate of parasitization was low (5.4%), and this is consistent with previous investigations (Doutt, 1961; Force, personal communication; Hopper, 1984; Ehler et al., 1984; Ehler, 1987).

At sites three and four, 48 chambers contained a total of 50 *E. inyoensis*. Of the 50, 17 occurred singly—i.e., developing as solitary primary parasites on midge larvae. Thirty occurred in chambers with other species of parasites—i.e., representing either multiple parasitization or hyperparasitization. The remaining 3 occurred in the same chamber with another species of parasite; this represents a case of both super- and multiple parasitization. No additional superparasitization was detected. Although preliminary, these data suggest that *E. inyoensis* shows little or no restraint with respect to multiple parasitization. (A possible exception involves hosts parasitized by *Torymus baccharidis* (Huber) [Force, personal communication]). In contrast, the data are consistent with a pattern of almost total restraint in the case of superparasitization. An alternative explanation for the latter pattern would be that ovipositing females simply do not have enough eggs immediately available to

superparasitize. We also recognize that, in a relatively rare parasite, superparasitization could be virtually absent by random expectation alone. In any event, because *E. inyoensis* is a facultative secondary parasite, it would not be surprising to find that it does indeed avoid superparasitization, but not multiple parasitization.

Distribution of Progeny

Eupelmus inyoensis may be relatively rare in the field because it has a low capacity for increase. Although we were unable to test this hypothesis directly (i.e., by calculating r_c or r_m), we were able to assess indirect evidence which is consistent with the hypothesis. In a previous study, Ehler et al. (1984) collected over 3000 galls of *R. californica* at the Jasper Ridge Biological Preserve and the adjoining suburban areas of Woodside and Portola Valley. Galls were held in individual containers in the laboratory so that numbers of emerging midges and parasites could be recorded. *E. inyoensis* occurred in only 97 of 3023 galls (3.2%). This is probably a conservative estimate of actual occurrence because galls were removed prematurely from the field, and because there was usually some mortality of gall occupants in the laboratory. Nevertheless, the data again attest to the general rareness of *E. inyoensis* under natural field conditions.

The distribution of progeny was relatively consistent—i.e., an average of 1–2.5 *E. inyoensis* per exploited gall, regardless of the number of chambers (hosts) per gall (Figure 1). Although the regression in Figure 1 is significant, there is little slope to the regression line, and it is reasonable to assume that ovipositing females of *E. inyoensis* do not distribute their progeny in a manner which would result in a strong, direct-density dependent response. An inverse density-dependent response would be expected. The females evidently lack the reproductive capability to fully exploit the hosts in those galls in which they deposit progeny. For example, 71 of the 97 galls (73%) contained a single *E. inyoensis,* whereas 83 (85%) contained either one or two per gall. The highest number per gall was six ($n = 1$). Apparently, a large proportion of the exploited galls were exploited by only one ovipositing female. Statistical analysis of all 97 data points (as opposed to group means in Figure 1), gave essentially the same result as shown in the Figure, except for the expected lower coefficient of determination ($Y = 1.0271 + 0.0326\,X$, $r^2 = 0.08$, $P = 0.002$).

Discussion

In the parasite guild associated with *Rhopalomyia californica, Eupelmus inyoensis* is a relatively rare species. This is presumably due to a relatively low reproductive rate, as opposed to its being suppressed through interspecific competition or hyperparasitization. Nevertheless, this species is able to persist and this must be due in large measure to its flexible life style. As a facultative secondary parasite, *E. inyoensis* is a member of at least three parasite guilds associated with two native and one exotic phytophagous species on *Baccharis pilularis.* Within the guild associated with *R. californica,* it can develop as either a primary parasite of midge larvae, or as a secondary parasite of primary parasites such as *T. koebelei* and *P. californica.* In cases of multiple parasitization, it is evidently the superior competitor. (In this case, we would view hyperparasitization as "competition induced.") In the dissected galls, *E. inyoensis* was frequently observed parasitizing other parasite species, including older, more developed individuals. It may also avoid superparasitization, further

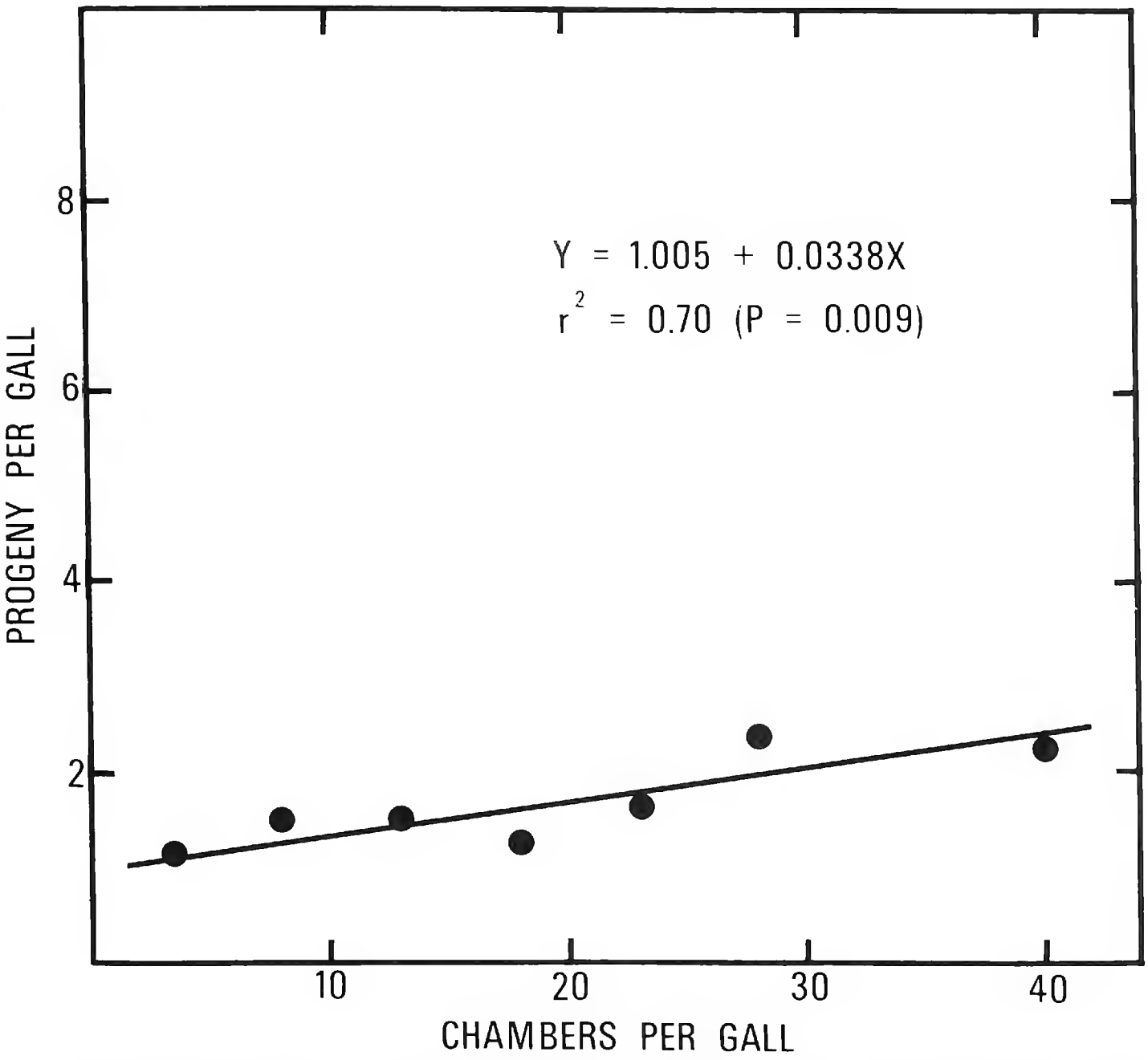

Figure 1. Mean number of *E. inyoensis* per gall as a function of number of hosts (chambers) per gall. Samples sizes (± SEM) for group means left to right: 11 (0.09), 23 (0.24), 19 (0.19), 19 (0.17), 9 (0.29), 9 (0.60), and 7 (0.60). Sample dates as given in Ehler et al. (1984) except for Woodside (only dates 4, 5, and 6).

enhancing the survival of its relatively few progeny. In summary, this rather unusual parasitic species appears well suited for coexistence in competitive parasite guilds.

The role of facultative secondary parasites in structuring parasite guilds is in need of investigation. In the case of *R. californica,* the parasite guild consists of over 10 species, but only seven are regularly collected throughout the host's range. Of the seven, three are facultative secondary parasites—i.e., *E. inyoensis, Z. capitis,* and an undescribed pteromalid in the genus *Mesopolobus.* The latter two can be relatively abundant at times. Primary parasites in the guild evidently do not oviposit in chambers containing either species (see Force, 1974). Also, evidence suggests that both *Z. capitis* and *Mesopolobus* preferentially parasitize certain primary parasites (Force, 1974; Hopper, 1984). Thus, these two species of facultative secondary parasites must have a considerable influence on the structure of the parasite guild. In contrast, *E. inyoensis* may have little influence on guild structure because it is so rare.

Acknowledgments

We thank R. W. Carlson for confirming our determination of *Eupelmus inyoensis* and D. C. Force, G. A. P. Gibson, and K. Thorarinsson for critical review of the manuscript.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 39–42

The Mandible and Maxillary Stylets of *Scirtothrips citri* (Moulton) (Thysanoptera: Thripidae)

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Abstract.—The external morphology of the mandible and maxillary stylets of *Scirtothrips citri* (Moulton) are examined with scanning electron microscopy. The morphology of the mandible concurs with recent studies on other Thysanoptera indicating that it punctures the substrate. A method for directional control of the maxillary stylets without engagement of the apices is discussed.

The unusual, asymmetrical mouthparts of Thysanoptera include two structures capable of piercing food. One is the left mandible modified into a stout, sharp piercing organ that is hollow but lacking an aperture. The second piercing structure is the maxillary stylets comprised of paired styliform lacineae interlocked into a single feeding tube (Mound 1971). Protracted only during feeding, both structures otherwise are retracted into a mouth cone at the ventral-caudal margin of the head. During feeding by phytophagous *Haplothrips verbasci* (Osborn), suborder Tubulifera, (Heming 1978) and *Limothrips cerealium* (Haliday), suborder Terebrantia, (Chisholm and Lewis 1984), the mandible punctures the leaf cuticle and epidermis, and the maxillary stylets penetrate the wound to transport the contents of underlying mesophyll cells to the hypopharynx.

One of the most serious arthropod pests of citrus in California is the citrus thrips, *Scirtothrips citri* (Moulton), a species of Thysanoptera (suborder Terebrantia) whose feeding damages foliage and scars fruit. Although Horton (1918) described fruit scarring as the cell walls of punctured cells forced outward by the growth of surrounding tissue, exactly how *S. citri* feeding causes scarring is not well understood. To better understand this process, the present study examines the external morphology of the mandible and maxillary stylets.

Materials and Methods

S. citri were collected from a navel orange grove at the University of California Lindcove Field Station near Exeter, California, and reared in a glasshouse on *Rhus laurina* Nuttal seedlings (Tanigoshi and Nishio-Wong 1981). Voucher specimens were deposited in the Entomology Museum, University of California, Riverside.

First instar, second instar, and adult female mandible and maxillary stylets were protracted by modifying the method of Milne and Manicom (1978). A specimen container was constructed by cutting the pyramidal end from a #00 tissue embedding capsule (Electron Microscopy Sciences, Ft. Washington, PA) and covering both ends of the capsule with 102 μm polyester mesh (Tetco Inc., Elmsford, NY). The

fabric was held in place with capsule caps each with a hole slightly smaller than their diameter to permit adding and withdrawing fluid. Leaves infested with *S. citri* were agitated in 1% Liqui-Nox detergent (Scientific Products, Evanston, IL), and the immersed thrips were transferred by Pasteur pipette into the specimen container. After the container dried and the enclosed thrips were moving, it was filled with amyl acetate to induce mouthpart protraction. After standing for 30 min, the container was immersed in 1% Liqui-Nox solution to remove residual amyl acetate. The thrips were dehydrated in progressive concentrations of ethanol, critical-point dried in carbon dioxide, and sputter coated with gold. Specimens were examined with a JEOL JSM-35C scanning electron microscope and photographed with Polaroid Type 55 Positive-Negative Film. Mandible and maxillary stylet dimensions were measured on the photographs and divided by the photographic magnification to convert to actual size. Because amyl acetate induced differing amounts of mandible and maxillary stylet protraction, only the maximum dimensions observed in each life stage are presented.

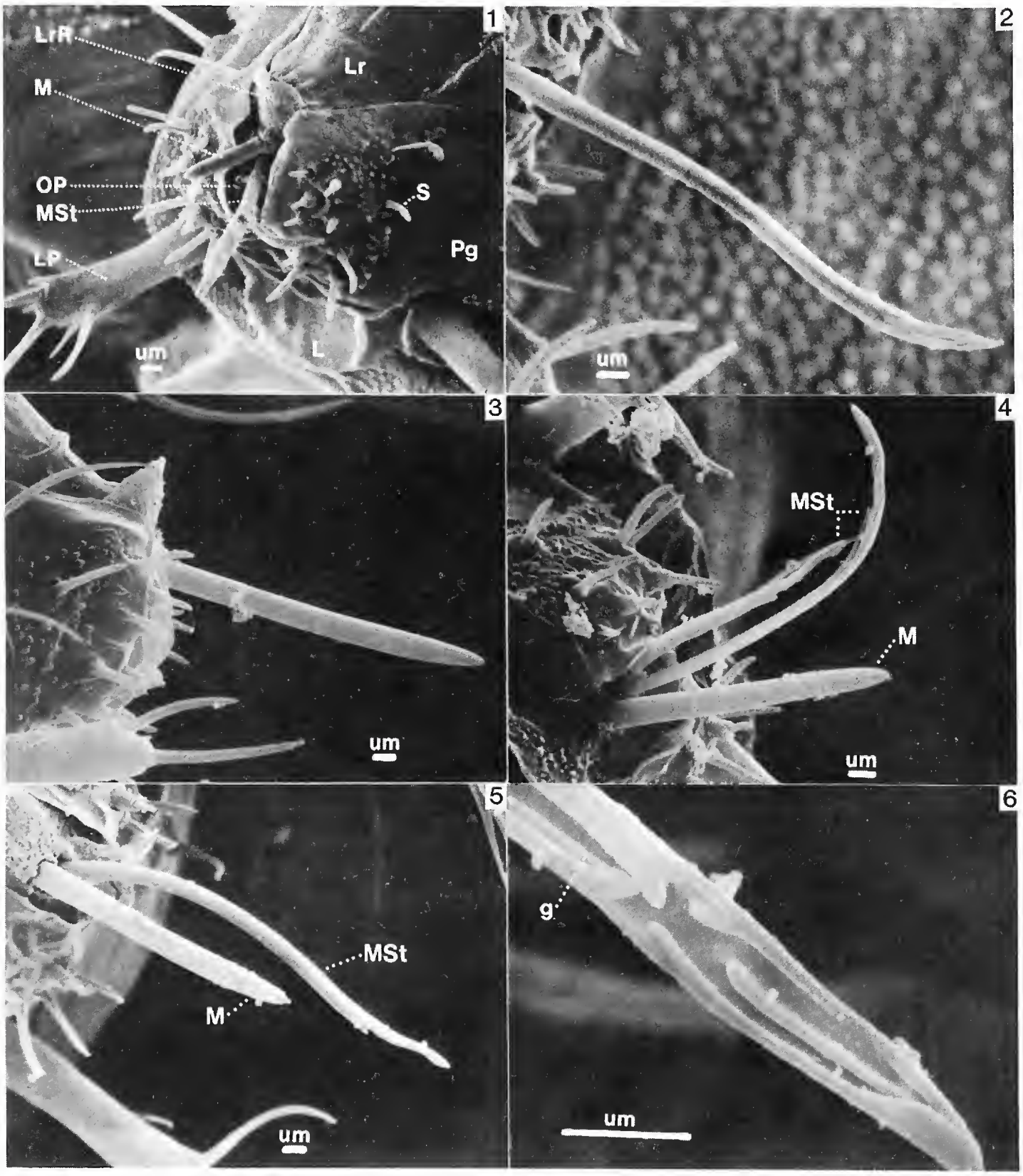
Results and Discussion

Surrounding the mandible and maxillary stylets, the mouth cone is comprised of the cephal labrum, caudal labium, and lateral paraglossae covered apically with sensilla (Fig. 1). Beneath the paraglossae the mandible and maxillary stylets pass through the labral ring (Fig. 1). During feeding by *L. cerealium,* the paraglossae move laterad and the labral ring is placed against the substrate (Chisholm and Lewis 1984). Oral papillae (Milne and Manicom 1978) are visible caudal to the labral ring (Fig. 1).

Immersion in amyl acetate ineffectively induced mouthpart protraction, and the maxillary stylets were more often protracted than the mandible. Of the 230 specimens examined, five protracted both the mandible and stylets, 13 protracted only the stylets, and two protracted only the mandible. Although the maxillary stylets of Thysanoptera are protracted by direct muscular action (Matsuda 1965), the mandible of *L. cerealium* is fused to the exoskeleton and protraction occurs only by contracting muscles that compress the mouth cone (Chisholm and Lewis 1984). If the mandible of *S. citri* is similarly fused, this may explain the lesser success of inducing mandible protraction.

In all life stages examined, the mandible is a stout cylinder tapering to a point (Figs. 3–5) suggesting that it punctures plant tissue as observed in *H. verbasci* (Heming 1978) and *L. cerealium* (Chisholm and Lewis 1984). A puncturing rather than rasping (Metcalf et al. 1962) mode of action agrees with the leakproof feeding punctures observed when *S. citri* was fed through an artificial membrane (Wiesenborn and Morse 1985). The greatest length *X* diameter of the protracted mandible (and number of specimens measured) was 10.0 μm in first instars (2), 20.8 μm *X* 1.3 μm in second instars (2), and 14.8 μm *X* 1.4 μm in adult females (3).

The maxillary stylets are longitudinally grooved on the inner surface (Figs. 4 & 6) to interlock into a single piercing and sucking organ with a sub-apical aperture (Fig. 2). The greatest length *X* diameter of the protracted stylets (and number of specimens measured) was 32.8 μm *X* 1.0 μm in first instars (9), 34.5 μm *X* 1.3 μm in second instars (6), and 22.8 μm *X* 1.0 μm in adult females (3). An internal median ridge and asymmetrical circular indentations are visible on the inner surface of a single stylet at the feeding aperture (Fig. 6). Similar morphology of the feeding aperture in



Figures 1–6. Scanning electron micrographs of *Scirtothrips citri* mouthparts: 1. First instar, ventral-lateral aspect of mouth cone showing labium (L), labial palp (LP), paraglossae (Pg), sensillum (S), labrum (Lr), labral ring (LrR), oral papillae (OP), mandible (M), and partially separated maxillary stylets (MSt). 2. First instar, interlocked maxillary stylets. 3. Second instar, lateral aspect of mandible. 4. Second instar, ventral aspect of mandible (M) and separated, unequally-protracted maxillary stylets (MSt). 5. Adult female, ventral aspect of mandible (M) and interlocked maxillary stylets (MSt) with one stylet protracted slightly beyond the other. 6. Adult female, inner surface of a single maxillary stylet at the apex showing the groove (g) that interlocks with the opposite stylet.

Scirtothrips aurantii Faure (Milne and Manicom 1978) supports its congeneric ranking with *S. citri*.

Heming (1978) found in *H. verbasci* that the apex of one maxillary stylet was held within a socket at the apex of the other. He hypothesized that stylet tip engagement

would cause the interlocked stylets to bend if either set of left or right style protractor muscles contracted more than the other. In contrast, Chisholm and Lewis (1984) suggested that the stylet apices of *L. cerealium* are less complex than in the Tubulifera and do not engage, allowing either stylet to protract beyond the other. In *S. citri,* the morphology of the stylets near the apex appear intermediate in complexity between *H. verbasci* and *L. cerealium,* and a socket as described in *H. verbasci* is not present. However, Heming described the movement of the maxillary stylets of *H. verbasci* as a "jabbing-whipping motion," movement we also have observed in *S. citri* feeding through an artificial membrane. Therefore, engagement of the apices may not be required for the maxillary stylets to bend by differences in muscle tension. Instead, directional control of the stylets may be similar to that proposed for the phytophagous Hemiptera (Pollard 1969), whereby the proximal portion of each maxillary stylet is flexible, and the distal portion is rigid and curved inwards. Protraction of one stylet beyond the other initiates bending toward the shorter stylet. When the shorter stylet is then equally protracted, support from the plant tissue guides it along the same curved path. In this manner, different plant cells at the same depth can be evacuated from a single entry site on the leaf surface, an ability that Chisholm and Lewis (1984) observed in *L. cerealium.* In *S. citri,* a separated maxillary stylet protracted beyond the other stylet is seen to curve inward (Fig. 4) concurring with Pollard's hypothesis. In our observations of *S. citri* feeding, the rapid swinging of the paired stylets may have been due to their sliding alternately past each other. Examination of stylet movement into plant tissue or an artificial substrate (e.g., agar) would help to substantiate that the method of maxillary stylet movement proposed for phytophagous Hemiptera also applies to terebrantian Thysanoptera.

Acknowledgment

The research reported is a portion of a thesis submitted by W. D. W. to the University of California, Riverside, in partial fulfillment of the requirements for the M.S. degree in Entomology. This research was funded in party by a grant from the California Citrus Research Board.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 43–52

New *Perdita (Perdita)* Oligoleges of *Mentzelia*, with Notes on Related Species of the *Ventralis* Group (Hymenoptera: Andrenidae)

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Contribution from Utah Agricultural Experiment Station, Utah State University, Logan, UT 84322–4810, Journal Paper No. 3210, and USDA, Agricultural Research Service, Bee Biology & Systematics Laboratory, Utah State University, Logan, UT 84322–5310.

Abstract.—Two new *Mentzelia* oligoleges of *Perdita (Perdita)* are described: *P. multiflorae* Parker from the San Rafael Desert of Utah and *P. kiowi* Griswold from the Great Plains. *P. viridinotata* Timberlake is synonymized with *P. wootonae* Cockerell. New distributional records are provided for *P. wootonae* and *P. holoxantha* Timberlake.

While conducting a survey of aculeate Hymenoptera in the San Rafael Desert of central Utah, the nest of a species of *Perdita* was discovered. This *Perdita*, which proved to be undescribed, was one of two species common on *Mentzelia* in the late afternoon when the flowers opened. Study of related species of *Perdita (Perdita)* of the *Ventralis* Group oligolectic on *Mentzelia* showed that there was a second undescribed species and a previously unrecognized synonymy. Here we describe these new species, give new records for closely related species, and present a key to the included forms.

The *Perdita* here discussed constitute a small assemblage of mostly pale *Perdita (Perdita)* of the *Ventralis* Group. In these species, the body color is largely pale yellow or off-white, with minimal dark markings. The scutum has, at most, weak dark marks laterally and the dorsum of the abdomen is either entirely light or with brownish markings restricted to the first two metasomal terga. Similarly colored species exist in the *Octomaculata* Group (*P. luteola* Cockerell, *P. xanthodes* Timberlake, *P. xanthochroa* Timberlake) and *Sphaeralceae* Group (*P. genalis* Timberlake, *P. luciae* Cockerell, *P. punctosignata* Cockerell, *P. stathamae* Timberlake, *P. triangulifera* Timberlake), but do not forage on *Mentzelia*. The species treated here differ morphologically from these similarly colored species as follows: *Ventralis* males have a distinct lateral furrow on the pronotal collar and a strong, laterally ridged pygidial region on tergum VII which is not scooped in lateral view. Male *Ventralis* further differ from *Octomaculata* males by their long scimitar-like mandibles which reach beyond the far lateral margin of the labrum, the

ventrally toothed or angled gena, the lateral brush of stout hair on sternum VI, and the entirely light hindtarsomeres II-V. *Ventralis* males differ from *Sphaeralceae* males in the apically pointed rather than truncate sternum VIII. Female *Ventralis* differ from females in the other groups by the presence of a distinct inner tooth on the mandible (may be absent in worn specimens) and by the presence of hooked hairs on the foretibia, at least basally. The pygidium of *Ventralis* females is straight with a truncate, unnotched apex while in *Octomaculata* females, the lateral margin is curved and the apex notched. The scopa on the hind tibia of *Ventralis* females is more dense on the outer and anterior surfaces than in *Sphaeralceae* females, with the hairs shorter and more strongly curved.

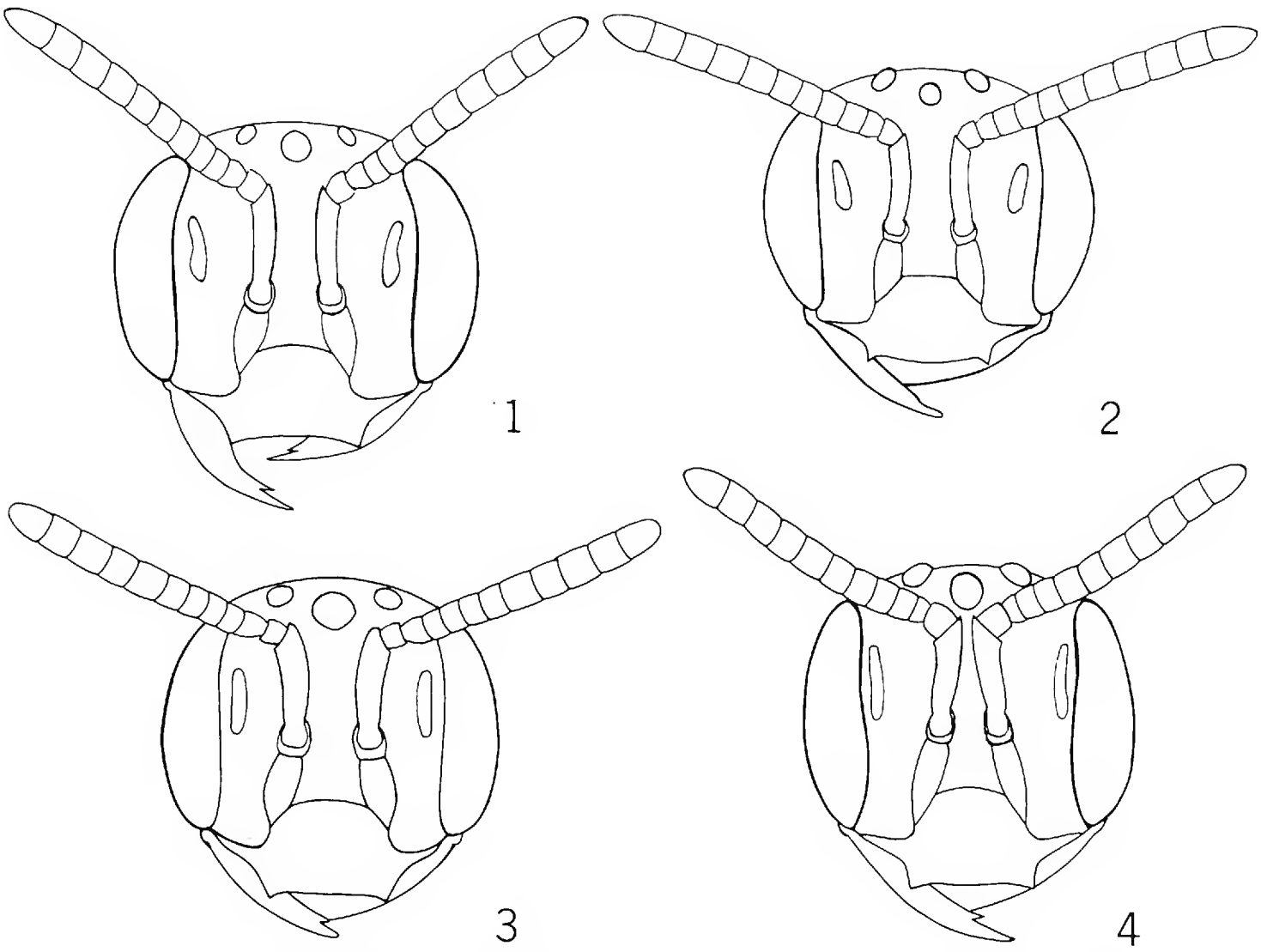
KEY TO INCLUDED SPECIES OF *Perdita*

Males

1. Sutures between scutum, scutellum, metanotum, and propodeum with dark markings, and/or propodeum with dark markings; hair of vertex and anterior part of scutum longer than pedicel 2
   Sutures between scutum, scutellum, metanotum, and propodeum without dark markings; propodeum without dark markings; hair of vertex and anterior part of scutum not longer than pedicel ..... *holoxantha* Timberlake
2. Dark markings present on tergum I; outer subantennal suture distinctly curved throughout except in macrocephalous individuals; lateral suture of clypeus just beneath juncture of outer subantennal suture oblique, forming low curve with rest of lateral suture; head length less than width 3
   Dark markings absent from tergum I; outer subantennal sutures straight except near juncture with clypeus; lateral suture of clypeus just beneath juncture of outer subantennal suture vertical, forming strong curve with rest of lateral suture; head length greater than or equal to width ..... *kiowi* Griswold
3. Mesopleuron ventrally with large metallic green spot; propodeal marks metallic ..... *wootonae* Cockerell
   Mesopleuron without ventral mark or with small brown non-metallic spot; propodeal marks non-metallic ..... *multiflorae* Parker

Females

1. Head width slightly greater than length (Figs. 1–3), face in part yellow; sutures between scutum, scutellum, metanotum, and propodeum without dark marks; post-axillary marks absent, or if present, brown not black 2
   Head length distinctly greater than width (Fig. 4), face off-white, without yellow areas; sutures between scutum, scutellum, metanotum, and propodeum with dark marks; black post-axillary marks present ..... *kiowi* Griswold
2. White on head restricted to clypeus. Mesopleuron without ventral mark or with submetallic brown spot 3
   Face at least white up to antennal base. Mesopleuron with metallic green ventral spot ..... *wootonae* Cockerell
3. Facial fovea linear (Fig. 3); mesopleuron without dark ventral spot ..... *holoxantha* Timberlake
   Facial fovea tear-shaped (Fig. 2); mesopleuron with dark ventral spot ..... *multiflorae* Parker



Figures 1–4. Heads of females: 1, *P. wootonae*; 2, *P. multiflorae*; 3, *P. holoxantha*; 4, *P. kiowi*.

Perdita multiflorae Parker, New Species
(Figs. 2, 5, 9)

Holotype female: Length, 5 mm. Yellow except: mandible red apically; basal half of mandible, labrum, lower half of clypeus white; antennal flagellomeres light brown dorsally, flagellomeres II–IV with dark brown transverse marks; large dark brown ventral patch with faint greenish reflections on mesopleuron; hind tarsi tinged with dark brown; facial fovea, posterior margin of median ocellus, mark inside base of hind wing, lateral line of tergum II black; tegula except basally, wing veins except brownish subcosta and stigma clear; tergum VI amber.

Head broader than long (Fig. 2); hair on vertex equal to length of antennal pedicel; facial fovea slightly tear-shaped, angled toward eye dorsally, upper end opposite indention in eye; outer subantennal suture not strongly curved below; line of lateral clypeal suture scarcely interrupted at juncture of outer subantennal suture; mandible with inner subapical tooth; gena in lateral view much narrower than eye, widest point of gena above middle of eye.

Scutum shagreened, shiny; scutal hair short, longest anteriorly where equal to length of pedicel; forecoxa, ventral mesopleuron covered with long, dense, apically hooked hair; forefemur with simple, apically hooked hair on posterior surface;

ventral margin of midfemur forming right angle basally; hindtibia with length of hair on dorsal margin approximately equal to width of segment.

Pygidium with carinate margins, surface flat, strongly shagreened, dull, apex narrowly truncate without medial notch.

Male: Length 4–4 1/2 mm. Color as in female except: lower half of clypeus pale yellow; antennal flagellomeres without dark markings; facial fovea, vertex around ocelli, scutum usually posterolaterally, postaxillary mark, sutures between scutum, scutellum, metanotum, and propodeum, anteriorly expanded V-shaped mark on disc of propodeum dark brown; tergum I basally and apically, often with median longitudinal connecting line, tergum II with lateral line, lateral preapical spot light brown; no black markings; no ventral dark patch on mesopleuron, occasionally indistinct light brown patch; no amber on terga.

Head slightly broader than long; hair on vertex longer than pedicel; facial fovea round to slightly oblong; outer subantennal suture distinctly curved except in macrocephalous individuals; lateral suture of clypeus just beneath juncture of outer subantennal suture oblique, forming low curve with rest of lateral suture; angle on lower gena usually present, acutely tuberculate in macrocephalous individuals.

Scutum highly polished, shagreening indistinct; mesopleuron ventrally with short, dense plumose hair; forefemur not greatly enlarged, length approximately twice width.

Tergum II with linear lateral line scarcely attenuated on the ends; tergum VII broadly rounded apically; sternum VIII as in Fig. 5; genitalia as in Fig. 9.

Variation: Females vary in the extent and darkness of the ventral mesopleural mark; most specimens lack greenish reflections. In some individuals the white portion of the head extends dorsally beyond the lower half of the clypeus.

As is common in this group, males vary greatly in the shape of the head. Macrocephalous individuals have a more quadrate head, the clypeal margin is more pronounced medially, the outer subantennal sutures are not distinctly curved, and the gena is expanded and bears a large posteriorly-directed tubercle below. There do not appear to be discrete classes of individuals; rather, there is a cline in all the above characters. Variation in the degree of dark maculations appears independent of the head structure.

Type Material.—Holotype female: "UTAH Emery Co. 5100′ 2 mi E Little Gilson Bt VIII–24/26–81 Veirs/Griswold/Parker." Paratypes: UTAH, Emery Co.: 33 males, 59 females same data as holotype; 2 males, 14 females, same except from nest, 26–VIII–81; 7 males, 11 females, San Rafael Desert, 5000′–5100′, near Little Gilson Butte, 24/27–VIII–80, A. S. Menke, F. D. Parker, K. A. Menke; 3 females, 1/2 air miles NE Little Gilson Butte, 12–IX–83, Parkers, Griswold; 1 female, Wild Horse Cr., 4900′, N of Goblin Vly., 21–IX–82, F. D. Parker, J. H. Parker; 1 female, Wild Horse Cr., 4800′, W of Goblin Vly., 23–IX–82, F. D. Parker, J. H. Parker; 1 female, 4 air miles N Gilson Butte, 5100′, 12/14–IX–83, Parkers, Griswold. Holotype is in the collection of the U.S. National Museum; paratypes in the AMNH, BBSL, and UK collections.

Additional Material.—UTAH, Wayne County: 1 female, E edge Capitol Reef, 15–IX–79, F. Parker, D. Veirs.

Range.—Known only from the San Rafael Desert and adjacent areas of the Colorado Plateau in Utah.

Discussion.—P. multiflorae coexists with *P. holoxantha* in the San Rafael Desert and both have been collected on *Mentzelia multiflorae* at the same date and location. In addition to the characters given in the key, *P. multiflorae* differs from *P. holoxantha* by the more shiny scutum, in the female by the longer length of the pubescence anteriorly on the scutum, and in the male by the more broadly rounded apical margin of tergum VII.

Perdita kiowi Griswold, New Species
(Figs. 4, 8, 12)

Holotype female: Length, 6 mm. Chalk-white except: mandible red apically; antennal flagellomeres brown dorsally, flagellomeres II–IV with dark brown transverse marks; subantennal sutures, facial fovea, small mark above antennal socket, posterior margin of median ocellus, mark inside base of hind wing, post-axillary mark, scutellar-metanotal suture black; irregular area around lateral ocellus, thin transverse line on pronotum, scutum along margin with tegula and scutellum, metanotal-propodeal suture, small ventral mesopleural spot, lateral line of tergum II dark brown; yellowish cast on scutum, lower mesopleuron; tegula except basally, wing veins except yellowish subcosta and stigma clear; tergum VI light amber.

Head longer than broad (Fig. 4); hair on vertex longer than antennal pedicel; facial fovea long, linear, parallel to inner eye margin, upper end above indentation in eye; outer subantennal suture distinctly arced; lateral clypeal suture distinctly angled at juncture of outer subantennal suture; mandible with inner subapical tooth; gena in lateral view as wide as eye, widest point of gena below middle of eye.

Scutum shagreened, shiny; scutal hair short, longest anteriorly where equal to length of pedicel; forecoxa, ventral mesopleuron covered with long, dense, apically hooked hair; forefemur with simple hair on posterior surface, some hooked apically; ventral margin of midfemur forming right angle basally; hindtibia with length of hair on dorsal margin approximately equal to width of segment.

Pygidium with carinate margins, surface flat, strongly shagreened, dull, apex narrowly truncate with shallow median notch.

Male: Length, 5 mm. Pale yellow except: mandible basally, face below level of antennal bases, pronotal lobe, tegula basally, scutellum, metanotum, subcostal vein, stigma whitish; mandible red apically; posterior margin of median ocellus (rarely expanded to lateral ocellus), mark inside base of hind wing, post-axillary mark black; clypeal and subantennal sutures, facial fovea, irregular area around lateral ocellus, mesopleuron beneath, sutures between scutum, scutellum, metanotum, and propodeum, subalar pit of mesopleuron, propodeum occasionally, median apical fovea of propodeum, lateral mark on tergum II dark brown; mesopleuron ventrally usually without mark or with small, indistinct brown mark, mark infrequently large, dark brown with metallic reflections; tegula except basally, wing veins except subcosta and stigma clear.

Head usually quadrate, length approximately equal to width; hair on vertex much longer than pedicel; facial fovea distinctly oblong; outer subantennal suture nearly straight, without distinct curve; lateral suture of clypeus just beneath juncture of outer subantennal suture vertical, at a distinct angle to rest of lateral suture; angle on lower gena usually present, acutely tuberculate in macrocephalous individuals.

Scutum highly polished, shagreening indistinct; mesopleuron ventrally with long, loose plumose hair; forefemur not greatly enlarged, length approximately twice width.

Tergum II with linear lateral line attenuated on the ends; tergum VII broadly rounded apically; sternum VIII as in Fig. 8; genitalia as in Fig. 12.

Variation: There is considerable variation in the dark markings on the head and thorax of the females. The ventral mesopleural spot varies from nearly absent to occupying the entire ventral surface and is occasionally submetallic, while the facial marks vary in extent and range in color from light brown to black. The population from El Paso County, Colorado contains individuals with much more highly developed dark markings than any other known populations. Some of these females have the frons, vertex, scutum, and propodeum mostly dark green, but we can find no structural differences indicating that these represent a sibling species.

Males vary in the shape of the head as in *P. multiflorae*, but not to the extent found in the latter. Variability in the extent of dark markings is much less pronounced than in females. Some males do have a dark mark surrounding the ocelli.

Type Material.—Holotype female: "USA, Nebraska: Dawes Co., Fort Robinson, VIII–12–1971, collected on *Mentzelia* between 5:30–6:00 P.M., J. G., B. L., and K. C. Rozen collectors." Paratypes: NEBRASKA, 22 males, 21 females, same data as holotype; 7 males, 7 females, same except 11–VIII–71, 7:00–7:45 P.M.; 4 males, 2 females, same except no floral data, 9/11–VII–72, J. G. Rozen, K. C. Rozen, R. McGinley; 7 males, same except R. McGinley; Garden County: 7 females, Oshkosh, 8 miles NE, 12–VIII–55, *Mentzelia*, W. E. LaBerge; 4 females, same except C. W. Rettenmeyer; Keith County: 5 males, 5 females, Cedar Point Biological Station, 1–IX–79, *Mentzelia nuda*, K. H. Keeler; Sheridan County: 1 female, Gordon, 10 miles SE, 9–VIII–55, *Mentzelia,* W. E. LaBerge; Sioux County: 1 male, 13–VIII–06, H. S. Smith; 1 male, Glen, 10–VIII–55, *Mentzelia*, C. W. Rettenmeyer; 1 female, same except 18–VIII–06, M. H. Swenk; 2 females, same except 4000′ *Mentzelia*, no collector; 16 males, 2 females, Glen, 3 miles E, 10–VIII–55, *Mentzelia*, W. E. LaBerge. KANSAS, 29 males, 19 females, Charleston, 5–IX–49, *Mentzelia decapetela*, Michener, Beamer; Barber Co.: 8 males, 11 females, Aetna, 5 miles SSW, 6–VIII–62, *Mentzelia decapetela*, W. B. Kerfoot; Finney Co.: 3 males, 10 females, Garden City, 2 miles S, 3–IX–51, *Mentzelia,* C. D. Michener, W. E. LaBerge; Hamilton Co.: 1 male, Syracuse, 22–VII–50, *Mentzelia decapetela*, C. D. Michener; Scott Co.: 1 male, 1 female, State Park, 8–VIII–64, C. D. Michener. Holotype is in the collection of the American Museum of Natural History, paratypes in the collections of AMNH, INHS, UCM, UK, and BBSL.

Additional Material.—COLORADO, 1 female, Denver, 29–VII–22, *Eriogonum effusum*, L. O. Jackson; Bent County: 8 males, 8 females, Caddoa, 2–VIII–57, *Mentzelia*, C. D. Michener; 1 male, Clay Ranch Gate, 8–VIII–57, *Mentzelia*, H. G. Rodeck; 6 males, 1 female, Hasty, 2 miles S, 12–VIII–74, U. N. Lanham; El Paso County: 2 males, 2 females, Foster Ranch, T15S R65W Sec. 22 NE/4, 6–VIII–77, *Mentzelia*; 2 males, 12 females, same except 7–VIII–77; 1 male, same except 12–VIII–77. TEXAS, 5 males, 3 females, 7 miles E Memphis, 5–IX–63, *Mentzelia*, G E. Bohart; Crosby County: 2 females, Cap Rock, 9 miles E, 29–VII–76, *Mentzelia nuda*; Lipscomb County: 2 females, Higgins, 18–IX–70, *Mentzelia nuda*, Baker, Kamm, Michener; Mitchell County: 1 female, Tex. Rd. 670, 22–VII–76, *Mentzelia*

nuda. NEW MEXICO, Roosevelt County: 11 males, 2 females, Oasis State Park, near Portales, 18–IX–70, *Mentzelia nuda*, Baker, Kamm, Michener. Specimens are in the BBSL, LACM, and UK collections.

Range.—Found on the Great Plains from Nebraska to Texas and New Mexico. All the records under *P. wootonae* given by Timberlake (1962) apparently belong here. This is the most distinctive species of the group. In addition to the characters in the key, the female differs from females of the other three species in this group in the greatly elongate facial foveae and the more strongly angled dorsolateral margin of the clypeus. It further differs from *P. multiflorae* and *P. holoxantha* in being off-white rather than pale yellow.

Perdita wootonae Cockerell

(Figs. 1, 6, 10)

Perdita wootonae Cockerell, 1898. Entomol. News 9:215. (Holotype female: Tularosa, New Mexico; ANSP.)

Perdita viridinotata Timberlake, 1962. Univ. Calif. Pubs. Entomol. 28:16. (Holotype female: Alamogordo, Otero Co., New Mexico; CAS.) New Synonymy.

Systematics.—Study of the types of *P. wootonae* and *P. viridinotata* showed them to be the same species. It appears that Timberlake never examined the type of *P. wootonae*. The description of *P. wootonae* given by Timberlake (1962), as well as all the records included, are referrable to *P. kiowi*.

Range.—Known only from Otero County, New Mexico. All localities are from the vicinity of White Sands.

New Records.—NEW MEXICO, Otero County: 2 males, 1 female, White Sands Monument area, 4000′, 9–IX–62, H. A. Scullen; 5 males, 16 females, White Sands Natl. Mon., 20–VIII–62, *Chrysothamnus* sp., H. V. Weems, Jr. Specimens are in the CAS, FSC, UCR, and BBSL collections.

Perdita holoxantha Timberlake

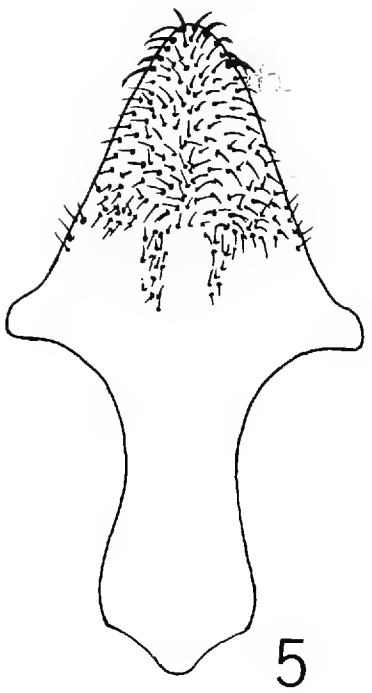
(Figs. 3, 7, 11)

Perdita holoxantha Timberlake, 1962. Univ. Calif. Pubs. Entomol. 28:17. (Holotype male: St. George, Washington County, UTAH; AMNH.)

Systematics.—This species is closely related to *P. multiflorae*. (For a discussion of the two, see the latter.) It is possible that two species are included under *P. holoxantha*. Males from Washington County, Utah (the type locality) and adjacent Clark County, Nevada have a more broadly rounded seventh tergum than males from the Colorado Plateau. There are no females from the type locality, but a single female from Clark County, Nevada appears to differ slightly from more eastern specimens in the shape of the facial fovea and in the shape of the head. Additional specimens are needed to determine if these differences are significant.

Range.—Known from southern Nevada, southern Utah, northern Arizona and New Mexico. One of the female paratypes of *P. viridinotata* is actually *P. holoxantha*.

New Records.—ARIZONA, Coconino County: 1 female, Cameron, 9–VI–77, R. C. Miller. NEVADA, Clark County: 5 males, 1 female, Riverside, 11/21–V–83, F. D., J. H. Parker. NEW MEXICO, Otero County: 1 female, Alamogordo, 13–IX–37, R. H. Crandall. UTAH, Emery County: 5 males, 33 females, 2 miles E Little Gilson Butte, 5100′, 24/26–VIII–81, Veirs, Griswold, Parker; 6 males, 10



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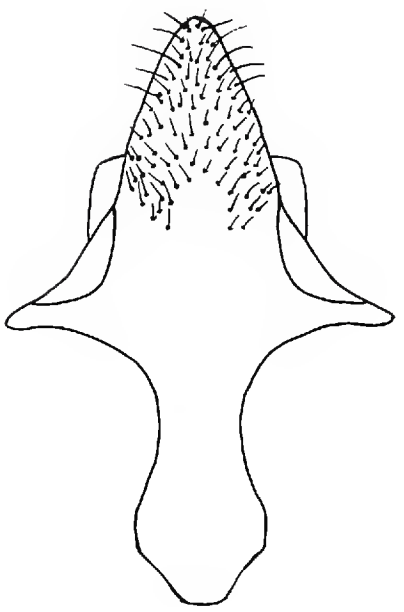

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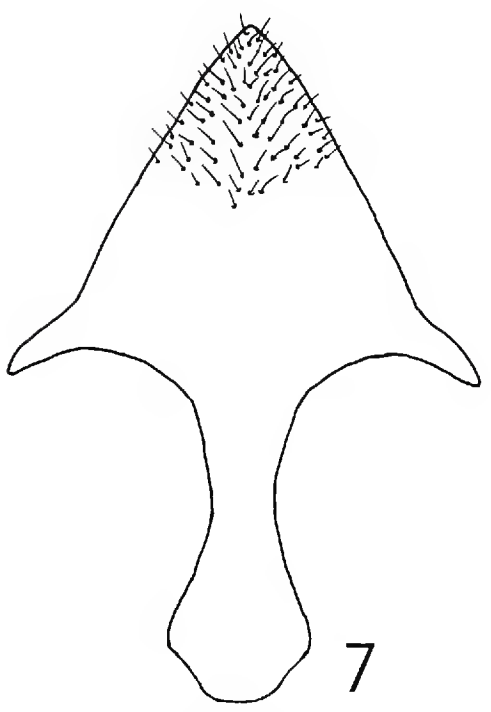

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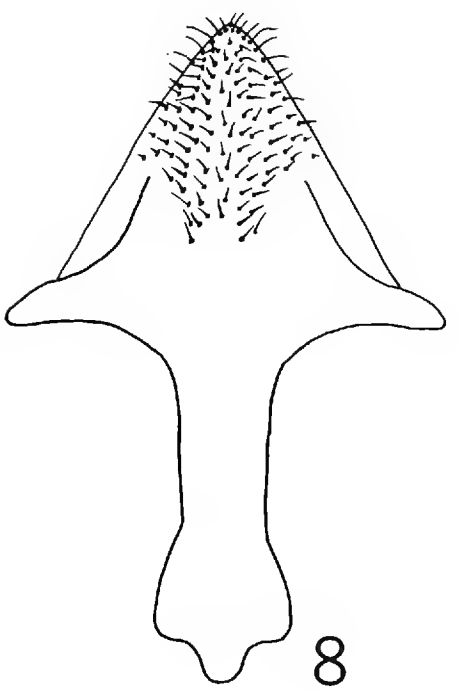

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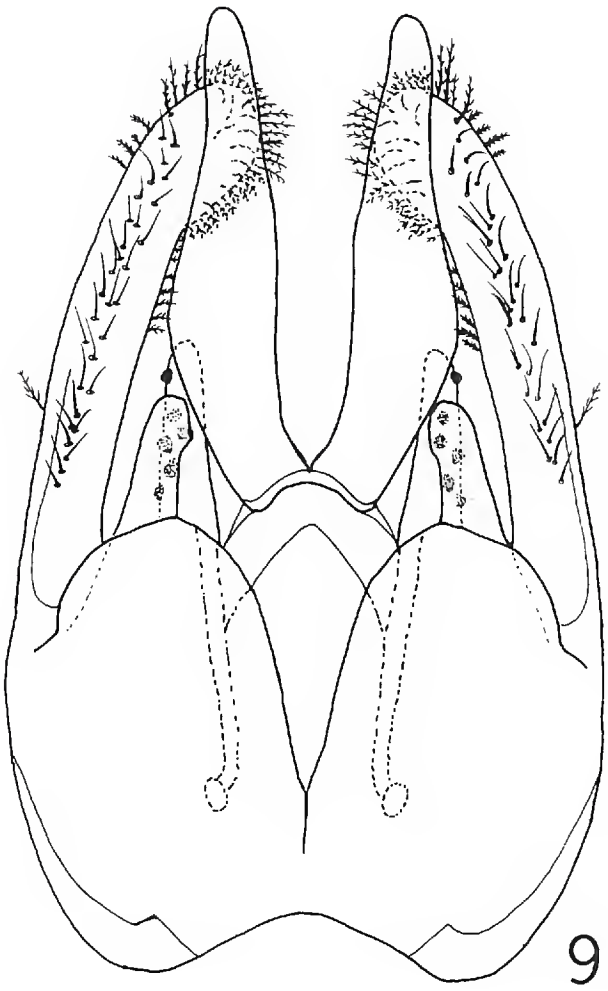
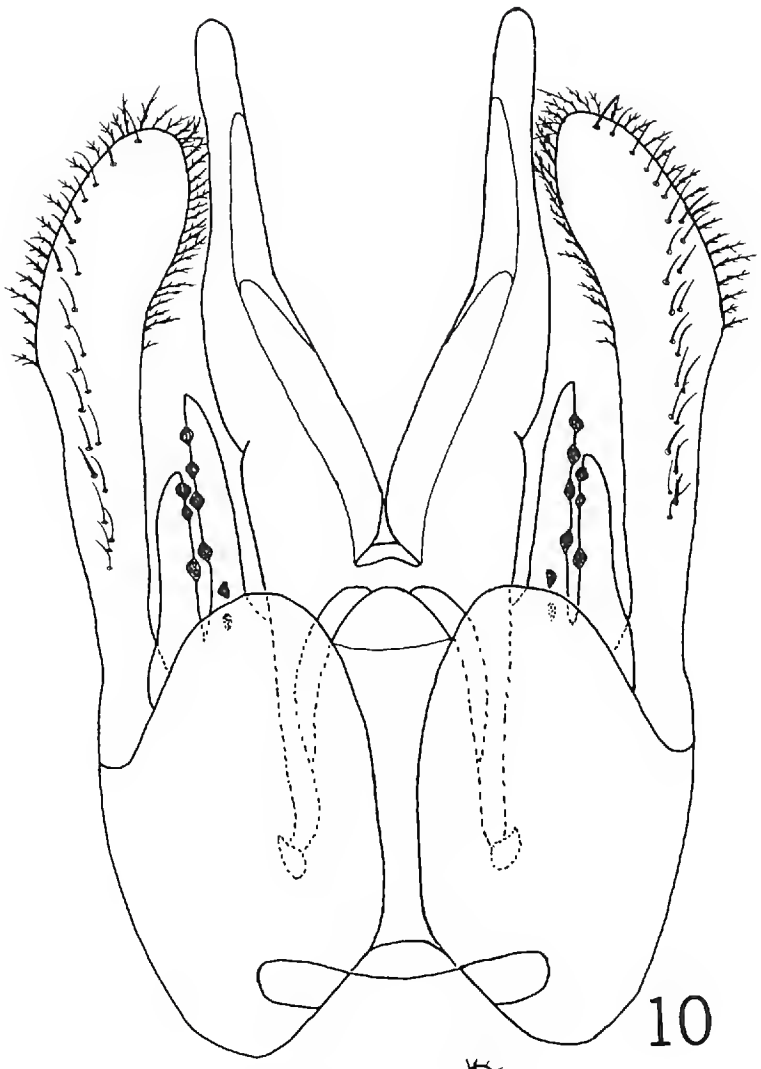
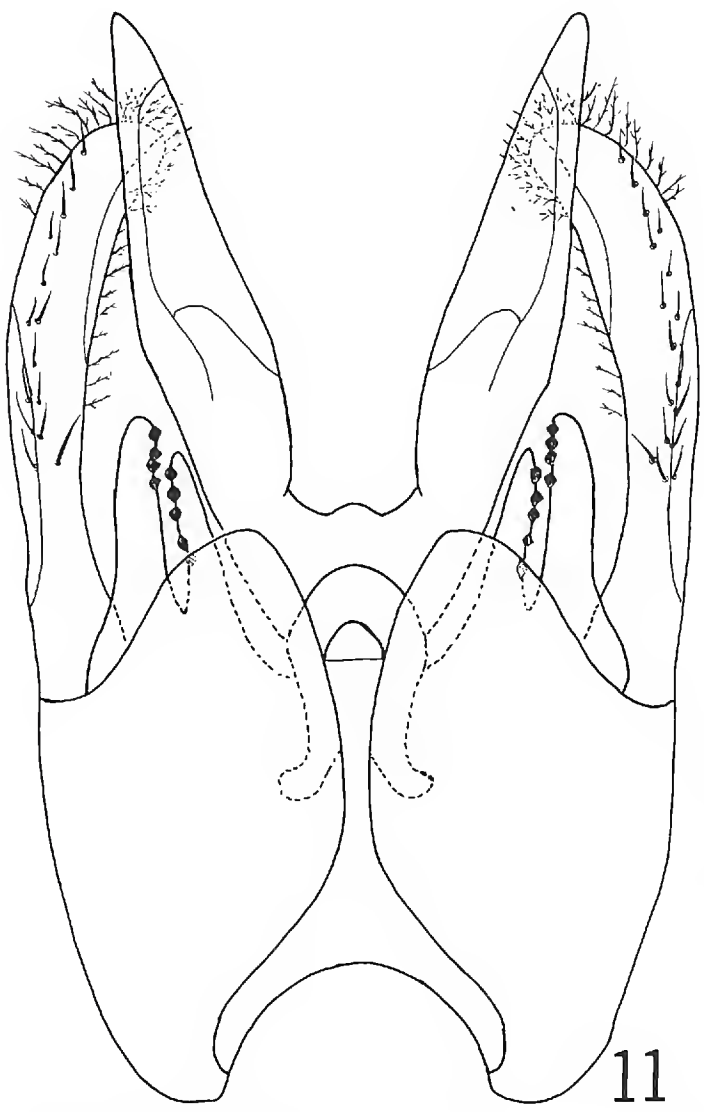
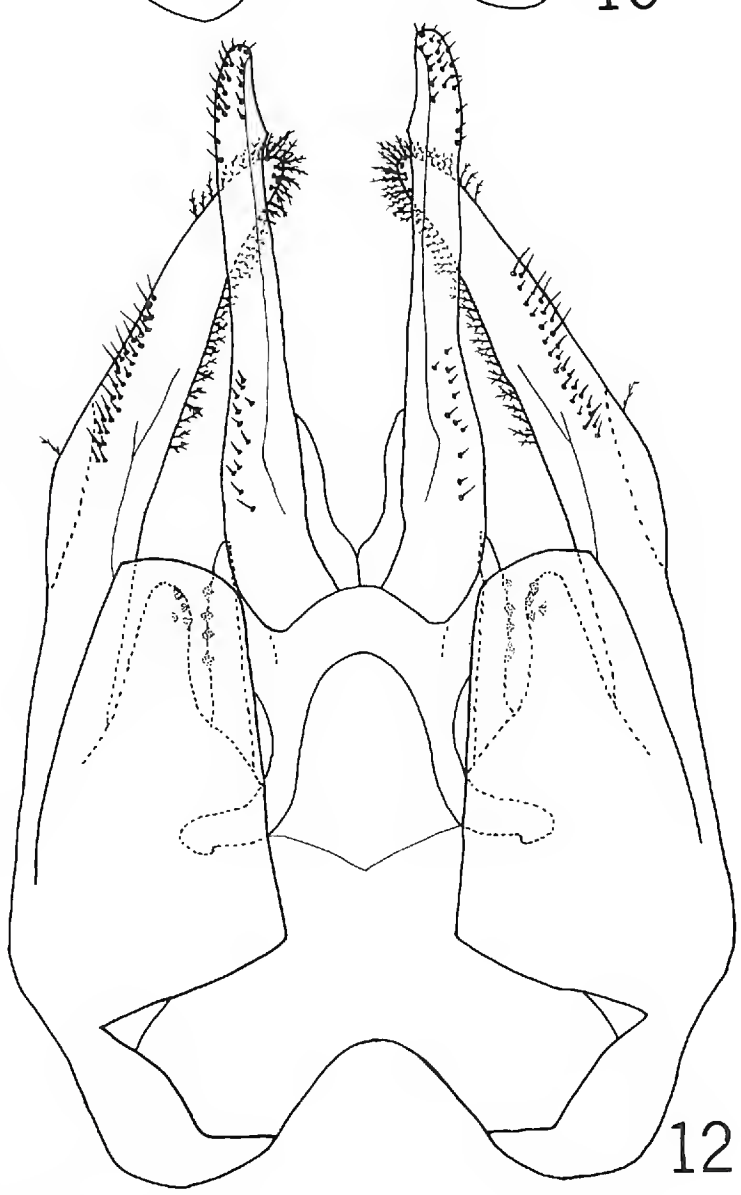
Figures 5–8. Male eighth sterna: 5, *P. multiflorae*; 6, *P. wootonae*; 7, *P. holoxantha*; 8, *P. kiowi.*

females, same except 15/17–IX–80, T. Griswold; 15 males, 21 females, San Rafael Desert, near Little Gilson Butte, 5000′–5100′, A. S. Menke, F. D. Parker, K. A. Menke; 2 females, 1/2 air miles NE Little Gilson Butte, 12–IX–83, Parkers, Griswold; 1 male, 2 females, Wild Horse Cr., N of Goblin Vly., 4900′, 23–IX–82, F. D. Parker, J. H. Parker; 7 males, 1 female, same except 3–VI–82, Parker, Griswold; 2 males, same except 14–VI–83, F. D. Parker, J. H. Parker; 2 males, 6 females, same except 21/23–VII–81, Veirs, Parker, Griswold; 1 female, same except 25/28–VII–83, Parkers, Griswold; 2 males, Buckskin Spr., N of Goblin Vly., 5150', 25–VIII–81, Parker, Veirs, Griswold; 1 male, 3.2 air miles NE Little Gilson Butte, 14–VI–83, F. D. Parker, J. H. Parker; 1 male, 1 female, 1 1/2 miles NE Little Gilson Butte, 23–VII–81, Parker, Veirs, Griswold; 1 male, Goblin Vly., sand dunes, 20–VI–80, F. D. Parker; Garfield County: 1 male, 7 females, Cane Springs Desert,









Figures 9–12. Male genitalia: 9, *P. multiflorae*; 10, *P. wootonae*; 11, *P. holoxantha*; 12, *P. kiowi.*

10 miles N Bullfrog, 4000′, 16–VI–83, T. Griswold; San Juan County: 3 females, Monument Valley, 7–VIII–69, T. Griswold; Washington County: 4 males, Santa Clara, 30–V–73, *Mentzelia*, F. Parker, P. Torchio. Specimens recorded here are in the UCD and BBSL collections.

Acknowledgements

Our thanks for the loan of material to J. G. Rozen, Jr. and M. Favreau, American Museum of Natural History (AMNH); W. Pulawski, California Academy of Sciences (CAS); G. Eickwort, Cornell University (CUIC); J. Wiley, Florida State Collection of Arthropods (FSC); W. LaBerge, Illinois Natural History Survey (INHS); R. Snelling, Los Angeles County Museum (LACM); F. Werner, University of Arizona (UA); R. O. Schuster, University of California at Davis (UCD); U. Lanham, University of Colorado Museum (UCM); J. Hall, University of California at Riverside (UCR); C. Michener, University of Kansas (UK); and the late P. Hurd, Jr., U.S. National Museum (USNM). Other records are from the Bee Biology and Systematics Laboratory (BBSL).

Illustrations of the female heads were prepared by Q. Truong; those of the male sterna and genitalia by D. Broemeling.

Literature Cited

Timberlake, P. H. 1962. A revisional study of the bees of the genus, *Perdita* F. Smith, with special reference to the fauna of the Pacific Coast. Part V. Univ. Calif. Pubs. Entomol. 28:1–123.

PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 53–61

Descriptions of Adults and Nymphs of the Taro Planthopper, *Tarophagus proserpina taiwanensis* ssp. n., from Taiwan (Homoptera: Delphacidae)[1]

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Abstract.—A new subspecies of taro planthopper, *Tarophagus proserpina taiwanensis* Wilson, is described for specimens from Taiwan. Male and female genitalia and first through fifth instar nymphs are described and illustrated. Features useful in separating nymphal instars include differences in body size and proportions, spination of metatibiae, metatibial spurs, and metatarsomeres, and number of metatarsomeres and body pits.

The taro planthopper, *Tarophagus proserpina* (Kirkaldy), has been reported from Hawaii south to Tahiti and west to Guam, Japan, Philippine Islands, Taiwan, northern Australia, Indonesia, Vietnam, and Malaysia (Fennah, 1978; Metcalf, 1943; Mitchell and Maddison, 1983; Wu and Yang, 1985; Zimmerman, 1948). It is a major pest of taro (*Colocasia esculenta* (L.) Schott) causing yellowing and stunting of leaves by adult and nymphal feeding and oviposition damage to stems (Mitchell and Maddison, 1983) and has been implicated as the vector of Alomae and Bobone rhabdoviruses in the Pacific Islands (Francki et al., 1981; Mitchell and Maddison, 1983; Ooka, 1983).

The biology of the taro planthopper has been studied by Fullaway (1937) who made some brief remarks about its life history in the Philippines and Matsumoto (1964) who reared it, studied the field biology of it and its egg predator *Cyrtorhinus fulvus* Knight (Hemiptera: Miridae) in Hawaii, and provided very brief descriptions of eggs and nymphs. Wu and Yang (1985) briefly described the fifth instar of *T. proserpina* and seven other delphacid species.

This paper presents descriptions and illustrations of male and female genitalia, and 1st through 5th instar nymphs of *T. proserpina taiwanensis* ssp. n. from Taiwan.

Descriptions

Specimens were preserved in 70% ethyl alcohol. The adult male and female genitalia and the 5th instar are described in detail but only major differences are described for preceeding instars. Measurements are given in mm as mean ± SD. Length was measured from apex of vertex to terminus of abdomen, thoracic length along the midline from anterior margin of the pronotum to posterior margin of the metanotum, and width across the widest part of the body. One specimen of each

[1]Florida Agric. Exp. Stn. Journal Series No. 8200.

nymphal instar was cleared in 6% KOH in order to examine distribution and number of body pits.

The collecting data for specimens used for description are: REPUBLIC OF CHINA: Taiwan, Tsao-Tun, Taichung, 1 October 1986, coll. J. H. Tsai, ex. taro (2–1st instars, 21–2nd, 5–3rd, 4–4th, 8–5th, 3♂♂ 9♀♀ brachypterous adults). Holotype ♂ and allotype of subspecies in Bernice P. Bishop Museum, Honolulu, Hawaii. Paratypes (2♂ , 8♀) and nymphs in collection of S. W. Wilson.

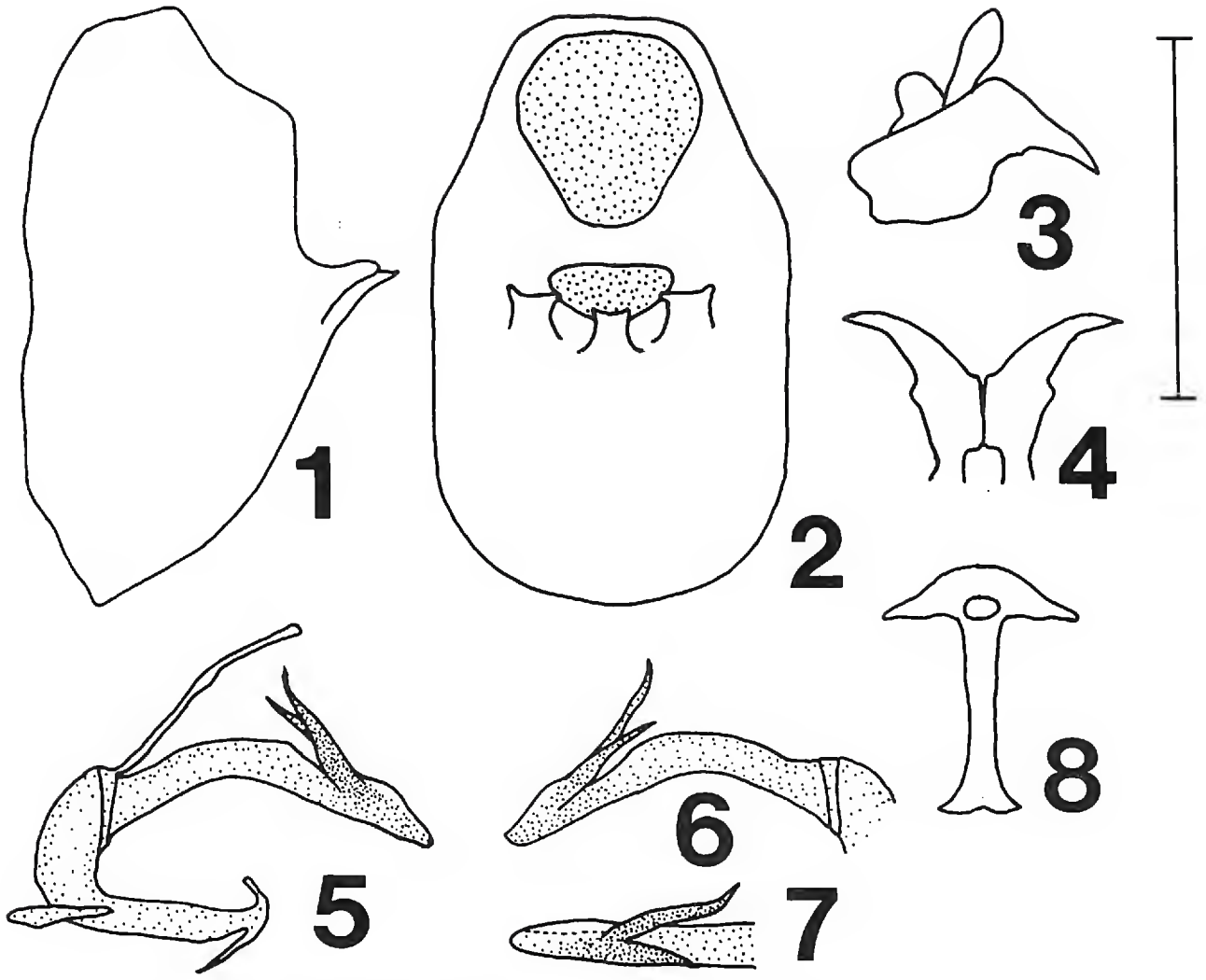
Tarophagus proserpina taiwanensis Wilson, New Subspecies

Adult.—Kirkaldy (1907) described and illustrated the head, and genital capsule of *T. proserpina* from Fiji. Zimmerman (1948) provided illustrations of the adult habitus of a brachypter, head, antenna, forewing from a macropter, and several views of the male genitalia and very brief descriptions of Hawaiian specimens. Matsumoto (1964) included body measurements and a short description of specimens from Hawaii. Fennah (1965) described macropterous *T. proserpina australis* Fennah from Queensland, Australia; this subspecies differs from the nominate subspecies in features of the vertex and male genitalia. In describing *T. p. australis* Fennah (1965) suggested that *T. proserpina* is polytypic in the form of the lobes of the pygofer, the major distinguishing feature of *T. p. taiwanensis*. *T. p. taiwanensis* agrees with the detailed description of *T. p. australis* given by Fennah (1965) except for the number of teeth on the metatibial spur (18–23 in *T. p. taiwanensis*, 36 in *T. p. australis*) and features of the male genitalia. Descriptions and illustrations of female genitalia have not been published.

Male genitalia—(Figs. 1–8). Pygofer subcylindrical; 1 median and 2 lateral caudodorsally directed quadrate processes; median process narrower than lateral ones. Anal tube subcylindrical, 1 acute process on either side extending from caudoventral angle. Styles widest in middle, apices diverging, acute. Aedeagus laterally compressed, curved, elongate; gonopore on dorsal aspect near apex; 2 sinuate acute processes extending anterodorsally from posterior 1/3, left process longer than right. Aedeagal chamber with wings T-shaped (see Asche, 1985 for terminology).

T. proserpina taiwanensis differs from specimens described and illustrated by Kirkaldy (1907) and Zimmerman (1948) in the width and shape of the lateral lobes of the pygofer—in *T. p. taiwanensis* the lobes are at most 2× the width of the median lobe and are quadrate; in *T. p. proserpina* (Kirkaldy and *sensu* Zimmerman) the lateral lobes are much more than 2× the width of the median lobe and are subtriangular. Additional differences include the shape of the median lobe of the pygofer (quadrate in *T. p. taiwanensis*, rounded in *T. p. proserpina*), the length of anal tube spines (longer in *T. p. taiwanensis*), and apices of the styles (acute in *T. p. taiwanensis*, blunt in *T. p. proserpina*). *T. p. taiwanensis* differs from *T. p. australis* in the shapes of the pygofer median and lateral lobes (median lobe knoblike and lateral lobes subacute in *T. p. australis*) and aedeagus (processes equal in *T. p. australis*).

Female genitalia—(Figs. 9, 10). Segment 9 extending anteroventrally, slightly swollen, longer than wide. Anal tube cylindrical. Valvifer 1 strongly sinuate on inner margin, terminating in strong hook like ventrally directed process anteriorly. Valvula 3 elongate, slender, widest in basal 1/3. Valvula 2 elongate, saber shaped, minute teeth on dorsal aspect. Genital scale ovoid, strong medial notch giving appearance of two plates.

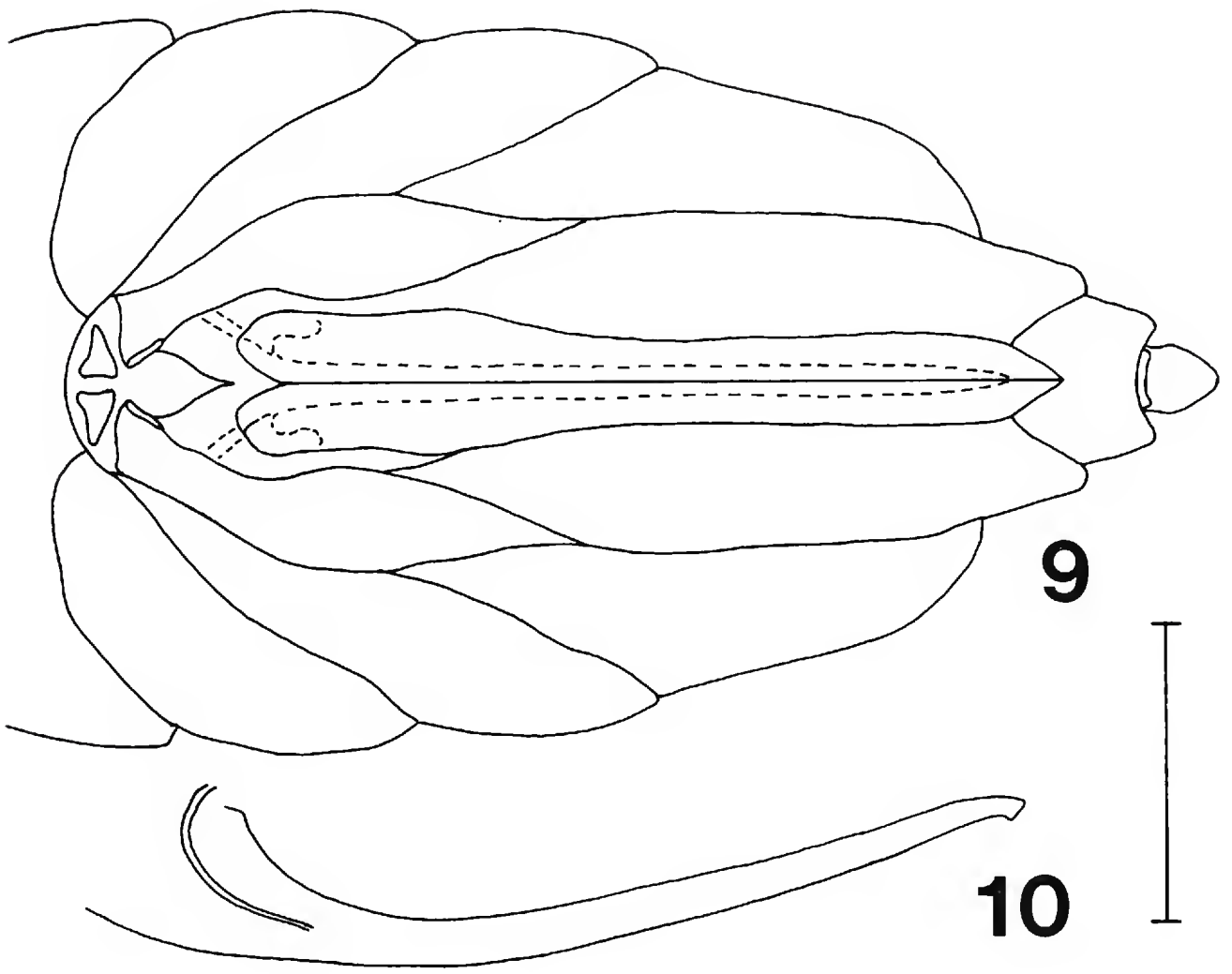


Figures 1–8. *T. proserpina taiwanensis* holotype male genitalia. 1. Pygofer, left lateral view of pygofer. 2. Pygofer, ventro-caudal view. 3. Anal tube, left lateral view. 4. Styles. 5. Aedeadus and anal tube and style connectives, left lateral view. 6. Aedeagus, right lateral view. 7. Aedeagus, dorsal view of apex. 8. Aedeagal chamber, anterior view. Bar = 0.5 mm.

Fifth instar—(Figs. 11–13, 18). Length 3.0 ± 0.23; thoracic length 0.9 ± 0.05; width 1.3 ± 0.11 (N = 8).

Form elongate, subcylindrical, slightly flattened dorsoventrally, widest across mesothoracic wingpads. Body mottled light to dark brown and cream, legs pale with dark brown apices.

Vertex quadrate, length subequal to width at base, posterior margin convex; carina on each side extending anteromedially from inner margin of compound eye and continuing onto frons as inner carina; with weak, shallow v-shaped transverse carina between lateral carinae, one shallow depression just anterior to transverse carina and two shallow depressions posterior to carina. Frons subrectangular; widest in upper 1/3, width ca. 0.75 × length; carinate lateral margins slightly convex, these outer carinae extending from vertex to near clypeal border and paralleled by pair of inner carinae; 9 pits between each inner and outer carina and 4 pits between each outer carina and eye; small ocellus or blemma ventral to posteroventral pit. Clypeus narrowing distally, consisting of subconical basal postclypeus and cylindrical distal anteclypeus. Beak extending almost to bases of metacoxae; 3-segmented, segment 1 obscured by anteclypeus, segment 2 slightly longer than 3; apex of segment 3 dark brown. Eyes red. Antennae 3-segmentéd; scape cylindrical, slightly longer than wide; pedicel subcylindrical, ca. 2× longer than wide and ca. 2× length of scape, with 10 pitlike sensoria; flagellum bulbous basally, with elongate, bristle-like extension distally, bulbous base ca. 0.25 × length of pedicel.



Figures 9–10. *T. proserpina taiwanensis* female genitalia. 9. Complete genitalia, ventral view. 10. Valvula 2, left lateral view. Bar = 0.5 mm.

Thoracic nota divided by middorsal line into three pairs of plates. Pronotal plates subrectangular; anterior margin following posterior margin of head, posterior border sinuate; each plate with slightly curved, oblique posterolaterally directed carina originating on anterior margin in median 1/3 and terminating in middle of plate, carina bordered along inner margin by row of 7 pits extending posterolaterally to lateral border of plate (lateralmost pits not visible in dorsal view). Mesonotal median length ca. 1.5–2× that of pronotum; each plate bearing an elongate lobate wingpad extending nearly to apex of metanotal wingpad in macropter or covering lateral half of metanotal wingpad in brachypter; with posterolaterally directed carina originating on anterior margin in median 1/4 and terminating on posterior margin; 2 pits, one on each side of carina and 3 pits in lateral 1/3. Metanotal median length ca. 0.7× that of mesonotum; each plate bearing an elongate lobate wingpad extending almost to anterior margin of tergite 4 in macropter and tergite 3 in brachypter; with weak longitudinal carina originating on anterior margin in median 1/4 and terminating on posterior margin; 1 pit just lateral to carina. Pro- and mesocoxae elongate, posteromedially directed; metacoxae fused to sternum. Metatrochanter subcylindrical, with row of many minute teeth on posteromedial aspect. Metatibia with 2 black-tipped spines on lateral aspect of shaft, an apical transverse row of 5 black-tipped spines on plantar surface and a subtriangular, flattened movable spur with row of 15–19 teeth on lateral aspect. Pro- and mesotarsi with 2 dark brown tarsomeres; tarsomere 1 wedge-shaped; tarsomere 2 subconical, curved, and with pair of apical claws and median membranous pulvillus. Metatarsi with 3 tarsomeres;

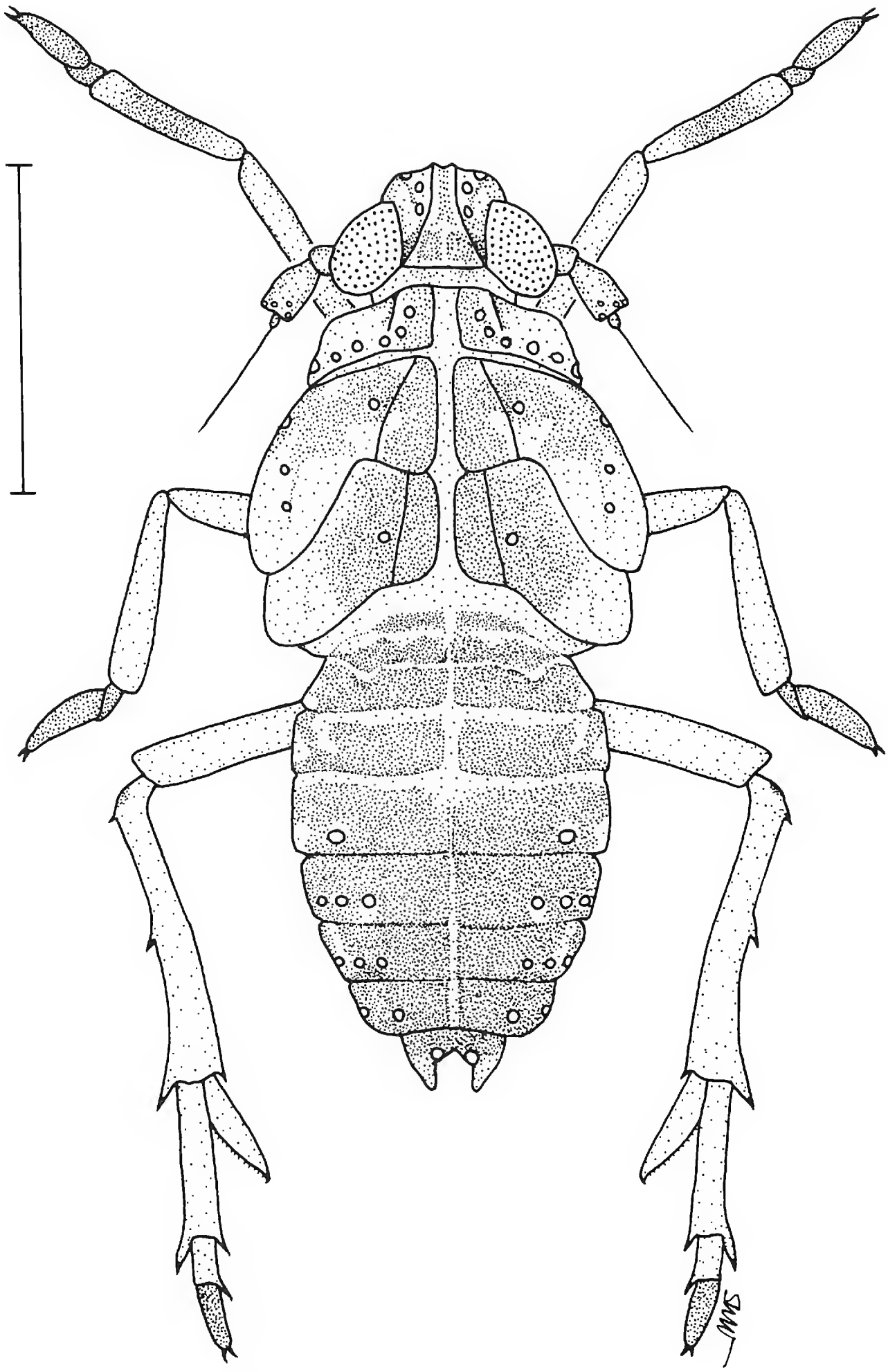
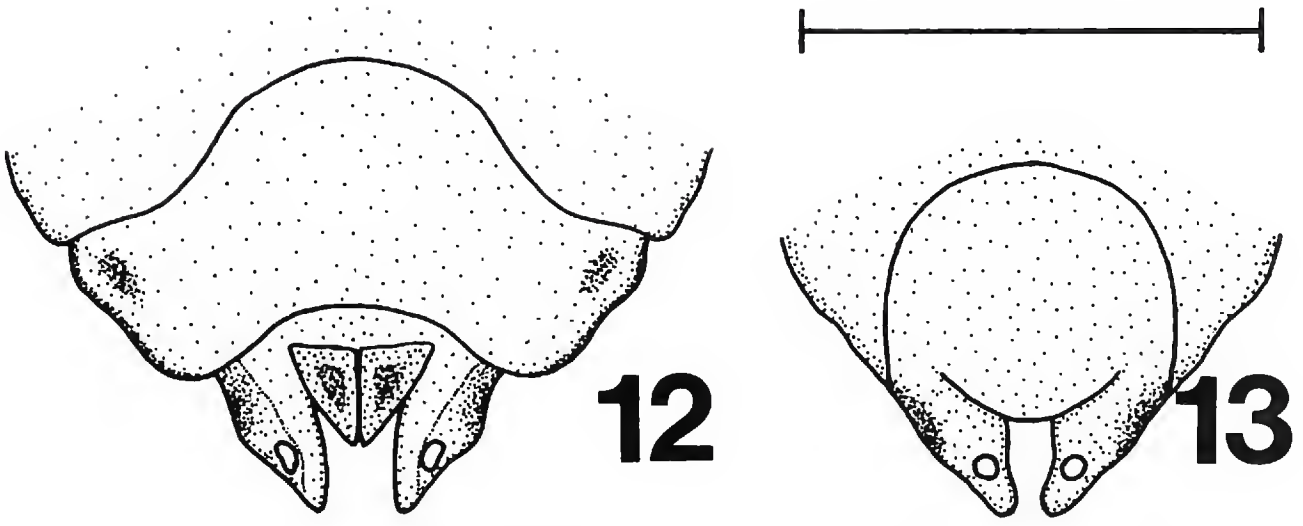


Figure 11. *T. proserpina taiwanensis* fifth instar. Bar = 1 mm.

tarsomere 1 cylindrical with apical transverse row of 7 black-tipped spines on plantar surface; tarsomere 2 cylindrical, ca. 0.25× length of tarsomere 1, with apical transverse row of 4 black-tipped spines on plantar surface; tarsomere 3 subconical, similar to terminal tarsomere of other legs.



Figures 12–13. *T. proserpina taiwanensis* fifth instar. 12. Ventral view of apex of abdomen of female. 13. Ventral view of apex of abdomen of male. Bar = 0.5 mm.

Abdomen 9 segmented; slightly flattened dorsoventrally, widest across segments 4 and 5. Tergites 1 and 2 reduced; tergite 5 with 1 pit and tergites 6–8 each with 3 pits on either side of midline (lateralmost pits not always visible in dorsal view). Segment 9 surrounding anus; with 3 pits on each side; female with 1 pair of subacute dark brown processes extending caudally from juncture of sternites 8 and 9; males lacking processes.

In their description of the 5th instar nymph, Wu and Yang (1985) indicate only 8 pits between each outer and inner carina on the frons. Nine pits are present on our specimens; one of the pits is in the anterolateral corner of the frons and is difficult to find unless the specimen is cleared and oriented correctly. In his extensive study of delphacid nymphs, Vilbaste (1968) also described 9 pits on the frons.

Fourth instar—(Figs. 17, 18). Length 2.1 ± 0.16; thoracic length 0.7 ± 0.03; width 0.9 ± 0.04 (N = 4).

Beak with segment 2 ca. 1.5 × length of 3. Antennal pedicel with 7 pitlike sensoria.

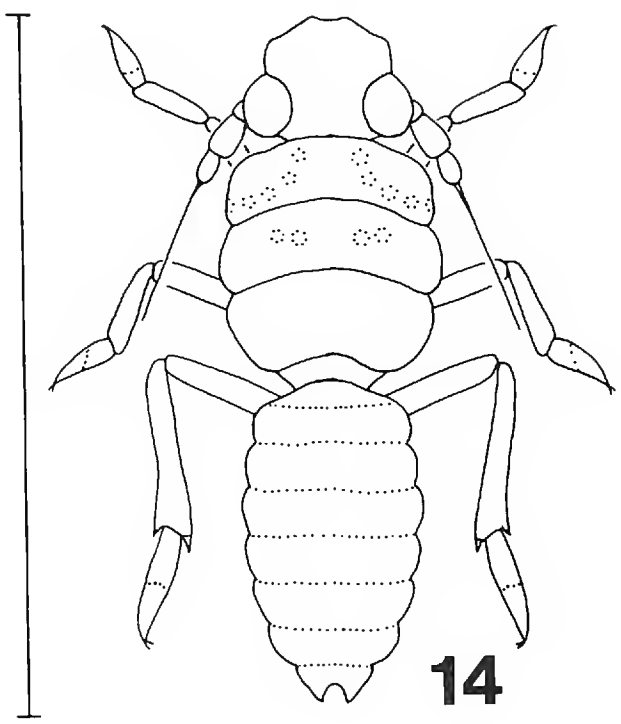
Mesonotal median length ca. 1.5 × that of pronotum; wingpad covering lateral half of metanotal wingpad in all specimens. Metanotal median length subequal to that of mesonotum. Metatibial spur convex on both sides, with row of 7–11 teeth on lateral aspect. Metatarsi with 2 tarsomeres; tarsomere 1 with apical transverse row of 6 black-tipped spines on plantar surface; tarsomere 2 subconical, similar to terminal tarsomere of other legs, ca. 0.5–0.7 × length of tarsomere 1, partially subdivided in middle, with transverse row of 3 very weak black-tipped spines in middle on plantar surface.

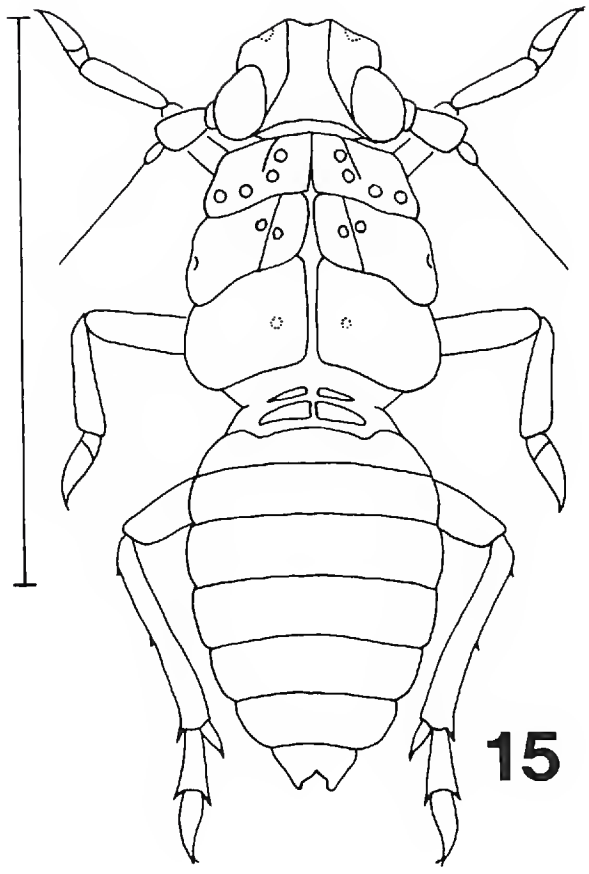
Abdominal subacute processes of female concolorous with sternum, poorly developed.

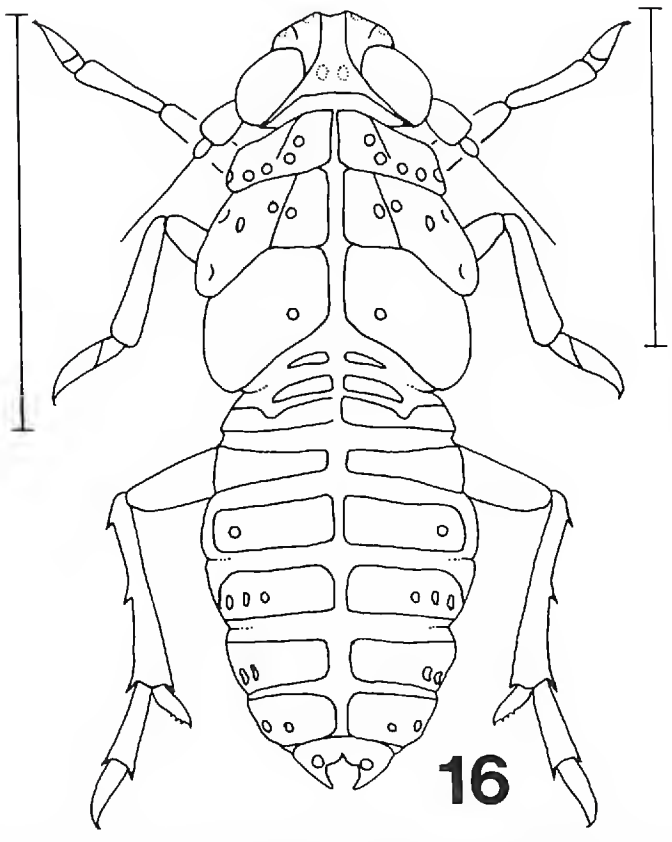
Third instar—(Figs. 16, 18). Length 1.7 ± 0.16; thoracic length 0.6 ± 0.03; width 0.7 ± 0.2 (N = 5).

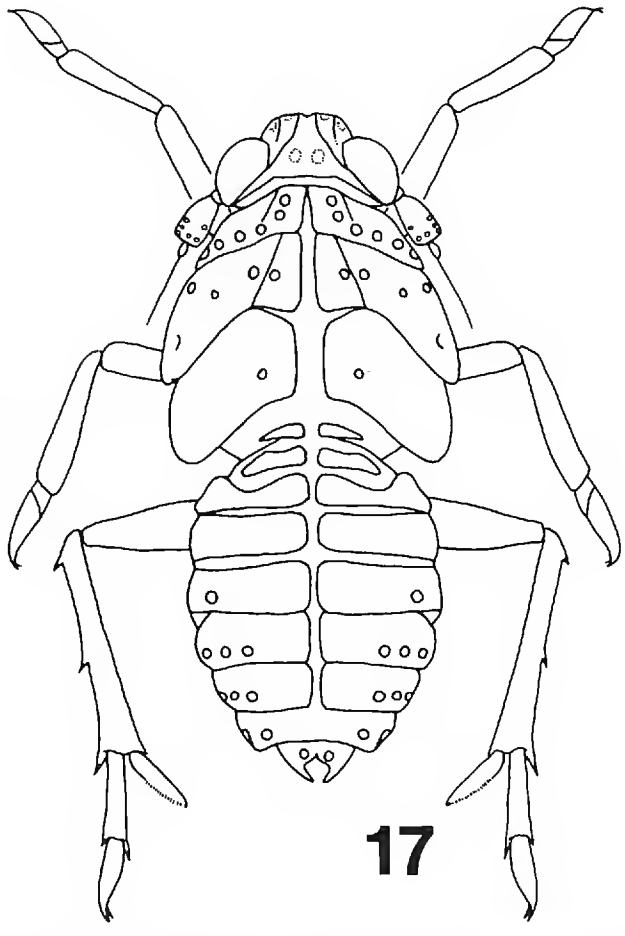
Antennal pedicel with 4 very weak pitlike sensoria; bulbous portion of flagellum ca. 0.33X length of pedicel.

Pronotal plates each with row of 6 pits. Mesonotal wingpads weakly developed, covering metanotal wingpad laterally at base. Metatibia with apical transverse row of 4 black-tipped spines on plantar surface; spur with row of 2–4 teeth on lateral aspect









Figures 14–17. *T. proserpina taiwanensis* first through fourth instars. 14. First instar. 15. Second instar. 16. Third instar. 17. Fourth instar. Bars = 1 mm.

and 1 apical tooth. Metatarsomere 1 with apical transverse row of 5 black-tipped spines on plantar surface; tarsomere 2 lacking spines in middle.

Abdominal subacute processes of female apparently absent.

Second instar—(Figs. 15, 18). Length 1.4 ± 0.13; thoracic length 0.4 ± 0.03; width 0.5 ± 0.02 (N = 21).

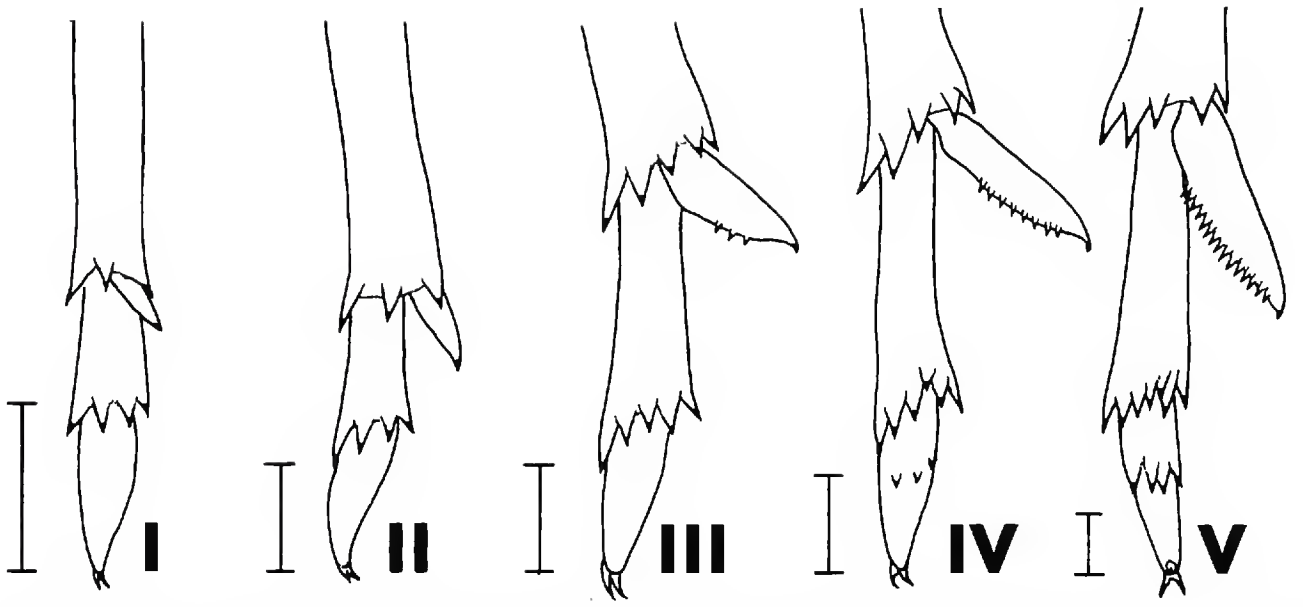


Figure 18. *T. proserpina taiwanensis* apices of metathoracic legs, plantar surface. I–V = nymphal instars. Bars = 0.1 mm.

Body white, occasionally with very light brown markings; apices of legs white to light brown.

Head with 3 pits between outer carina of frons and eye. Antennal pedicel with pits not apparent.

Mesonotal wingpads not developed, not covering metanotum laterally. Metatibia with apical transverse row of 3 black-tipped spines on plantar surface; spur with spike like, ca. 2X length of longest tibial spine, bearing 1 terminal black-tipped tooth. Metatarsomere 1 with apical transverse row of 4 black-tipped spines on plantar surface.

First instar—(Figs. 14, 18). Length 1.15–1.20; thoracic length 0.35; width 0.35–0.45 (N = 2).

Body and legs white; pits very obscure.

Antenna with bulbous portion of flagellum ca. 0.5X length of pedicel.

Metatibia lacking lateral spines on shaft; spur weakly developed, slightly longer than longest tibial spine.

Key to Nymphal Instars

1. Metatarsi with 3 tarsomeres or with tarsomere 2 partially subdivided and bearing 3 weak spines in middle on plantar surface (Fig. 18 IV, V) 2
   Metatarsi with 2 tarsomeres; tarsomere 2 lacking spines (Fig. 18 I–III) 3
2. Metatibial spur with 15 or more teeth; metatarsi with 3 tarsomeres, tarsomere 1 with apical transverse row of 7 spines, tarsomere 2 with apical transverse row of 4 spines (Fig. 18 V) . . . . . Fifth instar
   Metatibial spur with fewer than 12 teeth; metatarsi with 2 tarsomeres, tarsomere 1 with apical transverse row of 6 spines, tarsomere 2 partially subdivided and with 3 weak spines in middle (Fig. 18 IV) . . . . . Fourth instar
3. Metatibial spur with 2 or more marginal teeth and 1 apical tooth; metatarsomere 1 with apical transverse row of 5 spines (Fig. 18 III) . . . . . Third instar
   Metatibial spur lacking marginal teeth, with 1 apical tooth; metatarsomere 1 with apical transverse row of 4 spines (Fig. 18, I, II) 4

4. Metatibial spur ca. 2× length of longest metatibial spine (Fig. 18 II); metatibia with 2 lateral spines on shaft (Fig. 15) ..... Second instar
   Metatibial spur less than 2× length of longest metatibial spine (Fig. 18 I); metatibia lacking lateral spines on shaft (Fig. 14) ..... First instar

Acknowledgments

We thank Drs. M. Asche and H. Hoch, Fachbereich Biologie-Zoologie, Philipps Universität, Marburg, West Germany for supplying us with a copy of the Matsumoto thesis.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 63–66

Incidence of Pre-Emergence Sib-Mating in *Monodontomerus obsoletus, Pteromalus venustus,* and *Tetrastichus megachilidis,* Three Chalcid Parasitoids of the Alfalfa Leafcutting Bee, *Megachile rotundata* (Hymenoptera: Chalcididae)

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Contribution from Utah Agricultural Experiment Station, Utah State University, Logan, Utah 84322–4310, Journal Paper No. 3356, and USDA-Agricultural Research Service-Bee Biology and Systematics Laboratory, Utah State University, Logan, Utah 84322–5310.

Abstract.—Three species of chalcid wasps (*Monodontomerus obsoletus, Pteromalus venustus,* and *Tetrastichus megachilidis*) that parasitize the immature stages of the alfalfa leafcutting bee (*Megachile rotundata*) were studied to determine if females of these spanandrous species are inseminated before they emerge from the host cocoon. In contrast to earlier reports, moderate pre-emergence mating occurred in *M. obsoletus* and *P. venustus* but not in *T. megachilidis*.

INTRODUCTION

Hamilton (1967) constructed what he called "a biofacies of extreme inbreeding and arrhenotoky" for small haplodiploid arthropods in which mating seems normally to take place between siblings. Among the important characteristics Hamilton (1967) listed were: 1) gregarious development of a clutch of siblings; 2) a sex ratio strongly biased towards females (spanandry); 3) protandry; 4) mating immediately after (or occasionally before) females eclose, with males capable of multiple mating and of fertilizing a female's entire egg production with a single insemination; and 5) sperm storage and single mating by females. Hamilton's (1967) explanation for this biofacies hinged upon restricted opportunities for mating in what he termed "viscous" or small, subdivided populations. When the probability of mating between siblings is high, then female parents should produce only as many sons as are necessary to inseminate their daughters.

Three species of hymenopterous protelean parasitoids that attack *Megachile rotundata* (Fabricius) (MR), the alfalfa leafcutting bee, fit Hamilton's (1967) list of attributes quite well; *Monodontomerus obsoletus* Fabricius (Torymidae) (MO), *Pteromalus venustus* Walker (Pteromalidae) (PV), and *Tetrastichus megachilidis* Burks (Eulophidae) (TM). They are haplodiploid and all sting immature MR, usually at the prepupal stage, and then lay numerous eggs either in (TM) or on (MO,

PV) the host. The sex ratios of clutches of parasitoids hatching from individual hosts are spanandrous for MO and TM, but are less so for PV. Mating of at least some females by their protandrous brothers occurs immediately after eclosion as the parasitoids emerge from the host cocoon. Females store sperm and most, if not all, of their egg production can be fertilized by a single insemination. (See Krombein 1967, Hobbs 1968, Hobbs and Krunic 1971, Eves 1970, Whitfield and Richards 1985 for additional details).

Aside from thelytoky, the most extreme development in Hamilton's (1967, 1979) biofacies is for sib-mating to occur within the host cell before the parasitoids emerge. Under such circumstances, opportunities for outbreeding would be all but eliminated. Indeed, if inbreeding is the most favorable option for such species, then pre-emergence mating should be quite common. Hamilton (1967, 1979) cites several examples. The purpose of this study was to determine the incidence of pre-emergence mating in MO, PV and TM.

Methods

Cocoons of MR that had been parasitized by one of the parasitoid species were removed from stock cultures maintained at 29°C on the morning of expected emergence, isolated in clean petri dishes, and placed under constant observation. Several females were removed as soon as they emerged from the host cell, usually in the order of emergence. The remaining adult progeny from each host cell were counted later.

After removal, experimental females were isolated in individual petri dishes and maintained for three days (or prior expiration) at 29°C, and 16L:8D photoperiod with three fresh MR cocoons containing prepupae. Because females will parasitize hosts before being fed, food was not supplied. MR cocoons had previously been radiographed (Stephen and Undurraga 1976) so that those with dead larvae could be detected and removed. After three days, cocoons were placed in individual gelatin capsules and incubated at 29°C, 82% RH until parasites or host emerged. At that time, the number and sex of progeny was recorded.

Results

Monodontomerus obsoletus: Emergence of parasitoids was monitored for 13 parasitized prepupae. In nine (69.2%), males emerged before females. However, the difference in emergence time between the sexes was slight: frequently males and females emerged within seconds of each other; occasionally, males emerged a few minutes earlier. Thus, with respect to emergence from the host cocoon, MO is marginally protandrous.

Seventy-one females were removed and used for the study: 6 females were removed from each of nine cocoons, five were removed from one cocoon, and four were removed from each of three cocoons. These females parasitized 186 of the 213 cocoons provided (87.3%). The 27 unparasitized cocoons contained dead MR larvae when subsequently examined.

Only five of the 71 emergent females (7.0%), from two of the 13 cocoons, had mated prior to the emergence. In one cocoon, only the fifth of six females was mated. She parasitized all three host cocoons offered and produced a total of ten males and 15 females. Female progeny were produced in two of the three cocoons. In the other cocoon, all four females had mated. Together, they parasitized eight of the 12

cocoons offered and produced 12 males and 53 females. It may be relevant to note that the cocoon from which these females emerged had the highest ratio of males to females (1:2) of any of the 13 cocoons used (the next highest ratio was 1:4). However, the only other cocoon which produced a mated female had a male:female ratio of 1:8.

Pteromalus venustus: Protandry appears to be absent in PV: females emerged before males from six of the 13 cocoons monitored. Fifty-eight females were removed for study. PV females displayed much greater variation in the number of hosts parasitized than did MO: 16 females (27.6%) did not parasitize any host cocoons, while ten, 19 and 13 females parasitized one, two, and three cocoons, respectively. Of the 174 cocoons offered, only 87 (50.0%) were parasitized; of the 87 unparasitized cocoons, 44 (50.6%) subsequently produced healthy adult bees. The reasons for this large number of seemingly acceptable, but unattacked, hosts are unclear.

Of the 42 females that did parasitize, 5 (11.9%), from four different cocoons, produced some female progeny. The numbers of adults (males:females) from these four cocoons ranged from 1:8 to 4:4. Together, the five females produced 121 males and 59 females in 13 parasitized cocoons.

Tetrastichus megachilidis: For TM, only four cocoons were monitored. Males emerged from these cocoons before females in three cases. A total of 25 females (10, 5, 5, 5) were removed and isolated with host cocoons. Of these, five parasitized two cocoons, 18 parasitized one cocoon, and two did not parasitize. Thus, of the 75 cocoons supplied, only 28 (37.3%) were used. Of the 47 unused cocoons, 38 (80.9%) subsequently produced live adult bees. TM is the smallest of the parasitoids and the only endoparasite; smaller individuals may have difficulty reaching the host through the cocoon with their ovipositor.

None of the 28 cocoons parasitized produced females.

Discussion

In contrast to previous findings, based on much smaller sample sizes, of no pre-emergence mating in MO or PV (Eves 1970, Hobbs and Krunic 1971), both species displayed a moderate level (7–12%) of within-host cocoon mating. No evidence of pre-emergence mating was found for TM but females from only four cocoons were monitored. For at least two species, however, the behavioral characteristics necessary for complete inbreeding to develop are currently present should such an option become selectively advantageous. Hamilton (1979) has discussed some situations under which higher levels of inbreeding might evolve.

Acknowledgements

I thank K. Ruggeri for conducting the observations and experiments; E. Klomps and S. Jennings for aid with data tabulation; E. E. Grissell for confirming the identity of MO; and E. E. Grissell, F. D. Parker and W. P. Stephen for commenting on the manuscript.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 67–71

Aspects of Host Acceptance by *Pteromalus venustus* Walker and *Monodontomerus obsoletus* Fabricius, Parasitoids of *Megachile rotundata* (Fabricius), the Alfalfa Leafcutting Bee (Hymenoptera: Chalcididae)

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Abstract.—Preliminary experiments were conducted to: 1) determine the cues used by two species of chalcid parasitoids (*Monodontomerus obsoletus* [MO], *Pteromalus venustus* [PV]) to accept immature alfalfa leafcutter bees as hosts; and 2) compare the suitability and vulnerability to the parasitoids of different aged hosts. Initially, parasitoids accepted only fully authentic hosts. After 24 hours with hosts that were artificial in one or more respects, host acceptance behavior expanded to include some previously unacceptable hosts. However, the species differed in the kind of artificial hosts accepted with PV being more selective than was MO. All immature stages from prepupae to late pupae were acceptable as hosts to both species.

INTRODUCTION

Parasitoid wasps accept prospective hosts as food for rearing their offspring only after those hosts have satisfied a combination of stringent requirements. Stimuli that lead to oviposition by parasitoids can be physical or chemical and may include host size, shape, texture, activity and odor. The acceptance process, from host encounter to oviposition, is usually hierarchical and may consist of several steps (see Arthur 1981 for a review).

This report presents a preliminary description of host acceptance by two species of chalcid parasitoids. *Pteromalus venustus* Walker (Pteromalidae) and *Monodontomerus obsoletus* Fabricius (Torymidae) (subsequently referred to as PV and MO, respectively) were apparently introduced accidentally to North America with one of their several hosts, the alfalfa leafcutting bee (ALCB), *Megachile rotundata* (Fabricius). They are gregarious external parasitoids of the immature stages of bees and, perhaps some wasps, and can be abundant pests of the ALCB, the most important commercial pollinator of alfalfa, (*Medicago sativa* L.) in the Pacific northwest. The parasitoids immobilize the host by stinging and then deposit eggs between host and inner cocoon lining (Eves 1970, Hobbs and Krunic 1971). Immature individuals of any stage are vulnerable, but attack prior to the prepupal stage is usually fatal to both host and parasitoid offspring (Eves 1970). The eggs hatch in 36 to 48 hours and the first instar larvae begin to feed on the host. At 29°C, oviposition to adult eclosion takes about 21 days for MO (Eves 1970) and 12 days for PV (Whitfield and Richards 1985). Both species are multivoltine; individuals

overwinter as prepupae within host cocoons. (The species studied by Eves [1970] and Hobbs and Krunic [1971] was identified as *Monodontomerus obscurus* Westwood. Recent taxonomic work strongly suggests that *M. obsoletus* was actually the species studied [E. E. Grissell, pers. comm.; see below]).

Information was sought on two aspects of host acceptance/choice. First, the effect on host acceptance of manipulating several general characteristics of host larvae and cocoon was assessed. In the case of MO, these experiments both replicate and extend the work of Eves (1970). A second question, engendered by the more rapid developmental rates of parasitoids than hosts, relates to the suitability of ALCB pupae as hosts. When ALCB prepupae are incubated by beekeepers in anticipation of alfalfa bloom in late spring/early summer, adult parasites emerge first and may then attack other unparasitized, maturing ALCBs. Thus, it is of interest to determine if developing bee pupae of different ages are as attractive and suitable as hosts as are the more commonly parasitized prepupae.

Methods

All experiments were conducted using freshly emerged, unfed parasites from stock populations maintained at this laboratory. ALCB prepupae were removed from overwinter storage at 4–5°C and held at room temperature (~25°C) for 24 hours before being used in experiments. Experiments were conducted in clean glass petri dishes at 29°C and 16L:8D photoperiod.

To determine the importance of the cocoon and prepupae, 10 to 20 females of each species were each isolated with two specimens of one of the following five types of "host" until they either oviposited or expired: a) unencased (naked) ALCB prepupae; b) ALCB cocoons from which the prepupae had been removed through a partial slit at one end; c) ALCB prepupae inside #2 gelatin capsules; and, agar "prepupae" inside either d) empty ALCB cocoons slit as in (b), or e) #2 gelatin capsules. Hosts encased by cocoons or #2 gelatin capsules (18mm × 6mm) were fixed to filter paper in the bottom of the dishes by applying a small drop of non-toxic glue to the encasement. Unencased hosts, i.e., naked larvae, were not anchored to the substrate. Care was taken to avoid handling the hosts. Artificial "bees" were made from plain agar in dimensions of leafcutter bee prepupae (8mm × 4mm diam.). Hosts were monitored several times each day to record the time and number of eggs laid.

The second part of the study was designed to compare acceptance and suitability of hosts at different developmental stages. Overwintering ALCB prepupae were removed from storage at 4–5°C and incubated at 29°C for 8 or 16 days (8D, 16D). Individual freshly emerged parasites were offered two hosts each from 8 day, 16 day and unincubated groups for 24 hours under 16L:8D photoperiod. To minimize effects of host size on acceptance, all prepupae were weighed and only those within 10% confidence limits of the mean were used for experiments. Hosts were incubated at 29°C for another 7 days and then cocoons were opened and the contents recorded.

Results

The majority of females of both species did not lay eggs in treatments in which either prepupae or cocoon were manipulated (Table 1). The only hosts parasitized by PV females were naked prepupae. Seven of 10 females parasitized the naked

Table 1. Results of experiments on cocoon and host manipulations. Number of females tested, N = 10 for all but agar bees in gelatin capsules for *Monodontomerus* where N = 20.

	Monodontomerus				*Pteromalus*			
	Number		Mean (± SD)		Number		Mean (± SD)	
Treatment	♀♀ parasitizing	"Hosts" parasitized	First day oviposition	Eggs/ host	♀♀ parasitizing	"Hosts" parasitized	First day oviposition	Eggs/ host
naked prepupa	0	0	——	0	7	9	1.7 ± 1.1	7.1 ± 5.2
empty cocoon	1	1	4.0	7.0	0	0	——	——
prepupa/gel cap	9	17	2.9 ± 0.9	8.3 ± 3.6	0	0	——	——
agar bee/gel cap	3	4	2.0 ± 0.0	5.3 ± 3.9	0	0	——	——
agar bee/cocoon	6	8	1.33 ± 0.82	3.3 ± 1.5	0	0	——	——

Table 2. Number of females of MO and PV parasitizing over a 24-hour period, number of hosts parasitized, and mean number of eggs/host for three incubation treatments.

	Monodontomerus			*Pteromalus*		
	Number		Mean (± SD)	Number		Mean (± SD)
Treatment	Parasitizing	Hosts Parasitized	Eggs/ Host	Parasitizing	Hosts Parasitized	Eggs/ Host
Unincubated	22	27	3.8 ± 1.5	18	22	8.3 ± 5.2
8 D	27	47	4.1 ± 1.6	13	13	14.0 ± 6.0
16 D	26	42	4.1 ± 1.2	10	13	9.1 ± 4.5

prepupae, and those seven laid fewer eggs per host and took longer on average to lay them, than has been observed for unfed females (Tepedino 1987a, see below).

Naked prepupae (the only treatment accepted by PV females) were completely rejected as prospective hosts by female MO. All other host types were accepted by at least one female (Table 1). Significantly more prepupae in gelatin capsules were parasitized than any other treatment ($X^2 = 46.1$), d.f. = 1, $P < 0.001$); and significantly more agar "bees" in cocoons were parasitized than naked prepupae, empty cocoons and agar "bees" in gelatin capsules combined ($X^2 = 9.72$, d.f. = 1,

$P < 0.005$). Females also deposited the most eggs per host in the treatment with the most acceptable hosts, i.e., prepupae in gelatin capsules.

Although MO females oviposited in three times as many hosts as did PV females, there is evidence they did so under duress. First, with the exception of the prepupa in gelatin capsules treatment, females rarely oviposited more than once; and second, the average time to initial oviposition was more than 48 hours after the experiment began. This is hardly typical behavior as unfed female MO commonly parasitize more than one host within the first 24 hours (Tepedino 1987a, b, see below).

In contrast to the outright rejections of, or reluctance to oviposit in, hosts that were artificial in some aspect, all developmental stages were accepted as hosts by both species of parasitoid within 24 hours (Table 2). However, the species differed in their acceptance criteria. MO females oviposited significantly less frequently in unincubated cocoons than in 8D or 16D hosts ($X^2 = 7.9$, $P < 0.005$), but did not distinguish among treatments in the number of eggs laid per host (ANOV, $P > 0.50$). Conversely, PV females oviposited more frequently in unincubated hosts, but this distinction was not significant ($X^2 = 3.6$, d.f. $= 2$, $P > 0.10$). They did, however, lay significantly more eggs/host in 8D hosts than in the others.

Discussion

This study illustrates both the flexibility of host acceptance behavior in two parasitoid species and how those species may differ in the combination of cues used to accept a host individual. Initially, adult females of both species required that both cocoon and prepupae be authentic for a host to be accepted (Table 1). Unlike the prompt parasitization of authentic hosts of different developmental ages (Table 2), few artificial hosts were parasitized by any females of either species during the first 24 hours. Subsequently, PV females expanded their acceptance behavior, but only to include hosts in the naked prepupae category. The fact that authentic prepupae in gelatin capsules were ignored suggests that some characteristic of the cocoon other than size and shape is necessary for probing with the ovipositor to begin. Chemical and textural properties of the cocoon need to be examined.

In contrast, MO females were less selective in their behavior: after 24 hours, they began to accept hosts composed of a representative cocoon and prepupae so long as either of these was authentic. Thus, MO females replaced an obligatory initial requirement for cocoon and prepupal authenticity with a conditional requirement that only one be authentic. How "inauthentic" the artificial component of the cocoon-prepupal pair can be before becoming unstimulating or even repellent remains to be investigated as does the combination of cues that will support continued host investigation or oviposition. In any case, host acceptance behavior in MO appears to be more complicated than typical depictions of insect automatons reacting in simple concatenated sequences (Eibl-Eibesfeldt 1975).

Not only was the behavior of MO and PV females distinctive, but MO females treated empty cocoons differently from the behavior reported by Eves (1970). Largely because the females he observed invariably oviposited into empty cocoons, Eves (1970) concluded that the cocoon was the primary stimulus to oviposition and that the presence of a prepupae or larvae was of secondary importance. In contrast, none of the MO females in this study oviposited into empty cocoons and host acceptance seemed to depend on a complex interaction of individually flexible cues.

The most facile explanation for these differences is that Eves (1970) and I studied different species, but this seems improbable (E. E. Grissell, pers. comm.).

Both PV and MO also exhibited the ability to distinguish among authentic hosts of different developmental stages. Females of both species preferred immature stages of a particular (but different) age when given a choice. However, all stages from prepupae to late pupae were both acceptable and suitable. Unless appropriate control measures are taken (Richards 1984), unparasitized bees incubated for release into alfalfa fields are vulnerable to attack by female parasitoids which emerge well before maturing bees are ready to eclose.

Acknowledgements

I thank K. Ruggeri for conducting the experiments, M. E. Klomps and S. Jennings for help with data tabulation and analysis, and D. R. Frohlich and F. D. Parker for reviewing the manuscript.

This is a contribution from the Utah Agricultural Experiment Station, Utah State University, Logan, Utah 84322–4810, Journal Paper No. 3397, and USDA-Agricultural Research Service-Bee Biology and Systematics Laboratory, Utah State University, Logan, Utah 84322–5310.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 73–79

Biology of *Ammophila evansi* and *A. mediata* in Northern Michigan (Hymenoptera: Sphecidae)

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Abstract.—The sphecid wasps *Ammophila evansi* Menke and *A. mediata* Cresson were observed in the Huron Mountain region of Marquette County, Michigan. The eastern *A. evansi* is restricted to exposed rocky slopes, while the western *A. mediata* occupies level sand plains dominated by *Pinus banksiana*. Both species prey on arboreal caterpillars, utilizing one prey per one-celled nest. Both species are at the limits of their ranges in Michigan, but do not occupy the same habitats when they occur together.

INTRODUCTION

The genus *Ammophila* in North America has been relatively well studied ethologically (Evans 1959, 1965; Powell 1964; Parker et. al. 1980; Hager and Kurczewski 1985, 1986) and taxonomically (Menke 1965), but many gaps remain in our knowledge of the behavior of the majority of the species. For many taxa, all that is known is their recorded distribution from which some inferences can be made, such as the type of habitat in which they are likely to occur. Usually though, a mere label cannot impart the full spectrum of desirable data. A case in point is our study of *Ammophila evansi* Menke and *A. mediata* Cresson made at the Huron Mountain Club in northwestern Marquette County, Michigan.

A. mediata is a predominantly western montane and boreal Canadian species (Krombein 1979) reaching its easternmost U.S. distribution in northern Michigan (Fig. 1). *A. evansi*, however, is an eastern U.S. species reaching its westernmost distribution in the upper peninsula (UP) of Michigan (Fig. 1). Extensive collecting within the state has failed to yield any *A. evansi* specimens from the lower peninsula (LP). Were one to be guided by county records alone, it might seem that *A. evansi* and *A. mediata* are sympatric in the UP. However, upon closer inspection, we find that the two species are actually microallopatric in this region, differing greatly in their habitat preferences, which apparently do not overlap. These differences are detailed in the observations that follow.

Ammophila evansi

A. evansi was observed on exposed granitic outcrops on Breakfast Roll Mountain in full sunlight from 1400–1700 h on August 4, 1985, and briefly on June 27, 1986. Ambient temperature during the observation periods was 26°–28° C, and the surface

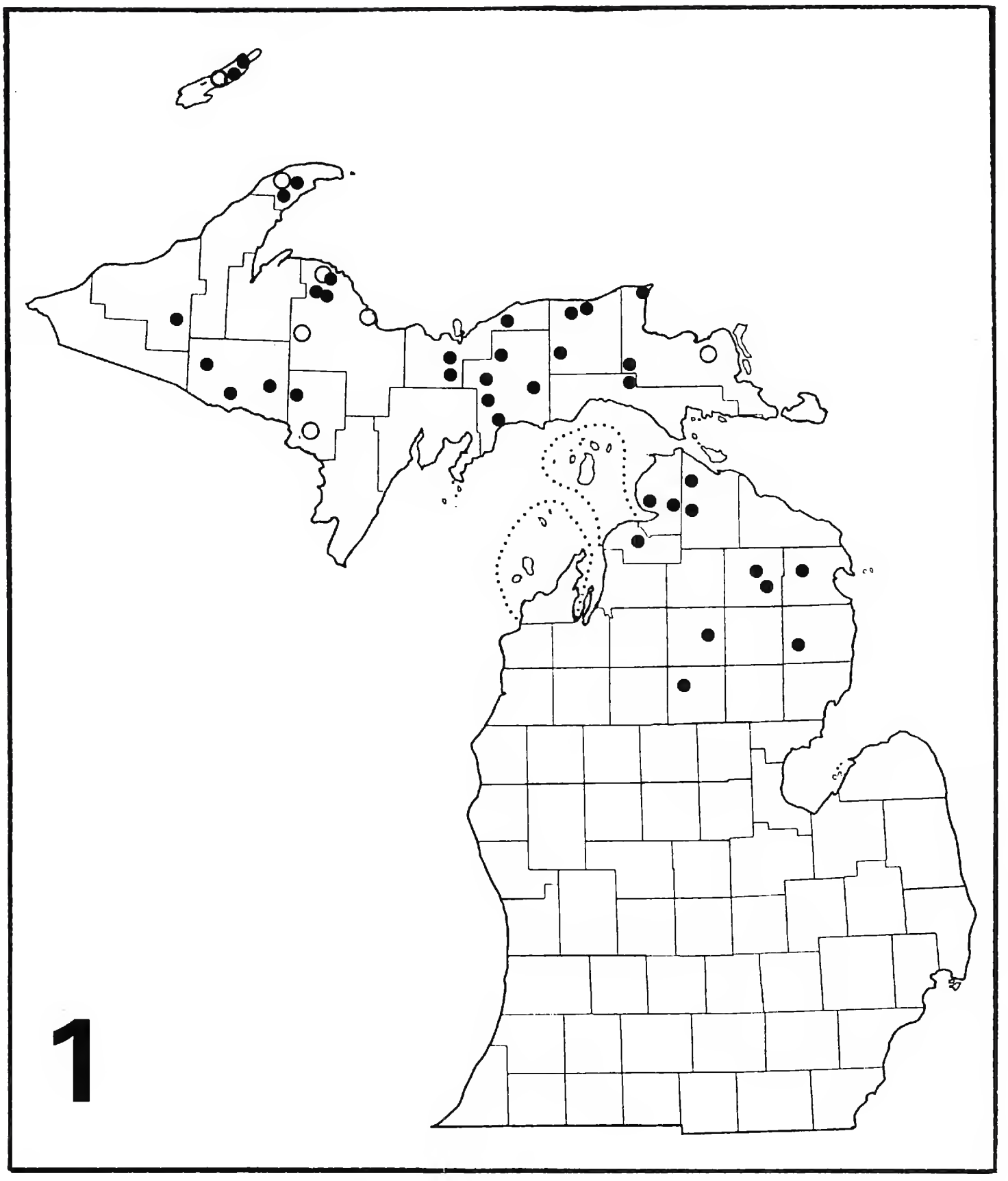

Figure 1. Map of Michigan, showing the distribution of *Ammophila evansi* and *A. mediata*. Open circles denote *evansi*; closed circles, *mediata*.

temperature of the rock was 30°–38° C. The rock outcrops ranged from 25 to 100 m above the flat areas of the Huron Mountain Club.

Males were seen flying 10–30 cm above the ground, and visiting flowers of *Solidago hispida*, which was flowering profusely on the rocky slopes in August, and *Rhus glabra* inflorescences in June. Even with a fairly stiff breeze, the males were quite active, flying from one flower clump to another, and searching for females.

A. evansi females were seen running over bare rock and sparsely vegetated, moss-covered rocks. Several females flew to low shrubs (*Rhus* sp.) and examined the branches before flying off, while others were seen obtaining nectar from *S. hispida* and *R. glabra*. The only female found nesting (85–2) had begun her nest closure at 1545 h. The nest was situated in a moss-covered depression surrounded by rock on a SE facing slope. The soil was very dry, sandy-organic, and quite dark. Making at least 14 trips to gather filler material from the immediate area, she filled the entrance, using some soil, but mostly pieces of dried moss, small twigs, and pieces of dead sumac leaves. Bits of organic debris used for fill were less than two times the diameter of her head. Most of the sand removed during the excavation of the burrow was scattered on the moss; thus she did not use much of it for fill. She did, however, fly up with one load of soil from what little tumulus was present, and dropped it on the moss away from the entrance. At 1607 h she flew off to feed on *Solidago* flowers, and returned three minutes later to pull a dry leaf over the burrow entrance, and then departed. She returned at 1615 h, searched briefly around the nest area, picked up small twigs of sumac, discarding them until she found one of the proper size, which she then dropped over the entrance. Appearing to be finished at 1620, she began to leave the area and was captured.

The nest of 85–2 was a typical "*Ammophila*-type"; a single cell at an oblique angle to the burrow. The dimensions were as follows: Entrance diameter = 1.0 cm, cell depth = 3.7 cm, with the cell 2.4 cm long × 1.3 cm wide. The prey, a single large noctuid of the genus *Zale*, was curled up in the cell with the wasp's egg on the right side of the third abdominal segment. Four miltogrammine fly larvae were on the wasp's egg, which measured 3.0 × 0.6 mm. The flies were not reared.

Ammophila mediata

A. mediata was commonly encountered at the Huron Mountain Club, especially in flat, sandy areas dominated by Jack pine (*Pinus banksiana*) or near the Lake Superior shore at Conway Bay. Nesting areas were situated where the soil was sand to sand-gravel, friable, and not compacted or stony.

Based on hand collecting and Malaise trap catches from 1983 to 1985, *A. mediata* was the most common species of *Ammophila* at the Huron Mountain Club, accounting for 42% of the total (266 specimens), followed by *A. urnaria* Dahlbom (29%), *A. azteca* Cameron (25%) and *A. evansi* (4%). Since most Malaise traps were placed in open sandy areas, the catches may be somewhat biased towards *A. mediata*. No *A. evansi* were caught in the Malaise traps from these areas.

Several female *A. mediata* were observed hunting for arboreal caterpillars among the branches of Jack pines bordering the nesting areas. One wasp spent 15 min searching along the small branches and twigs of a Jack pine, flying up and down from branch to branch, and then walking along the length of the branches, tapping the bark with her antennae. Although prey capture was not seen, two females provisioned their nests with *Zale* sp. larvae (The "pine false-looper", family Noctuidae) that are mottled gray and brown and resemble the color of Jack pine branches, where they presumably were captured.

On Aug. 4, a female *A. mediata* (85–4) was excavating a nest at 2023 h at the edge of a depression along a powerline right-of-way. She brought out a load of sand every 15–20 s, and dropped it on the surface while flying up and away from the entrance. At

2046 h she temporarily closed the nest and left the site. The ambient temperature was 24°C.

On Aug. 5, we returned to the site of 85–4's nest and at 1059 h spotted the wasp carrying a large caterpillar back to the nest. The prey was carried in the usual ammophiline fashion (mandibles and mid-legs used to carry the prey venter-up). She stopped for 10 s, 1.5 m from the nest, dropped the prey amidst some dead branches and picked it up again. She resumed her trek to the nest, pausing for 2 s when 20 cm from the entrance. She then dropped the prey at the entrance, removed the temporary closure, went inside, and pulled the prey inside headfirst. She exited the nest 43 s later and began closure at 1108 h, finishing three minutes later.

The wasp used some sand during closure but mostly bits of organic debris, choosing pieces that were about the size of her head to fill the burrow. The fill was tamped in with her head, and then she removed any remaining tumulus.

On Aug. 6, a female (85–9) was caught carrying a geometrid larva along the powerline right-of-way at 1920 h. She had carried her prey in a straight line through several small brush piles for a distance of 16 m before being netted.

Wasp 85–17 was nesting at the edge of a sparsely vegetated area surrounded by patches of open sand in an old aspen clear-cut on Aug. 7. The nest site was adjacent to a stand of Jack pines, and aspens were regenerating in clones not far from the open sand. The wasp was first observed at 1600 h carrying her prey 6 m from the nest. Travelling in a straight line, she dropped her prey at the entrance, removed the closure, went inside, and then pulled the prey into the nest. The prey, a notodontid of the genus *Gluphisia*, feeds on poplars and willows (G. Godfrey, in litt.), suggesting that the wasp may have caught the prey within a short distance from the nest.

In a Jack pine forest on Aug. 8, another female (85–22) was seen carrying a *Zale* sp. larva at 1200 h, just prior to placing it in the nest. The nest was situated in a sloping edge of a sand-gravel road in an open sandy clearing bordered by pines. Because of the gravelly soil, the entrance was irregularly shaped. At 1201 h the wasp dropped her prey near the entrance, removed the temporary closure, went inside, and came out headfirst to pull the caterpillar inside. She took 84 s to oviposit and return to the entrance to start closure.

At 1600 h the same day, another female (85–28) was found clasping a large noctuid on a wave-thrown tree trunk about 20 m from the shore of Lake Superior (Conway Bay). The ambient temperature was 18°C. The wasp did not attempt to move when approached, and stayed motionless when attempts were made to disturb her. After walking for only a few cm with prey, the wasp and prey were taken for identification.

Wasp 86–3 was found digging her nest in loose sand near bracken fern and blueberries along the power line right-of-way at 1400 h on June 22. She walked backwards with each load of soil, dropping it 10–20 cm from the entrance. A load would be removed every 10–12 s. At 1414 h she made a temporary closure, filling the entrance with a small pebble, pieces of moss, and other organic debris; briefly oriented, and walked off. The burrow was checked at 2000 h, and again the next day. No provisioning had occurred. We theorize the wasp may have been captured in a nearby Malaise trap. Another wasp of this species (86–5) was observed at 1900 h, as she was carrying her geometrid prey back to the nest. After following a meandering route for 35–40 m in 12 min, she dropped the prey alongside the nest entrance at the periphery of a blueberry bush near a sand road. She removed the temporary closure,

went inside and pulled the prey into the burrow. She emerged 60 sec later to close the nest.

Wasp 86–7 was observed on June 23, near the aspen clear cut area. The wasp was first seen with her prey in a grass clump at 1300 h, and was dragging the caterpillar towards the entrance of her nest, 4 m away. A miltogrammine fly was stationed nearby, but apparently did not oviposit on the prey. The female emerged 40 sec after provisioning and ovipositing to complete final closure of the nest. Organic debris was mostly used to fill the burrow.

We observed one case of suspected nest usurpation. On June 23, at the aspen clear cut, a wasp (86–8) opened up a fully provisioned nest and removed the prey and late instar wasp larva, which she proceeded to discard to one side, as if removing debris from a closure. It is unknown if she was the originator of the nest. Unfortunately, we disturbed her and she did not return to the site.

Many male *A. mediata* were found flying close to the ground, and inspecting low shrubs in open sunlit areas of Jack pine woods near the aspen clear cut. One male approached a female from the rear, clasped her with his legs and mandibles (behind her head), and repeatedly stroked her abdomen from side to side with his. They remained coupled while still on the ground.

Table 1 lists all of the nest dimensions, egg placement, and species of prey from the *A. mediata* nests. No miltogrammine maggots were found on the prey. Three eggs (P85–4, 17, 22) each measured 3.0 × 0.6 mm.

Discussion

Although *A. evansi* and *mediata* appear sympatric at the Huron Mountain Club and in other areas of the UP, they are still microallopatric, due to their different habitat requirements. *A. evansi*, most often encountered in the eastern U.S., has been collected on rocky limestone outcrops (MFO pers. obs.), boulder-strewn ridges and river edges (Menke, in litt. 1985), and dry, rocky hillsides (M. Arduser, in litt. 1986). Thus, it is no surprise that its distribution in the UP corresponds to exposed rocky areas (Fig. 1). The paucity of these sites in the LP explains its absence there. Conversely, *A. mediata* is a western-montane and trans-boreal species that seems to be limited to flat sandy areas where conifers predominate. In Michigan, such areas are widespread in the UP and northern LP.

Although the two species are placed in the *azteca* species group (Menke 1965), they are quite similar in behavior to *A. urnaria* Dahlbom, (in the *urnaria* species group) in that they provision each nest with a single large caterpillar, rather than using multiple small caterpillars in the manner of *A. azteca* Cameron. Prey are transported on the ground due to their large size, rather than aerially, as with *azteca*. Due to the limited number of observations on *evansi*, it is premature to compare the behaviors of *evansi* and *mediata*.

Thus far, Michigan and Quebec (Finnamore 1982) are the only areas where the ranges of *mediata* and *evansi* are known to overlap, and the Huron Mountain area is the only locale where the species have been studied biologically. Observations on the behavior of each species at the other ends of their ranges could be compared to data from Michigan, to see if any displacement of behavior has occurred where they contact each other. Morphologically, *mediata* and *evansi* appear to be sibling species

Table 1. Summary of *Ammophila mediata* nest data.

WASP	Entrance Diam. (mm)	Burrow Length (cm)	Cell Depth (cm)	Cell Size L × W (cm)	Egg[1] Position	Prey
85–4	6.0	2.6	2.0	1.6 × 1.0	R-4	*Melanolophia* sp. (Geometridae)
85–9	—	—	—	— —	—	*Ectropis crepuscularia* (D.&S.) (Geometridae)
85–17	8.0	2.5	1.8	1.2 × 1.0	L-4	*Gluphisia* sp. (Notodontidae)
85–22	12.0	4.2	3.5	2.6 × 1.3	L-3	*Zale* sp. (Noctuidae)
85–28	—	—	—	— —	—	*Zale* sp.
86–5	6.0	3.2	3.7	1.8 × 0.6	L-4	Geometridae
86–7	6.0	2.4	2.7	1.5 × 0.7	L-4	Geometridae

[1]Left (L) or right (R) side and abdominal segment number.

(see Menke 1965), and our behavioral observations point toward this direction as well. Future studies should consider this aspect when analyzing behavioral data.

Acknowledgments

We thank the Huron Mountain Wildlife Foundation for their generous support, and for providing the research facilities at the Huron Mountain Club. D. C. L. Gosling provided many of the specimens from his Malaise traps, which have been extremely valuable for this and other studies.

We thank the following specialists for providing identifications of the prey: G. L. Godfrey, Illinois Natural History Survey; R. L. Heitzman and D. Weisman of the Smithsonian Institution. Special thanks go to F. E. Kurczewski, SUNY College of Environmental Science and Forestry, for critically reviewing the manuscript.

The wasps, prey, and associated field notes have been deposited in the University of Michigan Museum of Zoology.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 81–82

The Use of the Thai Giant Waterbug, *Lethocerus indicus* (Hemiptera: Belostomatidae), As Human Food in California

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Lethocerus indicus (Le Peletier & Serville) is a large (60–80 mm) belostomatid that is native to Southeast Asia (Menke 1960). This bug is eaten by people in Burma, China, India, Indonesia, Laos, Thailand and Vietnam (Mitsuhashi 1984). In 1969, I observed Thais gather large quantities of a belostomatid (probably *L. indicus*) during their dispersal flights at Korat on Thailand's paddy rice growing plain. The preserved whole bugs were subsequently common in Korat's food markets.

In 1986 I was surprised to find *L. indicus* (Figure 1,A) for sale at a Thai food shop (Oy's Market) in Berkeley, California. The bugs, called "mangda" in Thai, had been preserved by boiling in salt water and were priced at $1.50 each. Oy Sanok, the market's owner, says (pers. comm.) that the bugs, which she imports from Thailand, have been met with enthusiasm from her Thai and Laotian customers, who use *L. indicus* to make bug-paste condiments. The Thai bug-paste, called "nam prik mangda," is usually prepared by combining and mashing a whole bug with salt, sugar, garlic, shallots, fish sauce, lime juice and hot Thai capsicum peppers in a mortar and pestle. Some cooks remove the bug's eyes, wings and other sclerotized parts before using. "Nam prik mangda" is commonly used as a vegetable dip and as a topping for cooked rice. The bug has been reported (Bodenheimer 1951) to have a strong gorganzola cheese taste, a flavor not very discernable in the red pepper dominated "nam prik mangda."

A commercial preparation of the bug-paste (Figure 1,B) was found in a San Francisco Thai market. In addition, clear alcohol extracts of the bug (Figure 1,C) called "Mangdana essence" were being sold in Southeast Asian markets in Berkeley, Oakland and San Francisco. A few drops of "mangdana essence" is used as a substitute for a whole bug in the preparation of "nam prik mangda." The commercial bug-paste and the bug extracts, which are made in Thailand, are considered to be inferior in taste to home-made "nam prik mangda" which uses whole bugs. These products cost between 79¢ and $1.20.

It is interesting to note that no mention of the bug was made on the English language ingredient labels of these products. Are the manufacturers of these products concerned that openly marketed insect foods might prove culturally offensive and harmful to business?

I have been unable to find *L. indicus* being sold in California's Chinese markets, as observed by Usinger (1956) in San Francisco, but suspect that the bug is still used by some California Chinese.

The presence of *L. indicus* and its products in California markets is indicative of the great diversity of Asian food entering America.

Figure 1, A. The Thai giant water bug, *Lethocerus indicus*, B., a commercial preparation of a food paste made from *L. indicus*, C., a commercial alcohol extract of *L. indicus* for use in the preparation of the food paste.

Acknowledgements

I thank: A. Menke, USDA-Smithsonian, for identifying *L. indicus*; Oy Sanok, Berkeley, CA for the information on the use of *L. indicus* and reviewing the manuscript; Neitnapa Puckbang, Berkeley, CA for preparing "nam prik mangda" for me; R. Wong and G. Johnson, USDA, Albany, California for photography; and D. Light and B. Chan, USDA, Albany for reviewing the manuscript.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 83–85

Efficacy Diminution of the Rush Skeletonweed Gall Midge, *Cystiphora schmidti* (Diptera: Cecidomyiidae), by an Indigenous Parasitoid

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Rush skeletonweed, *Chondrilla juncea* L. (Asteraceae), a herbaceous perennial plant of Eurasian origin, was inadvertently introduced into eastern Washington during the late 1930s (Piper, 1985). The weed has since spread to infest over 810,000 ha of rangeland, semiarid pasture land, transportation rights-of-way, residential properties, and cropland in 12 counties. Heaviest infestations are confined to rangeland where *C. juncea* displaces livestock and wildlife forage plants but its encroachment into dryland wheat production areas has increased considerably during the last decade. The plant's extensive root system enables it to effectively compete with grain crops for moisture and nutrients. The fibrous, latex-exuding stems of mature plants can obstruct harvest machinery, making harvesting costly and difficult, if not impossible.

Herbicidal control of rush skeletonweed in non-cropland is often uneconomical because of low productivity of the land infested and the high cost of effective chemicals. Consequently, attention has been focused on the importation and release of exotic, host-specific biological control organisms. Natural enemies successfully utilized thus far include the rust fungus, *Puccinia chondrillina* Bubak and Sydow (Uredinales: Pucciniaceae), a gall mite, *Eriophyes chondrillae* (G. Canestrini) (Acari: Eriophyidae), and a gall midge, *Cystiphora schmidti* Rübsaamen (Diptera: Cecidomyiidae) (Lee, 1986).

The initial release of *C. schmidti* in 1976 was made with adults supplied by USDA-ARS Biological Control of Weeds Laboratory, Albany, CA, personnel (Piper, 1985). Detailed accounts of the biology and ecology of the gall midge in Europe and North America have been provided by Caresche and Wapshere (1975), Littlefield (1980), and Mendes (1981). The insect is active from April until late October and normally completes 4 to 5 generations during this time, the number being dependent upon environmental conditions. Females insert eggs beneath the epidermis of rosette and cauline leaves and stems. Reddish-purple, blister-like galls ca. 2.0–3.0 mm in length soon develop around the larvae feeding upon underlying leaf mesophyll or stem parenchyma. Pupation normally occurs within the galls. Pupae rupture the gall tissue with their cephalic horns to facilitate adult emergence. The life cycle, from egg to adult, may be completed in 24 to 44 days. Mature larvae, prepupae or pupae overwinter within stem or rosette leaf galls or as pupae in the soil in a state of temperature-induced quiescence.

The midge damages *C. juncea* in both the rosette and flowering stem stages. The production of anthocyanescent, hyperplasic gall tissue coupled with the feeding damage inflicted by the larvae decreases the quantity of photosynthate available for

plant growth and maintenance (Caresche and Wapshere, 1975). Leaf and stem tissues are injured or destroyed, resulting in premature yellowing, desiccation, and death. Bolted plants can be so severely infested that almost no part remains ungalled. Such plants are stunted and produce up to 63% fewer flower buds than do unattacked plants of comparable size and age. Seeds that are produced exhibit decreased weight and viability (Mendes, 1981).

Mortality of both spring and fall produced rosettes, especially seedling rosettes, has been observed (Littlefield, 1980). *C. schmidti* is most damaging to fall rosettes, typically destroying in excess of 50% of the leaves produced and thus impair the weed's overwintering and competitive abilities. Variables affecting damage expression include rosette leaf size, plant vigor, and midge population density.

Exotic natural enemies introduced for biological weed control are frequently adversely impacted by indigenous predators, parasitoids, or pathogens (Goeden and Louda, 1976). In 1979, a parasitoid identified as *Mesopolobus* sp. (Hymenoptera: Pteromalidae), was first reared from midge galls collected at Nine Mile Falls, WA. Since then, the hymenopteran has been recovered from most sites where *Cystiphora* now occurs.

The life history and ethology of the wasp have been described by Wehling (1984). *Mesopolobus* sp. is a primary, solitary ectoparasitoid of *C. schmidti* third-stage larvae, prepupae, and pupae. The pteromalid completes 4 or sometimes 5 generations a year in eastern Washington. First generation adults emerge in mid-July, second generation adults appear during the first week of August, and each successive generation emerges ca. every 20 days thereafter until mid- to late October. Mature larvae, prepupae, and pupae overwinter inside stem galls.

The entomofaunas of 37 plant species found growing in association with rush skeletonweed throughout eastern Washington and suspected of harboring the indigenous/alternate host of the parasitoid were examined. No *Mesopolobus* sp. adults were recovered however.

The gall midge typically completes two generations before parasitoid activity becomes apparent in the field. Cecidomyiid galls produced on rosette leaves are not subject to attack by *Mesopolobus* sp. in nature even though the parasitoid will develop in such galls under greenhouse conditions. Studies conducted between 1981 and 1986 have shown that the parasitization rate of midge galls on stems is less than 10% in July, rises to between 45 and 65% by late August, approaches 85% during September, and may exceed 95% by mid-October prior to *C. juncea* stem senescence. This level of parasitism is similar to that recorded for *C. schmidti* in its area of indigenity where the parasitic eulophids, *Achrysocharella formosa* (Westwood) and *Tetrastichus* sp., together destroy in excess of 95% of the late season midge population (Caresche and Wapshere, 1975). In Australia, where the midge was also introduced for *C. juncea* suppression, parasitization by a native *Tetrastichus* sp. has reached 100% in some areas (J. Cullen, pers. comm.). It is most uncommon for an introduced weed phytophage to be parasitized by native Hymenoptera to the extent that *Cystiphora* is (Goeden and Louda, 1976).

A solitary, larval-pupal endoparasitoid also has been reared from midge-infested rush skeletonweed in California (L. Andres, pers. comm.) and Idaho (Littlefield, 1980) where it has attained densities like those experienced in Washington. It is not known if the wasp is *Mesopolobus* sp. or another species. In those areas of the western United States where biological control of *C. juncea* is being attempted, the

high incidence of parasitism, intensified by attrition of midge immatures in stem galls resulting from summer and early fall grasshopper predation (Littlefield and Barr, 1981) and mortality of overwintering pupae in the soil attributable to excessive moisture influx during late winter and early spring, has appreciably reduced the midge force available to infest the small, highly vulnerable fall and/or spring rosettes. In spite of the occurrence of *Mesopolobus* sp., *C. schmidti* is still able to reach population levels injurious to the weed and is regarded as being an important biological control agent of rush skeletonweed.

Acknowledgments

Appreciation is extended to Drs. Z. Bouček, Commonwealth Institute of Entomology, British Museum (Natural History), London, and C. M. Yoshimoto, Biosystematics Research Institute, Canada Agriculture, Ottawa, for providing the parasitoid identification. Scientific paper no. 7756. Work conducted under Project 0582, Washington State University, College of Agriculture and Home Economics Research Center, Pullman.

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 87–91

Lectotype Designations for African Bees of the Genus *Ceratina* Described by T. D. A. Cockerell (Hymenoptera: Apoidea)

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T. D. A. Cockerell proposed 106 new species group names for bees of the genus *Ceratina* in Africa and the Seychelles Islands. Except for 1 name, specimens from his type series exist in the British Museum (Natural History) (BMNH), American Museum of Natural History (AMNH), or Musee Royal de l'Afrique Centrale (MRAC). Usually one specimen from each series bears his hand written label with the species group name, "Ckll" (usually underlined), and "TYPE." Such specimens have been accorded Holotype status by the museums in which they are deposited. When both sexes were represented, he often stated the sex of the type. His descriptions include the location(s), date(s), and collector(s) for the specimen(s) he examined and sometimes one location out of several is stated to be the type locality. Unless more than one specimen is stated, the reader would assume that only one specimen was represented in the collection. Comparison of his text with specimens in museums supports this assumption. Despite this information about his intentions, he definitely identified the Holotype specimen with a clear statement in only 3 of his descriptions.

We were not able to locate the male specimen on which *Ceratina roseoviridis* (Cockerell, 1937a:31) is based. A female from Kampala is mentioned by Cockerell and is in BMNH, but the description is clearly based on the male.

Following the provisions of Article 73(a)(ii) of the International Code of Zoological Nomenclature (1985), we have inferred that the following species group names were based on a single specimen or that Cockerell's intended Holotype can be identified by the description. Each putative Holotype specimen matches the description and bears the appropriate collection and identification labels. We made these decisions under the following circumstances:

1) The Holotype is explicitly identified *or* only one sex is described, one collection is listed, and no statement is made that more than one specimen was examined.

The following are 36 names proposed in 1937a and the Holotypes are in BMNH (type numbers in parenthesis): *alberti* (17B–241), *albinasis* (17B–239), *braunsiana delta* (17B–248), *breviplicata* (17B–293), *citrinifrons* (17B–272), *concinnula* (17B–294), *cupreotincta* (17B–266), *decipiens* (17B–276), *electron* (17B–251), *elisabethae* (17B–283), *levisulcata* (17B–292), *leucostoma* (17B–290), *leucostoma rufigastra* (17B–291), *liberica* (17B–286), *lucifera sidifera* (17B–269), *mediolucens* (17B–278), *moerenhouti somereni* (17B–257), *natalensis* (17B–277), *nasalis arida* (17B–1254), *nilotica miranda* (17B–302), *ogilviei* (17B–264), *ordinaria* (17B–263), *pacis* (17B–295), *pallidipes* (17B–267), *pembana* (17B–306), *perpolita* (17B-304),

perpolita rowlandi (17B–305), *pondoensis* (17B–307), *punctifera* (17B–289), *rugosifrons* (17A–2812), *speculigera* (17B–273), *speculina* (17B–318), *subulatella* (17B–315), *tenkeana* (17B–265), *turneri* (17B–1193), *xanthorhina* (17B–245).

The following are 23 other names proposed in various publications and the types are in various museums: *albopicta* (1937a:3, MRAC), *atopura* (1937a:5, MRAC), *chrysorhina* (1939:42, BMNH 17B–261), *dallatorreana albosticta* (1931:351, BMNH 17B–198), *diloloensis* (1932a:276, BMNH 17B–250), *durbanensis* (1934:1, AMNH), *fimbriatula* (1920:248, BMNH 17B–297), *geigeriae* (1908:35, BMNH 17B–252), *holomelas* (1937b:548, BMNH 17B–298), *langi* (1934:2, AMNH), *mimula* (1920:247, BMNH 17B–284), *nitidella* (1937c:10, AMNH), *nodosiventris* (1912:35, BMNH 17B–227), *politifrons* (1937a:29, MRAC), *ruficauda* (1932b:12, AMNH), *rugosissima* (1932a:275, BMNH 17B–280), *samburuensis* (1910:219, BMNH 17B–317), *speculifrons* (1920:247, BMNH 17B–221), *spilota* (1932a:274, BMNH 17B–311), *tabescens* (1912:36, BMNH 17B–228), *tridontura* (1939:43, BMNH 17B–296), *viridifrons* (1934:3, BMNH 17B–321), *viridis kivuensis* (1932a:273, BMNH 17B–320).

2) One sex is described, one locality is stated or indicated to be the type locality (if other localities are also listed), and no statement is made that more than one specimen was examined from the type locality.

The following are 9 names proposed in 1937a and the Holotypes are in BMNH: *braunsiana gamma* (17B–249), *cabalica* (17B–254), *excavata* (17B–270), *littoralis* (17B–274), *lobulifera* (17B–287), *lobulifera subvirens* (male, 17B–288), *perobscura* (17B–285), *ruwenzorica* (17B–259), *viridis goetzeni* (17B–319).

3) Both sexes are described, one sex is stated to be the type, one locality is stated to be the type locality or only one locality is listed, and no statement is made that more than one specimen of the type's sex was examined from the type locality. The following are 8 names proposed in 1937a and the Holotypes are in BMNH: *albonota* (17B–242), *lucifera* (17B–1255), *microsoma* (17B–275), *nativitatis* (17B–279), *nilotica* (17B–300), *politula* (17A–2813), *politula griseipennis* (17B–262), *ruficornis* (17B–309).

The following are 3 other names proposed: *liliputana* (1932a:278, BMNH 17B–255), *penicillifera* (1932a:274, BMNH 17B–303), *subulata* (1932a:277, BMNH 17B–314).

The descriptions for the remaining 25 names are each based on several specimens with no definite information to identify the Holotype. In these instances, Lectotypes must be designated from the extant type series as was previously done for *C. aloes* Cockerell (1932a:272, BMNH) and some species group names proposed by other authors for *Ceratina* (Daly, 1973). To preserve Cockerell's original concept for each species group name, we have chosen the specimens labelled as types by him whenever possible. Winglength was measured from the base of the costal vein (not including the costal sclerite and tegula) to the maximum curvature of the wing tip. Commas have been added to the collection data for clarity.

Unless otherwise indicated the labels are rectangular and on white paper. Lectotypes in BMNH each have a round top label with purple margin and "Lectotype" printed. Beneath is a second label with "B. M. TYPE, HYM." printed and with the type number handwritten. The type number is listed below in parenthesis. Some specimens also bear a label printed "T. D. A. Cockerell, Exp. to Africa, 1931. Pres. by Imp. Inst. Ent. B. M. 1932–291" which refers to the British

Museum accessions register. These are indicated below by the abbreviation "TDAC."

Lectotypes are designated for the following:

1. *aliceae* 1937a:4. Lectotype female here designated; wing length, 3.3 mm. Labels: 1) written "Ceratina aliceae Ckll. TYPE"; 2) printed "S. Africa, Durban, The Bluff, x–1931," and written "Miss A. Mackie"; 3) TDAC. (BMNH 17B–243).
2. *alpha* 1937a:6. Lectotype male here designated; wing length, 5.2 mm. Labels: 1) written "Ceratina braunsiana v. alpha Ckll TYPE"; 2) printed "S. Africa: Yokeskei R., Johannesburg, 31.iii.1932, J. Ogilvie"; 3) TDAC. (BMNH 17B–246).
3. *beta* 1937a:6. Lectotype male here designated; wing length, 4.6 mm. Labels: 1) written "Ceratina braunsiana v. beta Ckll TYPE"; 2) printed "Natal: National Park, 3–15.iii.1932, J. Ogilvie"; 3) TDAC. (BMNH 17B–247).
4. *bilobata* 1937a:5. Lectotype male here designated; wing length, 4.8 mm. Labels: 1) printed "S. W. Africa, Aus, Jan 1930"; 2) printed "R. E. Turner, Brit. Mus. 1930–117"; 3) written "Ceratina bilobata Ckll TYPE." (BMNH 17B–1194).
5. *bukavana* 1932a:276. Lectotype male here designated; wing length, 5.0 mm. Labels: 1) printed and written "S. of Bukavu, 28. viii. 1931, Miss A. Mackie"; 2) printed "Belgian Congo"; 3) written "Ceratina bukavana Ckll male (symbol)"; 4) printed "Pres. by Imp. Inst. Ent. B. M. 1935–492." (BMNH 17B–282).
   No specimen from the type series with Cockerell's type label was found.
6. *carinifera* 1937a:8. Lectotype female here designated; wing length, 5.2 mm. Labels: 1) written "Ceratina carinifera Ckll TYPE"; 2) written "Tanganyika T., Dar-es-Salaam, 9.vi.1932, J. Ogilvie"; 3) TDAC. (BMNH 17B–258).
7. *cephalica* 1931:350. Lectotype female here designated; wing length, ca. 6.6 mm. Labels: 1) written "Ifran, Morocco, 27 Aug, A. Mackie"; 2) printed "Brit. Mus. 1933–567"; 3) written "Ceratina callosa cephalica Ckll TYPE." (BMNH 17B–199).
8. *citriphila* 1935:1. Lectotype female here designated; wing length, 4.9 mm. Labels (1–4 in P. Timberlake's handwriting): 1) "at orange bloom"; 2) "Martini's Concession"; 3) "Eritraea," "Mar 23, 30"; 4) "H. Compere Coll."; 5) Cockerell's handwriting "Ceratina citriphila Ckll TYPE"; 6) different handwriting "ac. 33583." (AMNH).
9. *crassula* 1937a:9. Lectotype female here designated; wing length, 4.5 mm. Labels: 1) printed "Kimilolo Riv., Elisabethville, Katanga B Cgo, 11.45S 27.40E, 6.xi.1920"; 2) printed "Mith. Bequaert Coll."; 3) written "Ceratina crassula Ckll Cotype." (BMNH 17B–271).
   The specimen bearing Cockerell's type label had lost all other original labels. We therefore chose another female from the type series.
10. *dolichorhina* 1937b:545. Lectotype female here designated; wing length, 5.2 mm. Labels: 1) written "Ceratina dolichorhina Ckll TYPE"; 2) printed "S. W. Africa: Usakos, 16.i.1934, J. Ogilvie, B. M. 1934–142." (BMNH 17B–260).
11. *duponti* 1912:35. Lectotype female here designated; wing length, 3.0 mm. Labels: 1) written "Ceratina fryeri duponti Ckll TYPE"; 2) printed "Aldabra I., Seychelle Is., P. R. DuPont, 1907-72." (BMNH 17B–225).
12. *fryeri* 1912:34. Lectotype female here designated; wing length, 3.6 mm. Labels: 1) printed on mounting block "Aldabra, '08–9, J. C. F. Fryer"; 2) written

"Ceratina fryeri Ckll TYPE"; 3) printed "Seychelles Expd., Pres. by Committee of the Percy Sladen Trust Fund, 1911–43." (BMNH 17B–226).

13. *insuta* 1937a:13. Lectotype female here designated; wing length, 4.6 mm. Labels: 1) written "Ceratina insuta female (symbol) Ckll TYPE"; 2) printed "DuRiver, Camp No 3, Liberia"; 3) TDAC. (BMNH 17B–253).
14. *macrospila* 1937a:18. Lectotype male here designated; wing length, ca. 4.4 mm. Labels: 1) written "Ceratina macrospila Ckll TYPE"; 2) printed "Okahandja, 17–23.ii.1928"; 3) printed "S. W. Africa, R. E. Turner, Brit. Mus. 1928–144." (BMNH 17B–256).
    Cockerell gives the collection date of his type series as Jan. 1–12, 1928 and lists two males and one female. Turner collected other bees such as *C. rhinura* at Okahandja on Jan. 1–12, 1928, but no *C. macrospila* have been found among them. In BMNH are 4 specimens of *C. macrospila* collected by Turner on Feb. 17–23, 1928. One male is labeled TYPE by Cockerell, a second male is labeled COTYPE, and one of two females is labeled COTYPE with the second female not so labeled. Cockerell described a male with an abdomen. The abdomens of both males are now missing. We assume an error was made in the published date and that the Lectotype was later damaged.

15. *maculipes* 1937a:25. Lectotype male here designated; wing length, 6.1 mm. Labels: 1) written "Ceratina nasalis maculipes Ckll TYPE"; 2) printed "Belgian Congo, Katanga, tenke, 30.vii.–9.viii.1931, J. Ogilvie"; 3) TDAC. (BMNH 17B–301).
    This name was published as *C. nilotica maculipes*. Note error in the species name on Cockerell's handwritten label.
16. *matopina* 1937a:3. Lectotype female here designated; wing length 4.4 mm. Labels: 1) written "Ceratina albonota matopina Ckll. TYPE"; 2) TDAC; 3) printed, "S. Rhodesia, Matopo Hills, 17–30.iv.1932, Miss A. Mackie." (BMNH 17B–244).
17. *musarum* 1934:3. Lectotype female here designated; wing length, 4.6 mm. Labels: 1) printed "Banana, Congo, 6°S., 12°20'E., ix 1915"; 2) printed "Lang & Chapin, Collectors"; 3) written "Ceratina musarum Ckll TYPE." (AMNH).
18. *mutescens* 1937a:22. Lectotype female here designated; wing length, 4.9 mm. Labels: 1) written "Ceratina mutescens Ckll TYPE (female holotype)"; 2) printed "Pres. by Imp. Inst. Ent. B. M. 1936–30"; 3) written "Mombasa, Apr. 23, 1927." (BMNH 17B–322).
    Cockerell's statement "both sexes, including a mating pair" is indefinite as to the number of specimens in the type series. The Lectotype is mounted on one pin with a male.

19. *pileifera* 1937a:28. Lectotype male here designated; wing length, 5.0 mm. Labels: 1) written "Ceratina pileifera male (symbol) Ckll TYPE"; 2) TDAC; 3) written "Portug. E. Africa, Beira, 4.vi.1932, Miss A. Mackie." (BMNH 17B–313).
20. *rhinura* 1937a:30. Lectotype male here designated; wing length, 3.6 mm. Labels: 1) written "Ceratina rhinura Ckll TYPE"; 2) printed "Okahandja, 1–12.i.1928"; 3) printed "S. W. Africa, R. E. Turner, Brit, Mus. 1928–61." (BMNH 17B–308).

21. *rhodura* 1937b:544. Lectotype female here designated; wing length, 3.4 mm. Labels: 1) written "Ceratina rhodura Ckll TYPE"; 2) printed "S. W. Africa, Cape Town, Beaufort West, 30.vi.1934, J. Ogilvie"; 3) printed "Brit. Mus. 1934–78." (BMNH 17B–268).
22. *scintilla* 1931:351. Lectotype female here designated; wing length, 2.1 mm. Labels: 1) written "Ceratina scintilla Ckll TYPE"; 2) written "Asni, Morocco, Aug 11 (Cockerell)." (BMNH 17B–200).
23. *subscintilla* 1937a:34. Lectotype female here designated; wing length, 2.4 mm. Labels: 1) written "Ceratina subscintilla Ckll TYPE"; 2) printed "S. Africa, R. E. Turner, Brit. Mus., 1925–44."; 3) printed "Cape Province, Ceres, Dec. 1924." (BMNH 17B–312).
24. *umtalica* 1937a:36. Lectotype male here designated; wing length, 4.6 mm. Labels: 1) written "Ceratina umtalica Ckll TYPE"; 2) printed "S. Rhodesia, Xmas Pass, Umtali, 20–21.v.1932, L. Ogilvie"; 3) TDAC. (BMNH 17B–281).
25. *viridior* 1937a:24. Lectotype male here designated; wing length 6.2 mm. Labels: 1) written "Ceratina nasalis viridior Ckll TYPE male (symbol)"; 2) printed "Pres by Imp. Inst. Ent. B. M. 1935–492"; 3) printed "Cape Province, Ceres, Mitchell's Pass, 9–17.ii.1932"; 4) written "J. Ogilvie." (BMNH 17B–299).

Acknowledgements

We are indebted to M. Day for his advice and to the following curators for their cooperation in pursuing this task: J. G. Rozen, Jr., American Museum of Natural History, New York; and J. Decelle, Musee Royal de l'Afrique Centrale, Tervuren.

This research was supported in part by research grants to HVD from the National Science Foundation (GB–7933, GB–34089).

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PAN-PACIFIC ENTOMOLOGIST
64(1), 1988, pp. 93–97

Observations on the Biology of a New Species of *Dilyta* (Hymenoptera: Charipidae) from Washington State[1,2]

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Introduction

The members of the superfamily Cynipoidea are thought to be predominantly phytophagous, but several families, including the Charipidae, are parasitoids. Most species of the family Charipidae belong in the subfamily Alloxystinae, and all are hyperparasites on aphids. The few species of the subfamily Charipinae have been reared from Psyllidae.

The genus *Dilyta* belongs in the subfamily Charipinae, a small assemblage of species divided among 2 genera (Fergusson 1986). *Dilyta* is represented in Europe by a single species, *D. subclavata* Foerster, reared from *Psylla pyri* (L.). *Dilyta* is recorded from North America in the Hymenoptera Catalog (Krombein et al. 1979), but A. S. Menke[3] (in litt) has examined the types of *necans* Keiffer, the only species listed, and has concluded that "Dilyta" *necans* belongs in the Alloxystinae.

Ferris and Hyatt (1923) and Jensen (1957) reported on "Alloxysta" from psyllids in California, Eritrea (Ethiopia), and Italy. These were almost certainly misidentifications of a *Dilyta* species (Menke, in litt). We have reared a genuine species of *Dilyta* (det A. S. Menke) from a psyllid, however, thus confirming the presence of the genus in the New World. This insect is a new species, and it will be described by Evenhuis and Menke (in prep).

Methods and Materials

Dilyta adults were reared from nymphs of *Psylla alba* Crawford (det D. R. Miller). Fig. 1 shows a female *Dilyta* sp. reared from *P. alba* in central Washington. A character common to the genera *Alloxysta* and *Dilyta* is the dorsal, triangular depressed area of the mesopleuron. The abdomen of the *Alloxysta* has 2 or more visible terga; the visible abdomen of *Dilyta* consists of 1 large tergum. Other characteristics of the genus *Dilyta* are: small size (<2 mm) and abdominal base (tergum 1) with a ring of dense setae.

Psyllid nymphs were collected from narrow leaf willow, *Salix exigua* L., 13 km north of Wenatchee, WA (elevation 180 m) during 1985 and 1986 (Table 1). This site is in a 15 m ravine along the Nahahum Canyon road adjacent to highway 97. Dominant vegetation included *S. exigua, Rosa* spp., and *Cornus stolonifera*

[1]Received 1986

[2]Scientific paper number 7757, College of Agriculture and Home Economics Research Center, Washington State University, Pullman, WA 99164. Research supported by the Washington State Tree Fruit Research Commission and conducted under project 5090.

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Table 1. Collection and emergence dates for *Dilyta* n. sp. reared from *Psylla alba* in 1985 and 1986 in central Washington.

Collection Date	Emergence Date	Number	Sex[1]
19 AUG 85	NR[2]	3	F
31 MAY 86	18 JUN 86	2,1	M,F
31 MAY 86	21 JUN 86	2	F
4 JUL 86	27 JUL 86	1	F
4 JUL 86	28 JUL 86	1	M
9 JUL 86	NR	1	M
9 JUL 86	27 JUL 86	1	M
9 JUL 86	31 JUL 86	1	F
8 AUG 86	12 AUG 86	1	M
8 AUG 86	NR	3,8,1	M,F,U
8 AUG 86	15 AUG 86	1	F
8 AUG 86	21 AUG 86	1	U
8 AUG 86	22 AUG 86	3	F
8 AUG 86	25 AUG 86	2	U
8 AUG 86	27 AUG 86	2	U
2 SEP 86	8 SEP 86	1	F

[1] F = female, M = male, U = undetermined.
[2] NR = not recorded.

Michaux. Collections of *S. exigua* with associated psyllid nymphs were made along the east-facing slope and bottom of the ravine.

S. exigua branches containing *P. alba* nymphs were clipped and placed in plastic bags. In the laboratory collected plant material was placed inside 250 ml glass beakers containing ca 25 ml water. Beakers were placed in cylindrical cardboard ice cream containers (3.8 liter). A plastic vial (2.5 cm diam) extended through the lid of the cardboard container into a 100 ml clear plastic specimen cup containing cotton moistened with sugar water. Emerging *Dilyta* entering the specimen cup were collected daily with an aspirator. This technique kept plant material fresh for 7–10 days. Laboratory observations of *Dilyta* adults were made of the insects inside 35 ml glass shell vials with cork stoppers held at room temperature (25°C) and 16:8 photoperiod.

Dilyta specimens were also collected in 2 unsprayed pear orchards by G. Paulson[4] in May and July, 1986. Pear trees were sampled using a beating tray technique, and insects were collected from the beating tray with an aspirator. One orchard was located 6.6 km south of Cashmere, (Chelan Co.), WA in Yaxon Canyon (elevation 242 m), and the other was located 8.3 km southeast of Leavenworth, (Chelan Co.), WA in Derby Canyon (elevation 390 m).

To obtain electron micrographs adult *Dilyta* were killed after emergence by freezing, and then air-dried. Specimens were coated with gold (approximately 30 nm) using a Technics Hummer Sputter Coater and then examined with an ETEC Autoscan U–1 electron microscope.

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Results and Discussion

Field Collections

On 19 August 1985, 3 female *Dilyta* adults were reared from *P. alba* nymphs. In 1986 a total of 33 specimens (18 females, 9 males, 6 of undetermined sex) were reared from *P. alba* from May through September (Table 1).

Salix growing at the Nahahum Canyon site maintained lush growth through August in 1986. The leafrollers, *Pandemis pyrusana* Kearfott, *Choristoneura rosaceana* Harris and *Filatima saliciphaga* (Keiffer) were common on the terminal shoots of *S. exigua*. *P. alba* nymphs were frequently found inside both abandoned and occupied leafroller feeding sites.

Host Searching/Oviposition

On 30 July, 2 newly emerged *Dilyta* adults (male and female) were placed into a shell vial containing 6 nymphs of *P. alba*. Within 5 min the *Dilyta* female, with ovipositor visible, positioned herself on the dorsal surface of a psyllid nymph.

On 30 August, 3 *Dilyta* adults (1 male and 2 females), approximately 3 hrs post-emergence, were placed into a shell vial containing early and late nymphal instars of *P. alba*. Within 5 min both *Diltya* females were observed feeding on honeydew excreted by the psylla nymphs. Ten min after feeding, one female *Dilyta* positioned herself on the dorsal surface of a fourth instar. Both parasitoid and host were oriented in the same direction. Antennal contact between host and parasitoid was followed by probing behavior and penetration of the ovipositor into the psyllid abdomen. Oviposition lasted 2 min. In a 30 min period 4 psyllid nymphs were attacked by the female *Dilyta*. Psyllids moved back and forth apparently trying to dislodge the parasitoids as they attempted to oviposit.

Dilyta adults emerging 2 September (1 male and 1 female) were placed into a shell vial with various nymphal instars of *P. alba*. Behavior similar to that observed 30 August was noted. Feeding on honeydew was followed by searching, antennal contact with the host, and penetration with the ovipositor. Duration of a single oviposition attempt was approximately 2 min. The female died within 24 hrs following oviposition, but the male survived for 6 days.

Host searching and oviposition behavior observed in *Dilyta* sp. is similar to the described behavior of two aphid hyperparasite genera within the subfamily Alloxystinae, *Phaenoglyphis* and *Alloxysta*. *Phaenoglyphis americana* Baker has been studied extensively in California (Andrews 1978). *P. americana* palpates a host aphid with its antennae for several seconds, mounts the host, and palpates again while positioned on the dorsum of the aphid. If the aphid is accepted as a host, the parasitoid orients itself, head to head, and inserts its ovipositor into the abdomen of the aphid. The ovipositor may be inserted several times in the same host, with an insertion lasting as long as 5 min. A female *Alloxysta* will approach a live, parasitized aphid and rapidly palpate its surface. She then mounts the dorsum of the aphid, with her abdomen slightly bent, and inserts her ovipositor through the aphid cuticle, depositing the egg inside the still feeding primary parasitoid larva (Sullivan 1987).

Host Associations

All members of the subfamily Alloxystinae with known host associations are hyperparasites, attacking primary parasitoids belonging to the Aphidiinae

Figure 1. A new species of *Dilyta* (female) reared from *Psylla alba* in central Washington. x 66.

(Braconidae) and Aphelininae (Gordh 1981). Recent European authors disagree as to whether members of the Charipinae are primary or secondary parasitoids. Fergusson (1986) reported that *D. subclavata*, the single European species of the genus, is a primary parasitoid of psyllids. In southern France, however, *D. subclavata* is recorded as a hyperparasite of *Psylla pyri* through the encyrtid, *Prionomitus mitratus* (Dahlman) (Herhard 1986). *P. mitratus* is one of the key parasitoid enemies of *P. pyri* in Europe. It is Holarctic in distribution (Krombein et al. 1979) and has been recorded from several states in the USA on many species of psyllids (Jensen 1957). We have been unable to determine if our new *Dilyta* sp. is a primary psyllid parasitoid or a hyperparasite. Collection of *Dilyta* sp. from unsprayed pear orchards in central Washington indicates that this species may be an important component of the parasitoid complex of pear psylla, *Psylla pyricola* Foerster. Rearing records (Table 1) and collection of adults in the field during 1986 indicate the parasitoid was active from May through September.

Acknowledgments

We thank W. J. Turner, R. D. Akre and A. S. Menke for review of the manuscript. We also are grateful to A. S. Menke and D. R. Miller, Systematic Entomology Lab, Agricultural Research Service, USDA, Washington, D.C. for identification of *Dilyta* sp. and *P. alba*, respectively.

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64(1), 1988, pp. 98–99

Scientific Note

Records of the Palearctic Tortricid, *Clepsis consimilana,* In the Pacific Northwest: Can An Urban Moth be Overlooked for Half a Century?

In June, 1985, I collected a specimen of the widespread Palearctic species, *Clepsis consimilana* (Hübner) (= *unifasciana* Dup.) (Lepidoptera: Tortricidae, Archipini), at Eugene, Lane Co., Oregon (Powell, 1986, Pan-Pacific Entomol., 62:165). I speculated that the record represented a well established colony, rather than the improbable coincidence of an isolated introduction having been encountered by a lepidopterist during a brief visit to the area. This theory appears to have been corroborated by the discovery of this species at Longview, Cowlitz Co., Washington, in 1986.

My second collection of *C. consimilana* in the Pacific Northwest also was serendipitous: during an overnight visit to Longview, I found three dead males which had been trapped in a light fixture in a motel. Only slight fading of their colors suggested that they had been entombed only 2–3 months, since the preceding flight season in June or July, 1986. (NY-CN collection records span May 30 to July 22; Powell & Burns, 1971, Psyche, 78:45). The new locality is near the Columbia River, which is a likely avenue of introduction, via overseas shipping. The site is ca. 164 airline km north of Eugene, OR, and occurrence of *C. consimilana* at Longview indicates this immigrant has colonized widely in the Willamette Valley.

Adults of *C. consimilana* are commonly attracted to lights, and other collectors have recorded several additional species of Palearctic tortricids in the Pacific Northwest in recent years (Powell, 1986, loc. cit.); hence populations ought to have been discovered if resident in the region for many years. However, records of the introduction and spread of adventive insects in North America characteristically are sporadic in time and space. For example, *C. consimilana* has been established in the Long Island-Connecticut area for about 50 years, but it has been sampled at only 6 sites, in 9 seasons, including an 11-year gap (Powell & Burns, 1971, loc. cit.; USNM records), and not at all during the past 20 years. I contacted resident entomologists in Oregon for possible additional records but without success. However, a thorough search of unidentified material at the Smithsonian Institution in November, 1986, revealed a single worn male of *C. consimilana* which had been collected by J. F. G. Clarke at Portland, OR, more than half a century ago, June 22, 1931!

Thus available records in the northwestern U.S. render a picture so sketchy that we cannot tell if the species entered the region once early in the century and persisted, or died out and then colonized a second time. A second invasion might have come from the Old World, or via secondary transport from New York. The Portland collection in 1931 precedes by 8 years the earliest known eastern U.S. record.

The species lives in urban situations, where the larvae feed on Privet (*Ligustrum*) and may be polyphagous in some circumstances. Entomologists in the Pacific Northwest are urged to intensify sampling of moths, particularly in urban areas, in

order to better focus our view of the colonization by *Clepsis consimilana* and other introduced microlepidoptera.

I thank V. M. Carolin, Jr., Portland, OR, and R. L. Westcott, Oregon Dept. Agric., Salem, who made efforts to locate *C. consimilana* specimens in collections under their care.

J. A. Powell, *Department of Entomological Sciences, University of California, Berkeley, CA 94720*

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Vol. 64 April 1988 No. 2

THE PAN-PACIFIC ENTOMOLOGIST

SAN FRANCISCO, CALIFORNIA • 1988

Published by the **PACIFIC COAST ENTOMOLOGICAL SOCIETY**
in cooperation with **THE CALIFORNIA ACADEMY OF SCIENCES**

The Pan-Pacific Entomologist

Published quarterly in January, April, July, and October with Society Proceedings appearing in the October number. All communications regarding nonreceipt of numbers, requests for sample copies, and financial communications should be addressed to the Treasurer, Dr. Wojciech J. Pulawski, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

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Statement of Ownership

Title of Publication: The Pan-Pacific Entomologist.

Location of Office of Publication, Business Office of Publisher and Owner: Pacific Coast Entomological Society, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118-4599.

Editor: J. A. Chemsak, 201 Wellman Hall, University of California, Berkeley, California 94720.

Managing Editor and Known Bondholders or other Security Holders: None.

This issue mailed August 15, 1988

The Pan-Pacific Entomologist (ISSN 0031-0603)
PRODUCED BY A-R EDITIONS, INC., MADISON, WI 53703, U.S.A.

PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 101–106

The Genus *Phyllophaga* Harris, 1826 (Coleoptera: Scarabaeidae) in Cuba. III. Descriptions of Six New Species and the Male of *Ph. cardini* Chapin.

MIGUEL GARCIA-VIDAL

853 Arguello Blvd., San Francisco, CA 94118.

INTRODUCTION

This is the third part of a series on the genus *Phyllophaga* in Cuba, which I started a few years ago. It was in press when I left Cuba but it was never published. In the original the pictures were made by Heriberto Maza, to whom I express my gratitude. Also I wish to thank Dr. Alan Hardy for the pictures of the male genitalia. The female genitalia were made by the author of this paper.

Phyllophaga brevicornis, NEW SPECIES

Female.—Submedium. Head and pronotum piceous; elytra and underparts dark castaneous; ovoid. Frons very sparsely punctured, with a depression on both sides of median line; a tiny horn between median line and depressions. Clypeus narrow; punctures fine; margins abruptly reflexed; median indentation deep and angulate. Pronotum moderately punctured; margins entire; anterior angles acute; posterior curved; sides broadly medially dilated. Scutellum sparsely punctured, disc impunctate. Elytra more densely punctured than pronotum; punctures of different sizes, irregularly distributed; sutural margin slightly tumid, wider posteriorly. Pygidium punctured as elytra, but punctures finer; apex subtruncate; piceous spot on central, anterior region. Antennal club small, 3-segmented, long as three previous segments together. Sternites with short hairs, fine punctures. Urosternites densely, finely punctured; fifth segment with a slight depression on each side. Protibia tridentate; distal tooth elongate, median closer to distal. Longer calcar of metatibia slender, acuminate. Length: 13 mm.

Holotype: Female, Vinales, Pinar del Rio, 6-1964, at light, col. unknown. In Zayas collection.

This species is very close to *Ph. scaramuzzai* Garcia but is easily recognizable by its characteristics. When I tried the genitalia, they were missing and the pygidium was loose.

Phyllophaga cardini Chapin

Male.—Submedium, pruinose. Pronotum dark castaneous, head piceous, rest of the body dark brown; slightly ovoid. Frons densely, coarsely, irregularly punctured, base inpunctate; depression on disc forming an almost equilateral triangle with one apex pointing toward the base. Clypeus more densely, coarsely punctured; punctures rather large; margin slightly reflexed; median indentation deep, subangulate. Pronotum less densely, coarsely punctured; punctures more regularly distributed; margins entire; anterior angles acute, posterior obtuse; sides broadly, medially dilated with long reflexed hairs. Scutellum sparsely punctured, disc impunctate. Elytra more densely punctured than pronotum but less than head;

punctures finer; sutural margins slightly conspicuous; apical callus shining. Pygidium punctured about as elytra, but with finer punctures; apex broadly curved. Antennal club 3-segmented, about as long as stem. Sternites pubescent; hairs long and thick; punctures fine; metasternite less pubescent, hairs shorter, finer. Urosternites densely punctured; punctures fine; some short, fine hairs present; tuft of long hairs, laterally on fifth segments; last segment narrow, grooved almost completely. Protibia tridentate, teeth equidistant. Coxal plates with few thick, straight hairs. Longer calcar of metatibia acuminate, sable-shaped, longer than first tarsal segment. Claws strongly curved, especially the distal tooth. Length: 14–14.5 mm. Fig. 1, 5.

Female.—Frons more coarsely, densely punctured; depression more irregular; margins of clypeus broadly reflexed. Antennal club about as long as three previous segments together. Pygidium more narrowly curved, with a broad longitudinal depression. Tuft of hairs on fifth urosternite longer; the last convex. Length: 14 mm. Fig. 12.

Material Examined

One male, the Neallotype, col. F. de Zayas, from Turquino, Sierra Maestra, 6-1964, deposited in USNM; one male, col. J. Acuna, from Loma de Cala to P. Mocha, S. Maestra, May 16/48, 3600 to 3900 feet altitude, in Zayas Collection; male, col. F. de Zayas, Loma del Gato, Oriente, 6-1964, in Zayas Collection; female, col. F. de Zayas, Loma del Gato, Oriente, 6-1964; female, col. P. Cardin, Baracoa, Oriente, April 19, 1916, both in Zayas Collection.

Note.—When I started studying these specimens, at first I thought it was a new species, although it was very close to *Ph. cardini* Chapin. Since Chapin based his description upon a female and the genitalia were not published I was not sure if the material I was studying belonged to Chapin's species or not. Fortunately I found a female that belonged to the material that Chapin used for his description. When I studied the genitalia of my material, they were the same as Chapin's species from Baracoa. However, it called to my attention that Chapin included as paratypes specimens from Jaronu, Camaguey. Since these species are very restricted to specific areas, at least the majority, it seemed very probable that the specimens from Jaronu and Baracoa were different species. I was very lucky also in finding one specimen from Jaronu, collected by L. C. Scaramuzza. The genitalia of both groups were different. Consequently, I considered the specimens from Jaronu as a new species and the paratypes of *Ph. cardini* Chapin should be included in it. The description is as follows.

Phyllophaga laboriosa New Species

Very close to *Ph. cardini* Chapin. The main differences are: margins of the clypeus more elevated and median indentation deeper. Frons more strongly punctured but equally irregularly; urosternites less pubescent; underparts lighter than upperparts, which are piceous. The genitalia are completely different. Length: 12.5–14.5 mm. Fig. 11.

Holotype.—Female, col. L. C. Scaramuzza, at light, 5–6–30, No. C.S.C. Ent. 4027. In CAS, No. 14308.

Paratype.—Same data, in UNSM.

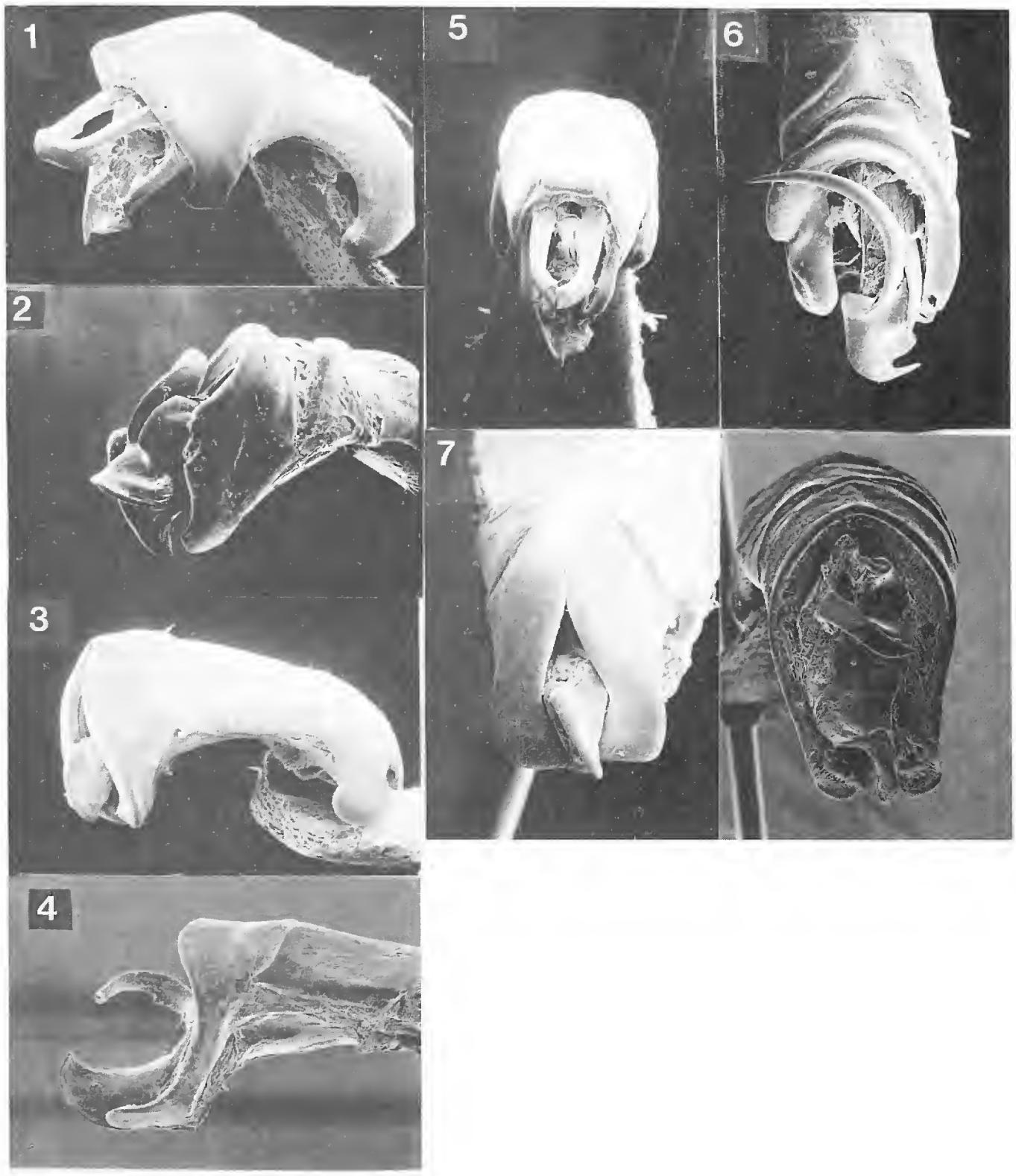


Figure 1. Phyllophaga cardini Chapin, male: Aedeagus, lateral view. Figure 2. Phyllophaga sandersoni, n.sp. male: Aedeagus, lateral view. Figure 3. Phyllophaga scaramuzzai, n.sp. male: Aedeagus, lateral view. Figure 4. Phyllophaga ahlbrandti, n.sp. male: Aedeagus, lateral view. Figure 5. Phyllophaga cardini Chapin, male: Aedeagus, dorso-frontal view. Figure 6. Phyllophaga sandersoni, n.sp. male: Aedeagus, dorso-frontal view. Figure 7. Phyllophaga scaramuzzai, n.sp. male: Aedeagus, dorso-frontal view. Figure 8. Phyllophaga ahlbrandti, n.sp. male: Aedeagus, frontal view.

Phyllophaga siboneyensis New Species

This species is also very close to *Ph. cardini* Chapin and to *Ph. laboriosa* but differs from both as follows: rufocastaneous, disc of pronotum darker; margins of clypeus very slightly reflexed, almost flat, median indentation angulate; frons with no depression on disc; lateral margins of pronotum subcrenulate; scutellum punctured as pronotum; sutural margins conspicuous but not elevated; apical apex of pygidium broadly curved; antennal club trisegmented, about as long as four preceding

segments; longer clacar of metatibia about twice as long as first tarsal segment; genitalia different. Length: 13 mm. Fig. 10.

Holotype.—Female, from Siboney, Cuba, Dec. Col. unknown. Deposited in UNSM.

Phyllophaga ahlbrandti New Species

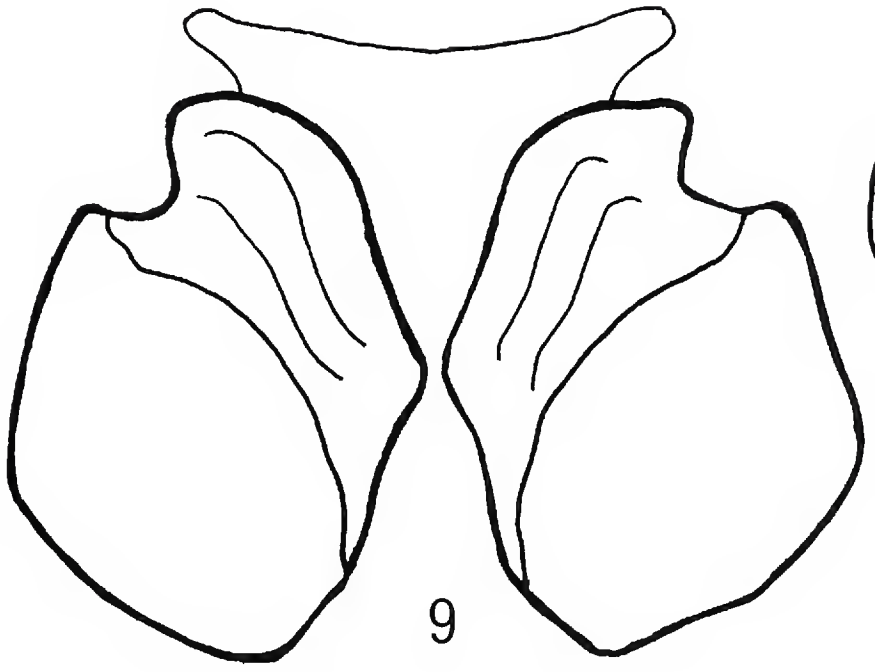
Male.—Large, shining, pubescent, elongate, wider posteriorly, castaneous ferrugineous, head dark brown. Frons densely punctured; punctures of different sizes, irregularly distributed. Clypeus punctured as frons; margins broadly reflexed; median indentation broad, deep, subangulate. Antellan club 3-segmented, long as funicle. Pronotum less densely punctured than frons; big punctures with long, thick, straight hairs; lateral margins crenulate, with long, thick, reflexed hairs; sides broadly, medially dilated; anterior, posterior margins entire; anterior angles slightly acute, narrowly reflexed; posterior rounded. Scutellum sparsely punctured on margins, disc impunctate, with a few short, thick hairs. Elytra more densely punctured than pronotum but less than head; big punctures with thick, straight hairs; sutural margin tumid. Pygidium densely punctured; fine punctures regularly distributed; hairs fine, short, straight; apex subtruncate with long, fine, straight hairs. Sternites, specially mesosternite, densely punctured; fine punctures with fine, long hairs; metasternite less densely punctured. Urosternites punctured as sternites, but with short, fine hairs. Coxal plates sparsely punctured; with thick, short, long hairs. Protibia tridentate; proximal tooth apart from others; distal stronger. Longer calcar of metatibia acuminate, strong, about as long as first tarsal segment with spines. Claws strongly curved; median tooth stronger than distal. Length: 26 mm. Figs. 4, 8.

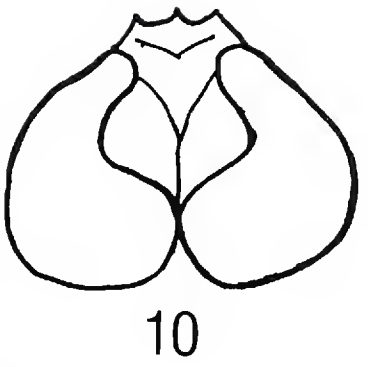
Holotype.—Male, col. J. Acuna, F. Valdes B. and C. Fortun, from Rio Yara, Oriente, Cuba, May 15–20/1948, 125–1000 feet altitude aprox. In CAS No. 14370.

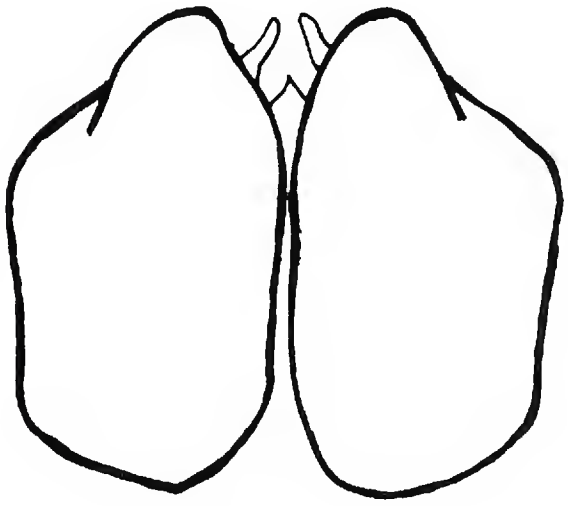
Note.—Very characteristic and easily recognized by its pubescence and the aedeagus, which is very complex. From the internal sac protrudes a long strong spine, curved laterally; on it internal margin shorter spines are present. This is dedicated to Mr. Jerry Ahlbrandt.

Phyllophaga sandersoni New Species

Male.—Medium. Castaneous-ferrugineous to yellowish brown. Frons densely punctured; punctures fine; base impunctate. Clypeus slightly more densely punctured; punctures fine, more orderly distributed; margins broadly reflexed; median indentation deep, angulate. Pronotum less densely, more orderly punctured than head; punctures bigger; margins entire; sides medially, slightly dilated, forming a broad curve; anterior angles almost straight, posterior obtuse; thick, long, reflexed hairs on sides. Scutellum punctured about as pronotum, but punctures finer; sutural margins tumid; few hairs posteriorly. Pygidium less densely punctured than elytra; apex broadly rounded. Antennal club with three complete segments, the fourth slightly shorter and a fifth shorter than half of fourth, longer than funicle. Protibia tridentate; teeth almost equidistant. Coxal plates pubescent. Sternites pubescent, specially mesosternite; hairs fine, long. Urosternites sparsely punctured; punctures fine with short hairs; last segment shallowly grooved with some long, fine hairs. Longer calcar of metatibia slender, acuminate, longer than first tarsal segment. Claws curved, median tooth stronger. Length: 18–19.5 mm. Figs. 2, 6.







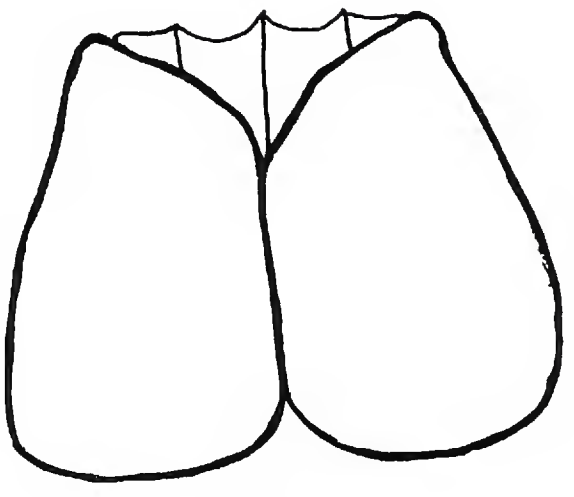


Figure 9. Phyllophaga sandersoni, n.sp. Female genitalia. Figure 10. Phyllophaga siboneyensis, n.sp. Female genitalia. Figure 11. Phyllophaga laboriosa, n.sp. Female genitalia. Figure 12. Phyllophaga cardini Chapin. Female genitalia.

Female.—Pygidium more narrowly rounded; antennal club shorter but 5-segmented also, with same proportions; longer calcar of metatibia wider, about twice as long as first tarsal segment, acuminate. Length 18.5–19.5. Fig. 9.

Holotype.—Male, col. F. de Zayas, Loma del Gato, Oriente, 6/1964, in CAS, No. 14309.

Allotype.—Col. M. W. Sanderson, Cuba, Loma (Pico) del Gato, Sierra Maestra, Prov. Oriente, May 26–28, 1959. In CAS No, 14309.

Paratypes.—Male, col. F. de Zayas, Sierra Maestra, Oriente, 5/1965; female, col. F. de Zayas, Loma del Gato, Oriente, 8/1966, both in Zayas collection, Havana. Three males and three female, col. M. W. Sanderson, Cuba, Loma (Pico) del Gato, Sierra Maestra, Prov. Oriente, May 26–28, 1959. One male and one female deposited in CAS, USNM and Illinois Natural History Survey, Urbana, Ill.

Note.—This species is dedicated with my respects and appreciation to Dr. M. W. Sanderson. The aedeagus presents a long, curved, strong spine and is asymmetric.

Phyllophaga scaramuzzai New Species

Male.—Submedium. Elytra, disc of pronotum and head dark castaneous; underparts, legs and lateral margins of pronotum yellowish brown. Frons densely, coarsely punctured; big, irregularly distributed punctures on disc; fine, orderly distributed on sides; base impunctate. Clypeus slightly less densely punctured; punctures fine; margins abruptly reflexed; median indentation almost obsolete. Antennal club 3-segmented, about as long as funicle. Pronotum less densely punctured than head; a little bigger punctures, more orderly distributed; sides medially, broadly dilated; margins entire; anterior angles almost straight, posterior rounded; depression central on sides, on the light area. Scutellum densely punctured, disc impunctate; punctures as on pronotum. Elytra punctured as pronotum, but punctures slightly smaller, very regularly distributed; sutural margins tumid, feebly carinate, epipleura narrow. Pygidium moderately punctured on disc, sparsely on sides; castaneous spot on center; apex subtruncate. Sternites densely punctured, pubescent, with fine, long hairs and fine punctures. Urosternites scarcely punctured, punctures fine; with few fine, short hairs. Coxal plates very sparsely punctured, disc impunctate, with few thick, long, hairs. Protibia tridentate, teeth equidistant; distal strong. Longer calcar of metatibia slender, acuminate, longer than first tarsal segment. Claws slightly curved; median tooth very small, apical slender. Length: 14 mm. Figs. 3, 7.

Holotype.—Male, col. J. Acuna from Las Martinas, Peninsula Guanacahabibes, Pinar del Rio, 15–6–1943. In CAS, No. 14310.

Note.—This species is very interesting by its general resemblance to *Ph. explanicollis* Blanch. However it is far smaller and the aedeagus is completely different. It is close also to *Ph. hardyi* Garcia. It is dedicated to the Cuban entomologist Luis C. Scaramuzza.

PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 107–113

Fungi Associated with Two *Vespula* (Hymenoptera: Vespidae) Species in the Eastern San Francisco Bay Area

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Abstract.—Fungi associated with two *Vespula* species were isolated from insects or nests from four sites in the eastern San Francisco Bay area. A total of twenty-two species representing six genera were recovered, including at least four facultative pathogens taken from dead insects. Fungi in the genera *Aspergillus* and *Penicillium* were most common. Successful fungal invasion of colonies usually occurs during late-season decline.

INTRODUCTION

A social insect colony presents a rich sequestration of resources susceptible to exploitation by non-colony organisms. Colonies of the honey bee *Apis mellifera* Linnaeus, the most widely studied social insect, are plundered by a variety of saprophytes, pathogens and predators ranging in size and complexity from viruses to bears (Morse, 1978). In colonies of vespine wasps, nutritive resources available for exploitation include structural paper, silk, the insects themselves, and their waste products.

The abundant literature concerning the organisms associated with, and presumably benefitting from, vespine colonies, is reviewed by Spradbery (1973) and Edwards (1980). Most emphasis is on arthropods. Although there is a modest number of references to vespine fungal associates, many are brief, mentioning little more than the co-occurrence of two organisms. Several original records have been cited repeatedly in subsequent works, inflating the literature in proportion to the actual number of specimens. Furthermore, since many fungi are facultative pathogens, also able to develop as saprophytes, a report of a vespine cadaver supporting fungal growth does not indicate the nature of the relationship between insect and fungus. Consequently our knowledge of fungal associates of the Vespinae is incomplete.

The earliest mention of fungal growth on a vespine is Gray's (1858) account of *Hymenostilbe sphecophila* (Ditmar) Petch on an adult of *Vespa crabro* Linnaeus. Additional records of this fungus, all on adult wasps, are provided by Smith (1882; 1884), Cooke (1892), Petch (1932; 1948), and Leatherdale (1970). Other fungi associated with vespine adults include *Cordyceps sphecocephala* (Klotzsch) (Cooke, 1892; Petch, 1932; Petch 1948; Poelt and Jahn, 1963; Leatherdale, 1970; Edwards, 1980); *Paecilomyces farinosus* (Dickson) Smith et Brown (Petch, 1932; Leatherdale, 1970; Kmitowa, 1982); *Beauveria tenella* Delacroix (Leatherdale, 1970); and

Beauveria bassiana (Balsamo) Vuillamin (Leatherdale, 1970; Thomas and Poinar, 1973). Unidentified fungi associated with adults are mentioned by Duncan (1939), Spradbery (1973), and Edwards (1980).

Fungi are less commonly noted to occur in association with larvae. Nakahara (1980) recovered a *Beauveria* species growing on larvae in a nest of *Vespula pensylvanica* (Saussure) on the island of Hawaii. Other records of unidentified fungi associated with larvae are found in Duncan (1939) and Akre and Reed (1981).

Old nest material commonly supports fungal growth. MacDonald (1977) found *Aspergillus* and *Penicillium* species growing on abandoned subterranean nests. Sagara and Kobayashi (1979) and Sagara *et. al.* (1985) found basidiocarps of *Hebeloma spoliatum* (Fries) Karst and *H. radicosum* (Fries) Ricken growing from abandoned ground nests of *Vespula flaviceps lewisii* Cameron. They speculated that the nitrogen-rich meconia provided nutrients otherwise lacking in the soil, thus allowing the mushrooms to develop to fruition at these specific sites. Other unidentified fungi, apparently involved in the decomposition of nest materials, have been noted by Spradbery (1973) and Edwards (1980).

Durrell (1965) proposed that hyphal ramifications of certain fungi may strengthen the paper of active nests by binding the fibers together, thus benefitting the wasps. He recovered *Aureobasidium pullulans* (deBary) Arnaud, *Fusarium roseum* Link, *Mucor varians* Povah, *Alternaria tenuis* Auct., *Stemphylium ilicis* Teng., and *Phoma* sp. from paper of an aerial *Vespula* (or more likely, *Dolichovespula*) nest. Additional support for this theory is provided by the findings of *Botrytis cinerea* Persoon in vespine nests by Acolat (1953) and Cymorek (1978), and of *Aureobasidium pullulans* by Edwards (1980).

Some yellowjacket species are significant economic pests (Akre and MacDonald, 1986). Because of the possible usefulness of fungi as biological control agents, we investigated those representatives that occur in association with two common Californian pest species, *Vespula vulgaris* (Linnaeus) and *V. pensylvanica*.

Materials and Methods

Fungi associated with *Vespula* wasps or their nests were collected from four east San Francisco Bay (California, U.S.A.) localities: Orinda (ORI; Contra Costa County), Berkeley (BER; Alameda County), Albany (ALB; Alameda County), and Tilden Park (TIL; Contra Costa County).

The ORI nests had housed active colonies during the early summer of 1983, but at the time of excavation no living adults were present and there were no immatures, alive or dead, in any of the cells. Fungi had grown and sporulated on the backs (tops) of some of the upper combs (Figure 1), in some cases covering nearly the entire comb. The nests were brought to the laboratory where fungal spores were inoculated onto Sabaraud dextrose agar + 0.2% yeast extract (Poinar and Thomas, 1984), or potato dextrose agar, in 100 × 15 mm Petri dishes. These standard artificial growth media were used to culture fungi throughout this study.

The BER (except BER–5), ALB, and TIL colonies were active immediately prior to excavation. Flying adults were removed by placing a funnel trap over the surface entrance hole of the tunnel leading to the nest. After removing the trap, the remaining wasps were anaesthetized by injecting ethyl ether into the hole before excavating the nest.

Intact nests were brought to the laboratory, where the envelope was removed and the combs separated. Combs containing brood, but free of adults, were installed in sealed plastic food containers and kept in an incubator at 28 ± 1.5°C. Larvae were reared using a modification of the methods of Parrish and Roberts (1983). Fungal growth was not evident on these combs at the time of installation. After one day, sporulating growth was apparent on a wall of a vacant cell of a comb of ALB–1. The capped cell opposite this cell wall contained a dead, fully formed adult worker that also supported some fungal growth. This adult and the portion of cell wall to which it was fused were removed from the comb and placed on growth medium. Combs from colonies BER–3 and BER–4 showed fungal growth after five days. Hyphae and spores were transferred from the combs to culture medium.

Fungi were also recovered from individual insects. A larva of colony BER–1 turned red one day after excavation. It was removed from the comb and placed on moist filter paper in a 30 mm Petri dish. It hardened, and after 5 days, a thin white fungal growth appeared over its surface.

Fifteen workers newly emerged from a comb of colony BER–2 were allowed to remain on the comb for up to 12 hours. All fifteen were transferred to a sterile 400 ml tissue culture flask, which was sealed and returned to the incubator. These wasps died after several days, and sporulating fungi issued from the cadavers after approximately 10 days (Figure 2).

Colony BER–5 was not excavated for this study. However, two adult workers partly covered with fungal growth (Figure 3) were recovered from moist leaf litter just outside the entrance hole.

To isolate fungi from the guts of larvae of colonies TIL–1 and BER–6, apparently healthy larvae were removed from cells of the excavated nests and placed on sterile filter paper in petri dishes. The next day larvae that had not defecated were individually surface-sterilized in two rinses of 70% EtOH. The gut was dissected out in sterile 0.7% NaCl saline solution and passed through four rinses of sterile distilled water. The gut was ground in sterile saline with mortar and pestle, and inoculum was transferred via loop to growth medium.

Wasps designated CAL–1 were dead adult workers supporting fungal growth, which were collected from an unspecified northern California locality and submitted to us for diagnosis.

Fungal cultures were examined with a stereo dissecting microscope. Sporulating portions were mounted in Guegen's medium for examination under a compound microscope.

Results and Discussion

Table 1 lists fungi recovered in this study. Because it was often difficult to distinguish between fungal growth arising from comb paper, silk, and meconia at the bottom of otherwise empty cells, these three sources of nutrition are collectively referred to as "comb" in the table.

Nearly all species of fungi recovered can be considered common saprophytic soil organisms (Thom and Raper, 1945; Raper and Thom, 1949; Barnett and Hunter, 1972; Samson, 1974). The occurrence of soil fungi in subterranean wasp nests is hardly surprising. Yellowjacket workers enlarge their nest cavity by removing soil pellets, and foragers must pass through a tunnel in the soil to return to the nest. The

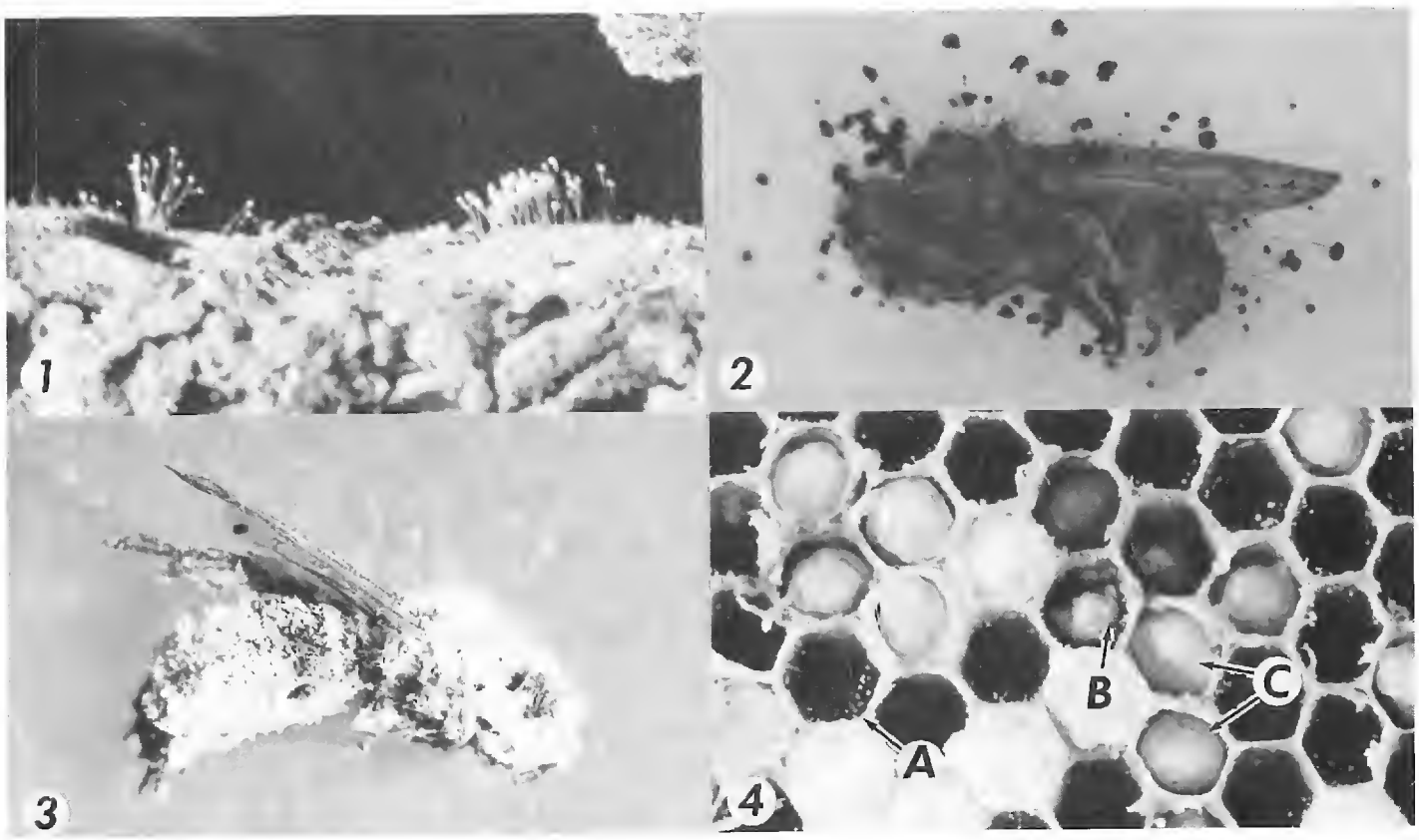

Figure 1. Sporulating heads of *Aspergillus oryzae* on back (top) of a *Vespula vulgaris* comb. Figure 2. Sporulating heads of *Aspergillus niger* on *V. vulgaris* adult. Figure 3. *Beauveria bassiana* spores on a *P. vulgaris* adult. Figure 4. Fungi on a *V. vulgaris* comb. Growth is present in empty cells (A) and those containing dead larvae (B), but absent in cells containing healthy larvae (C).

spread of fungal spores throughout the nest would thus seem inevitable. Some spores are ingested, but retain their viability, as indicated by the recovery of fungi from larval gut contents. Such spores, passed out with the voided meconium, would also account for the initiation of growth on this substrate.

Some of the saprophytic fungi that were recovered are also known to be facultative insect pathogens. Those recovered from insect cadavers during this study are implicated in this role. Two species, *Paecilomyces farinosus* and *Beauveria bassiana* attack many insects (Steinhaus, 1949), and have previously been associated with vespine adults (Leatherdale, 1970; Thomas and Poinar, 1973; Kmitowa, 1982). Both *Aspergillus flavus* Link and *A. niger* Bloch, which produce stonebrood in *Apis mellifera* (Morse, 1978), also have wide host ranges.

Although the flora varied between nests and sites, species of *Penicillium* and *Aspergillus* were the most common associates. Despite the single reference to these genera in the literature (MacDonald, 1977), their occurrence on old nests is probably widespread, and merely underreported. Members of the genus *Aspergillus*, which produce cellulolytic enzymes (Thom and Raper, 1945) would seem especially well adapted to derive nutrition from the structural paper of a nest.

Most subterranean colonies probably contain fungal spores, but these usually do not germinate and grow in active healthy colonies. The insects themselves may somehow inhibit fungal growth, as suggested by MacDonald (1977). In our rearing

Table 1. Fungi Associated with California Vespula Species.

Colony	Date	Species	Source	Fungus
CAL–1	6.ix.72	*pensylvanica*	Adult	*Paecilomyces farinosus* (Dicks.) Brown et Smith
ORI–1	21.ix.83	*vulgaris*	Comb	*Aspergillus restrictus* G. Smith
				Penicillium brevi-compactum Dierckx
ORI–2	21.ix.83	*vulgaris*	Comb	*Aspergillus niveus* Bloch
				Aspergillus niger van Tieghem
				Penicillium steckii Zaleski
				Penicillium stoloniferum Thom
ORI–3	21.ix.83	*vulgaris*	Comb	*Aspergillus oryzae* (Ahlberg) Cohn
BER–1	11.xi.83	*pensylvanica*	Larva	*Aspergillus terreus Thom*
BER–2	26.x.84	*vulgaris*	Adult	*Aspergillus niger*
				Aspergillus flavus Link
BER–3	26.x.84	*vulgaris*	Comb	*Aspergillus niger*
				Aspergillus niveus
				Aspergillus oryzae
				Aspergillus restrictus
				Cladosporium Link sp.
				Scropulariopsis brevicaulis (Sacchardo) Bainer
				Penicillium steckii
				Penicillium citrinum Thom
				Penicillium thomii Maire
			Larvae	*Aspergillus niveus*
				Aspergillus oryzae
				Aspergillus restrictus
				Penicillium steckii
				Penicillium citrinum
BER–4	8.xi.84	*vulgaris*	Comb	*Aspergillus oryzae*
				Penicillium steckii
BER-5	5.ix.85	*vulgaris*	Adult	*Beauveria bassiana* (Bals.) Vuill.
ALB–1	29.x.85	*pensylvanica*	Adult	*Penicillium corylophilum* Dierckx
TIL–1	16.x.86	*pensylvanica*	Larval Gut	*Penicillium restrictum* Gilman
				Penicillium phoenicium van Beyma
				Penicillium chermesinum Biorgue
				Penicillium decumbens series close to *P. citreo-viride* Biorgue
				Penicillium humili van Beyma
				Penicillium lanosum Westling
				Aspergillus wentii group
BER–6	16.xii.86	*vulgaris*	Larval Gut	*Penicillium aurantio-candidum* Dierckx

chambers, fungal growth was not visible in comb cells containing healthy larvae, even when growth and sporulation was abundant in adjacent cells (Figure 4).

When colonies enter late season decline, the depletion of the worker force reduces the efficiency of colony defense and sanitation, and regulation of temperature and humidity become irregular. Conditions within the nest then become more favorable for fungal spore germination and growth. With the overall health of the colony

weakened, facultative pathogens can overcome the defenses of live individuals, and saprophytes can spread over the abundant non-living material.

Acknowledgments

F. Ennik, provided the CAL–1 specimens. Translation assistance was furnished by T. Hukuhara and H. Gordon. H. Daly, J. DeBenedictis and G. Poinar read an earlier draft of the manuscript and offered suggestions for its improvement. The East Bay Municipal Utility District permitted research on its properties, and support was provided in part by the northern California chapter of the Achievement Rewards for College Scientists (ARCS) Foundation, Inc.

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64(2), 1988, p. 114

Scientific Note

New Record of *Lardoglyphus konoi* (Sasa and Asanuma), on Dried Lizard Carcasses (ACARINA:ACARIDAE)

Lardoglyphus konoi (Sasa and Asanuma 1951) is a widespread and serious mite pest of dried fish and shellfish in Asia and the East Indies. Many Asian Pacific Rim countries export these dried seafood products to the United States. At the port facilities in the greater Los Angeles area, the U.S. Food and Drug Administration (FDA) routinely examines these products for adulteration by stored product pests such as *L. konoi.* The FDA has previously intercepted *L. konoi* in dried seafood products arriving at Los Angeles port facilities from Hong Kong, Indonesia, Japan, Korea, Malaysia and the Philippine Islands. Although Hughes (1976, The mites of stored food and houses. Ministr. Agric. Fisheries and Food Tech. Bull. 9, London 400 pp.) reports that *L. konoi.* can be cultured on dried heart muscle and was once found on butcher's offal in England, this mite has not otherwise been recorded as infesting anything except dried seafood products.

On August 4, 1987, an FDA investigator in Los Angeles intercepted a shipment of dried lizards that had been infested with *L. konoi.* This is the first record of *L. konoi* infesting a reptile carcass and the first record of *L. konoi* on a non-seafood product from Asia. The shipment of dried lizards originated in Hong Kong and arrived by ship at the port of Long Beach on July 11, 1987. It consisted of 700 lbs. of dried gecko carcasses, *Gekko gecko* L., packaged in polyethylene bags containing two lizards each. Six packages were randomly sampled from the shipment by Consumer Safety Inspector James D. Marton and examined by myself at the FDA Los Angeles District Laboratory. Two of these packages contained *L. konoi* mites in numbers ranging from approximately 200 to 300 mites per package. Although all the mites were dead at the time of sampling, presumably from a prior fumigation, it was evident from the numbers and condition of mite specimens that a serious infestation had occurred. Approximately one-half of the specimens consisted of immature stages. All the immature stages of the life cycle of *L. konoi* were observed including larvae, protonymphs, deutonymphs and tritonymphs. Many gravid females as well as typical heteromorphic males were also found. Most of the mite specimens appeared undamaged and were flexible to a limited degree. The specimens that were examined at 200× magnification did not exhibit the invasive mold growth in their body cavities that is typical of older, desiccated specimens. To all appearances, this represented an infestation that had been viable up to a relatively short time prior to the collection of FDA samples. All of the packages examined contained larval cast skins, integument fragments or setae of a dermestid beetle, *Dermestes* sp., that is a frequent phoretic host for the deutonymph of *L. konoi.* The presence of these dermestids accounts for the mite infestation in some of the lizard carcasses. No adult beetles were found. This interception record is the first evidence that *L. konoi* will infest carcasses of food products other than fish or shellfish under natural conditions. It is the first record of any species of the genus *Lardoglyphus* Oudemans 1927 from the carcass of a reptile.

I thank Ron Crombie (USNMNH) for the determination of *G. gecko* carcasses and Mary E. Roberson (FDA Los Angeles) for assistance in extracting mite specimens from the lizard carcasses.

Alan R. Olsen, U.S. Food and Drug Administration, 1521 W. Pico Blvd., Los Angeles, CA 90015.

PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 115–125

Three New Species of *Essigella* (Homoptera: Aphididae)

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Essigella Del Guercio is a needle-feeding, linear-bodied genus of nearctic conifer aphids occurring on the Pinaceae. The genus has long been the subject of neglect and confusion among lachnines; currently 21 species names exist (Eastop and Hill Ris Lambers, 1976). After the generic description (Del Guercio, 1909), based upon *Lachnus californica* (Essig) (Essig, 1909), three species were added to the genus: *E. pini* Wilson (Wilson, 1919), *E. hoerneri* Gillette & Palmer and *E. fusca* Gillette & Palmer (Gillette and Palmer, 1924). The genus then sat taxonomically dormant until Hottes (1957, 1958) described 17 additional species. Unfortunately, all but four of Hottes' names are synonyms, and his key (Hottes, 1957) does not work because he failed to understand the complexity of character variation in the genus.

In response, Sorensen (in prep. a) revises the genus and provides a functional key, based upon multivariate analyses (Sorensen, 1983). Sorensen (1987) deduces a phylogeny for *Essigella*, based upon a new technique of using discriminant analysis with maximum-likelihood network generation algorithms. Most new species to be added to the genus (Sorensen, in prep. a) are members of species-complexes or groups, and require quantitative circumscription using multivariate techniques (Sorensen, in prep. b). Three, however, are not members of groups involving existing species and are described here. Measurements are given in ranges, followed by means and standard deviations, from individuals throughout the range of each species.

Essigella kathleenae Sorensen, NEW SPECIES
(Figure 1)

Type Series—USA, California, San Bernardino Co., 3 km S. jct. Hwy. 38 & Jenks Lake Rd., San Bernardino Mts., 2200 m, 16 SEP 1977, J. T. Sorensen, *Pinus lambertiana*; Sorensen 77I38. *Holotype*—vivip. apt.; on slide with 3 paratype vivip. apt., holotype at upper left (11 o'clock position). *Paratypes*—30 vivip. apt., same data, on 7 slides including holotype slide. Holotype retained in Sorensen collection, eventually to be deposited B.M.(N.H.), London; Paratype slides deposited: 1 slide in N.M.N.H., Washington DC, and 9 slides in Sorensen collection.

Viviparous Apterae—*Morphology* (n = 20): Body length: 1.35–2.01 (1.67 ± 0.18) mm. HEAD: Primary rhinarium on terminal antennal segment (V) not exceptionally distad, distance from tip of processus terminalis to distal face of rhinarial rim greater than 0.5 times diameter of rhinarium; distal face of rhinarial rim usually oblique to longitudinal axis of antennal segment; rhinarial membrane not conspicuously protuberant. Length of antennal segment V: 85–113 (102 ± 7) μ, processus terminalis: 28–43 (40 ± 4) μ; IV: 60–90 (75 ± 9) μ; III: 98–135 (118 ± 11)

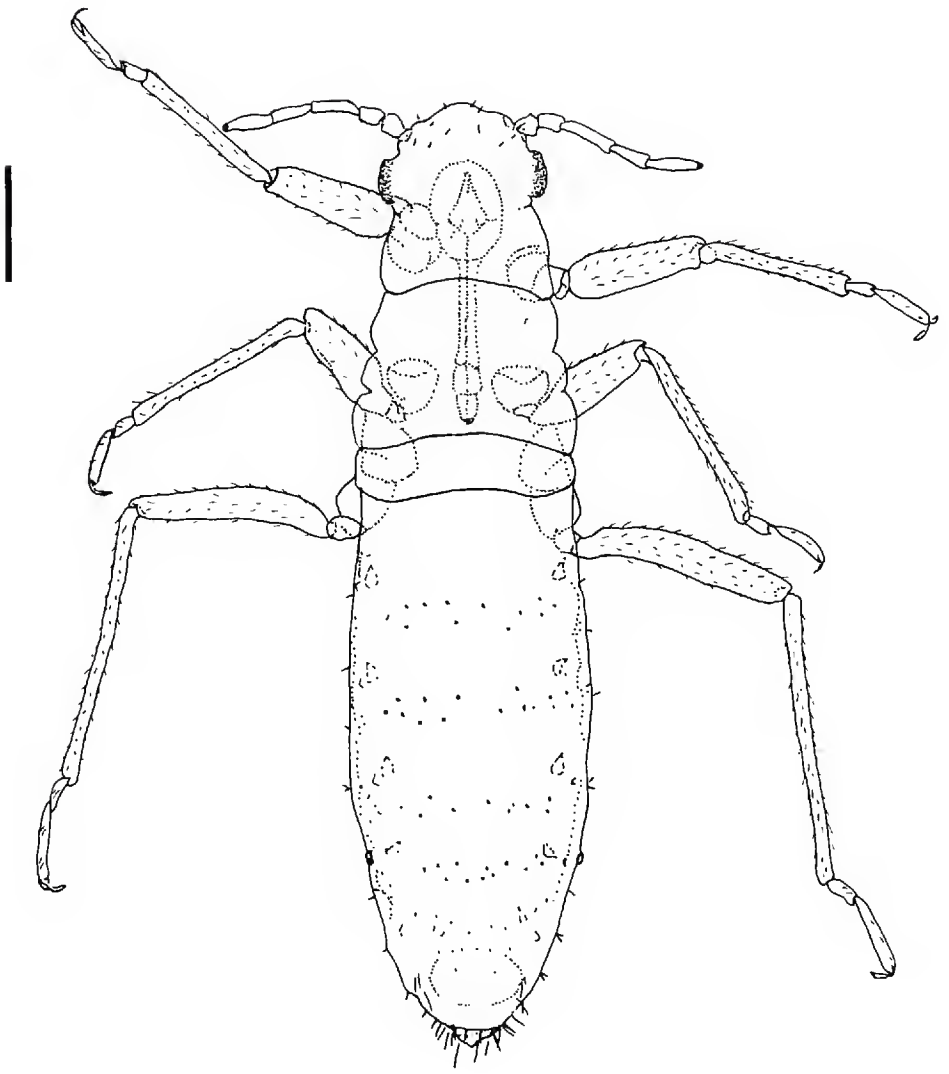

Figure 1. *Essigella kathleenae* n. sp. (viviparous aptera), type locality, 16 Sept. 1977 on *Pinus lambertiana* (JTS 77I38). Body setae omitted except frontals and setal positions on dorsum of abdomen. Measurement reference bar (upper left) = 0.2 mm.

μ; II: 55–68 (62 ± 4) μ. Longest frontal hairs: 8–25 (17 ± 6) μ, tips incrassate. Width of head: 215–258 (242 ± 11) μ. Length of stylets: 428–653 (581 ± 64) μ; ultimate rostral segment: 55–78 (66 ± 5) μ, rostral tip reaching metathorax to abdominal segment 3. Length of head + pronotum: 286–377 (334 ± 31) μ. THORAX: Length of mesothorax: 214–306 (280 ± 31) μ; metathorax: 93–133 (119 ± 12) μ. Meso- and metathorax not fused. ABDOMEN: Maximum distal width of flange on siphunculi: 23–38 (32 ± 4) μ; siphunculi flush to truncated conical, protrusion to 0.5 times maximum distal width. Ventral abdominal sclerites on segments II–IV subcircular, subquadrate to subelliptical; length: 36–60 (48 ± 8) μ, 1.3–2.1 times diameter of metatibiae. Dorsal hairs on abdominal terga II–IV: 11–14 (12 ± 1), tips sharp, in 2 irregular rows; marginal hairs 4–5 per segment each side. Hairs on abdominal tergum VIII: 7–13 (10 ± 2), length: 5–40 (14 ± 10) μ, tips incrassate to sharp, in 2 irregular rows. Cauda rounded; caudal protuberance moderately developed, to infrequently nearly absent; length of longest caudal hairs: 40–93 (61 ± 16) μ, tips sharp. LEGS: Length of metafemora: 316–541 (448 ± 67) μ; metatibiae: 428–704 (569 ± 77) μ; longest dorsal hairs on central one-third of metatibiae: 5–23 (13 ± 6) μ, 0.1–0.8 times diameter of metatibiae, tips incrassate; approximately equal or very gradually increasing distally, no hair length

dimorphism; longest ventral hairs on metatibiae: 10–25 (19 ± 5) μ, tips sharp. Length of metabasitarsus: 60–95 (79 ± 10) μ; metadistitarsus: 135–180 (162 ± 12) μ. Ratio of metadistitarsus to metabasitarsus averaging 2.05:1, greater than 1.9:1, and usually greater than 2.0:1.

*Pigmentation:*Color in life: Pale yellow throughout. Prepared specimens: Background of body dorsum pale (usually to 10, sometimes to 30, percent pigment density), unicolorous. Frontal hair bases and dorsal hair bases of abdomen concolorous with surrounding terga. Thoracic muscle attachment plates and dorsal muscle attachment plates of abdomen, pale, inconspicuous. Spiracular plates and ventral abdominal sclerites pale. Siphunculi concolorous with surrounding terga. Cauda, anal and subgenital plates pale, concolorous with abdominal terga, to slightly darker. Antennal segments V and IV pale, only very subtly darker than body dorsum, III very pale to distal one-third pale as V and IV; II concolorous with proximal III; I concolorous with frons. Pro-, meso- and metatibiae usually pale, concolorous with body dorsum, to very subtly darker. Distitarsi entirely pale to subtly dusky on distal one-third.

Ultimate Stadium Nymphs of Viviparous Apterae—Prepared specimens: Non-morphometrics as described for viviparous apterae except lacking body dorsum pigmentation syndrome; abdominal terga membranous with dorsal hairs, between muscle attachment plates, arising from distinct scleroites. Mesonotum with 2 sclerotized plates extending from muscle attachment sites to engulf neighboring hair bases; plates usually vague, faintly pigmented, diameter approximately equaling eye length.

Oviparae—Prepared specimens: Non-morphometrics as described for viviparous apterae, abdominal terga 1–7 fused, lightly to moderately sclerotic, including pleural areas, tergum 8 free; dorsal demarcations of anterad terga not evident; siphunculi incorporated into sclerotic dorsum; dorsal abdominal muscle attachment plates pale, unicolorous. Pseudorhinaria on metatibiae irregular, difficult to distinguish, 5–9.

Viviparous Alatae, Males, Fundatrices—Unknown.

Diagnosis—*Essigella kathleenae* can very usually be identified by the unique, exceptionally long metadistitarsus and short metabasitarsus. The length ratio of the metadistitarus to metabasitarus usually exceeds 2.0:1, and only rarely approaches 1.9:1, the upper value for all other *Essigella*, except some *E. kirki* (see: *E. kirki* diagnosis) *Essigella kathleenae* is consistently pale and yellow in life.

Discussion—*E. kathleenae* occurs in California and southwestern Oregon on *Pinus lambertiana*. It is considered monophagous, although rare collections have been made on other pine species, probably in part though my collection error. *E. kathleenae* is most closely related to *E. kirki*, which together are the most primitive group of *Essigella* (Sorensen, 1987). The species is named for my wife Kathleen H. Sorensen, who accompanied me in the field as my botanist, and encouraged the upcoming revision of this genus. Her help is greatly appreciated.

Material Examined—*CALIFORNIA*. CALAVERAS Co.: 18 km E. Arnold, Hwy. 4, 1680 m, 17–vii–1977, J. T. Sorensen (JTS 77G45), *P. lambertiana*, (apt.). DEL NORTE Co.: Panther Flat Cmpgd., Six Rivers Nat'l. Forest, Pioneer Rd. & Hwy. 199, E. Gasquet, 4–vii–1978, J. T. Sorensen (JTS 78G7), *P. monticola*, (apt.). EL DORADO Co.: Lake Tahoe, Emerald Bay, 1980 m, 16–vii–1977, J. T. Sorensen (JTS 77G30), *P. lambertiana* (apt.). FRESNO Co.: jct. Hwy. 180 & Sequoia Lake turnoff, nr. Pinehurst, 1710 m, 13–viii–1977, J. T. Sorensen (JTS 77H10), *P.*

lambertiana, (apt.). KERN Co.: Tiger Flat Rd., N. Hwy. 155, nr. Alta Sierra, 1890 m, 20–ix–1977, J. T. Sorensen (JTS 77I64), *P. lambertiana*, (apt.); *ibid.*, (JTS 77I66), *P. jeffreyi*, (apt.). LOS ANGELES Co.: 3 km S.E. Big Pines, Hwy. 2, E. Blue Ridge Summit, 2200 m, 17–ix–1977, J. T. Sorensen (JTS 77I48), *P. lambertiana,* (apt., ovip.). MARIPOSA Co.: Yosemite Nat'l. Park, 13 km W. Crane Flat, jct. Hwy. 120, 2140 m, 1–viii–1977, J. T. Sorensen (JTS 77H6), *P. lambertiana*, (apt.). MENDOCINO Co.: Fish Rock Rd., 27 km E. Hwy. 1, 490 m, 23–vii–1977, J. T. Sorensen (JTS 77G49), *P. lambertiana,* (apt.). MONTEREY Co.: Cone Peak Rd., 13 km N. jct. Nacimento-Fergusson Rd., Los Pardes Nat'l. Forest, 1310 m, 4–ix–1977, J. T. Sorensen (JTS 77I10), *P. lambertiana,* (apt.). PLACER Co.: 5 km S.W. Whitmore, Hwy. 80, 1430 m, 25–vi–1977, J. T. Sorensen (JTS 77F2), *P. lambertiana* (apt.). PLUMAS Co.: 6 km W. jct. Hwy. 36 & 89 on 36, 1460 m, 10–vii–1977, J. T. Sorensen (JTS 77G22), *P. lambertiana,* (apt.); 8 km E. Chester, Hwy. 36, 1520 m, 4–vii–1977, J.T. Sorensen (JTS 77G16), *P. lambertiana*, (apt.). RIVERSIDE Co.: South Ridge Rd., nr. Idyllwild, 1770 m, 9–ix–1977, J. T. Sorensen (JTS 77I21), *P. lambertiana,* (apt.). SAN BERNARDINO Co.: (type series) San Bernardino Mts., 3 km S. jct. Hwy. 38 & Jenks Lake Rd., 2200 m, 16–ix–1977, J. T. Sorensen (JTS 77I38), *P. lambertiana,* (apt.); *ibid.*, 3 km S. Lake Gregory, 1490 m, 17–ix–1977, (JTS 77I45). SISKIYOU Co.: Mt. Shasta Ski Bowl Rd., 2450 m, 2–vii–1977, J. T. Sorensen & D. J. Voegtlin (JTS 77G8), *P. lambertiana,* (apt.). TEHAMA Co.: Lanes Valley Rd., nr. jct. Hwy. 36, 490 m, 4–vii–1977, J. T. Sorensen (JTS 77G17), *P. sabiniana,* (apt.). TRINITY Co.: E. of County Line Rd., 5 km S. Buckhorn Summit of Hwy. 299, W. Tower, 1530 m, 20–viii–1977, J. T. Sorensen (JTS 77H19), *P. lambertiana,* (apt.). TUOLUMNE Co.: 2 km E. Groveville, Hwy. 120, 910 m, 30–vii–1977, J. T. Sorensen (JTS 77G62), *P. lambertiana*, (apt.); *ibid.,* (JTS 77G63), *P. ponderosa,* (apt.). VENTURA Co.: Reyes Peak Rd., 10 km E. Pine Mt. Summit of Hwy. 33, 2200 m, 19–ix–1977, J. T. Sorensen (JTS 77I58), *P. lambertiana,* (apt.). *OREGON*. JACKSON Co.: 15 km S. Union Creek, Hwy. 62, 850 m, 5–vii–1978, J. T. Sorensen (JTS 78G17), *P. lambertiana,* (apt.).

Essigella alyeska Sorensen, New Species
(Figure 2)

Type Series—USA, Alaska, College (Univ. Alaska campus), nr. Fairbanks, 24 JUN 1979, J. T. Sorensen, *Picea glauca;* Sorensen 79F1. *Holotype*—vivip. apt.; on slide with 1 paratype vivip. apt., holotype on top (12 o'clock position). *Paratypes*—25 vivip. apt. same data, on 13 slides including holotype slide. Holotype retained in Sorensen collection, eventually to be deposited B.M.(N.H.), London; Paratype slides deposited: 1 slide in N.M.N.H., Washington DC, and 12 slides in Sorensen collection.

Viviparous Apterae—*Morphology* (n = 10): Body length: 1.42–1.65 (1.51 ± 0.07) mm. HEAD: Primary rhinarium on terminal antennal segment (V) not exceptionally distad, distance from tip of processus terminalis to distal face of rhinarial rim greater than 0.5 times diameter of rhinarium; distal face of rhinarial rim usually oblique to longitudinal axis of antennal segment; rhinarial membrane not conspicuously protuberant. Length of antennal segment V: 100–120 (108 ± 8) μ, processus terminalis: 28–38 (34 ± 4) μ; IV: 83–98 (86 ± 5) μ; III: 138–170 (151 ± 11) μ; II: 63–73 (67 ± 3) μ. Longest frontal hairs: 33–53 (41 ± 7) μ, tips

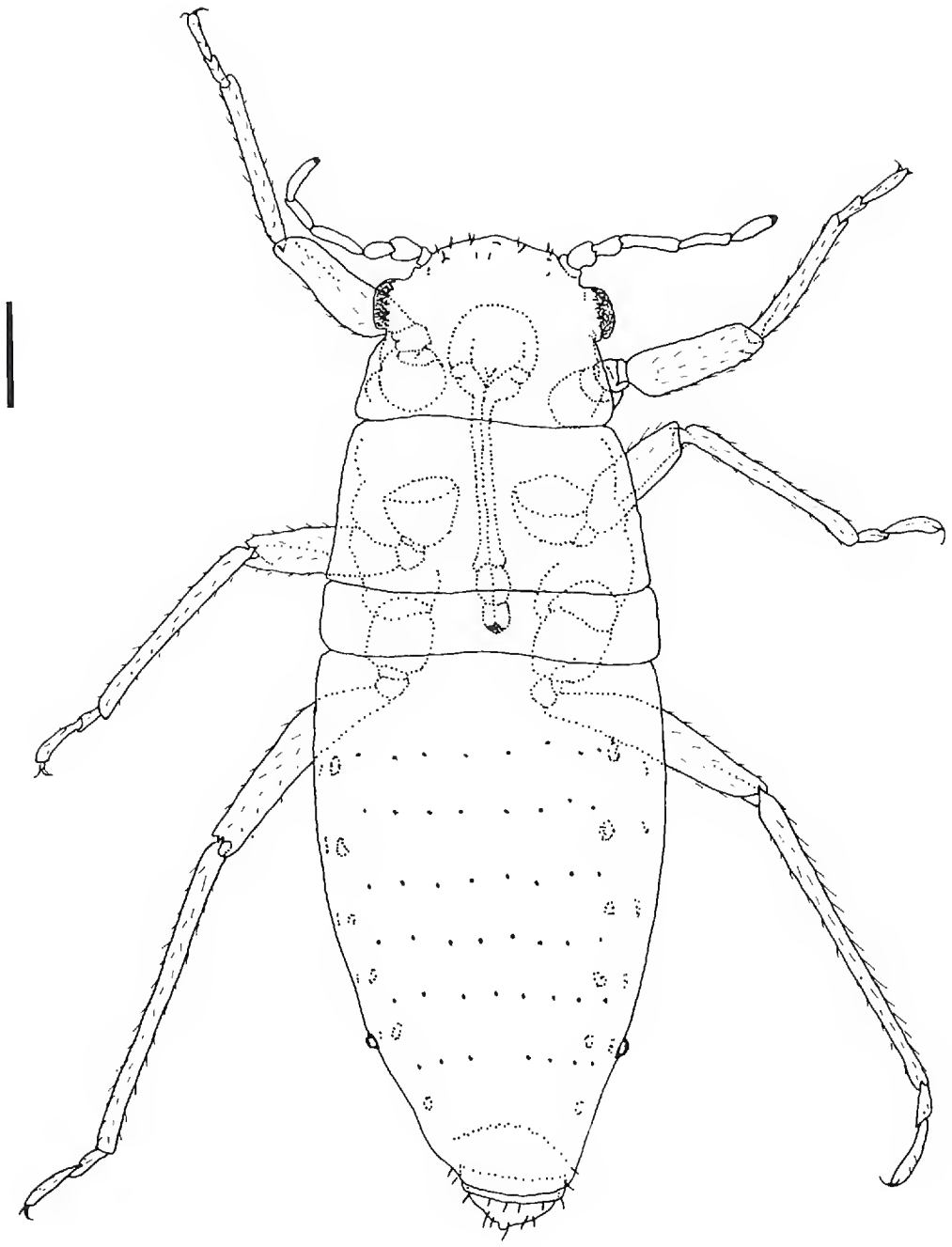

Figure 2. *Essigella alyeska* n. sp. (viviparous aptera), Perrault Falls, Ontario, 17 July 1963 on *Pinus banksiana* (APV 63–147–0). Body setae omitted except frontals and setal positions on dorsum of abdomen. Measurement reference bar (upper left) = 0.2 mm.

incrassate, rarely sharp. Width of head: 286–301 (292 ± 6) μ. Length of stylets: 561–775 (600 ± 69) μ; ultimate rostral segment: 63–85 (74 ± 8) μ, rostral tip reaching metathorax to abdominal segment 1. Length of head + pronotum: 337–388 (361 ± 16) μ. THORAX: Length of mesothorax: 265–316 (298 ± 17) μ; metathorax: 102–118 (108 ± 7) μ. Meso- and metathorax not fused. ABDOMEN: Maximum distal width of flange on siphunculi: 43–48 (46 ± 2) μ; siphunculi strongly protuberant, protruding 0.7–1.1 times maximal distal width. Ventral abdominal sclerites on segments II–IV irregular, to subcircular when large; length: 26–40 (35 ± 5) μ, 0.8–1.4 times diameter of metatibiae. Dorsal hairs on abdominal terga II–IV: 7–9, usually 8, tips sharp, in 1 row; marginal hairs 2 each side, per segment. Hairs on abdominal tergum VIII: 6–8, length: 15–45 (36 ± 10) μ, tips incrassate to sharp, in 1 row. Cauda broadly rounded; caudal protuberance poorly developed to absent; length of longest caudal hairs: 83–100 (91 ± 7) μ, tips sharp. LEGS: Length

of metafemora: 428–520 (488 ± 33) μ; metatibiae: 663–785 (731 ± 44) μ; longest dorsal hairs on central one-third of metatibiae: 30–45 (38 ± 5) μ, 0.7–1.5 times diameter of metatibiae, tips incrassate, rarely sharp; approximately equal or very gradually increasing distally, no hair length dimorphism; longest ventral hairs on metatibiae: 23–33 (28 ± 7) μ, tips sharp. Length of metabasitarsus: 95–103 (99 ± 2) μ; metadistitarsus: 135–158 (147 ± 8) μ. Ratio of metadistitarsus to metabasitarsus averaging 1.48:1, less than 1.9:1.

Pigmentation: Color in life: Body gray-green, head yellow-orange. Prepared specimens: Background of body dorsum pale to light brown (to 20 percent pigment density), unicolorous. Frontal hair bases and dorsal hair bases of abdomen concolorous with surrounding terga. Thoracic muscle attachment plates and dorsal muscle attachment plates of abdomen pale, inconspicuous, to moderate brown, conspicuous. Spiracular plates and ventral abdominal sclerites pale, to dark brown, conspicuous. Siphunculi concolorous with surrounding terga, to subtly darker, especially distally near flange. Cauda, anal and subgenital plates light to moderate brown, subtly to substantially darker than abdominal terga. Antennal segments V and IV light to moderate brown, IV sometimes proximally pale; III pale if proximal IV pale, to dusky on distal one-half, if IV entirely darker; II subtly darker than proximal III; I as dark as V, or nearly so, and subtly darker than frons. Pro-, meso- and metatibiae usually concolorous, pale, equivalent to body dorsum, sometimes slightly dusky on distal tip, entire tibiae infrequently slightly darker. Distitarsi entirely dusky.

Ultimate Stadium Nymphs of Viviparous Apterae—Prepared specimens: Non-morphometrics as described for viviparous apterae except lacking body dorsum pigmentation syndrome; abdominal terga membranous with dorsal hairs, between muscle attachment plates, arising from distinct scleroites. Mesonotum lacking 2 sclerotized plates extending from muscle attachment sites to engulf neighboring hair bases; area surrounding muscle attachment sites membranous.

Viviparous Alatae—Prepared specimens: Non-morphometrics as described for viviparous apterae except lacking body dorsum pigmentation syndrome; abdominal terga normally membranous, dorsal hairs between muscle attachment plates sometimes arising from distinct scleroites; antennal segments often as dark as tibiae, except proximal one-fifth of III pale. Antennal segment III with 0–2, IV with 0, secondary rhinaria. Epicranial suture absent to weakly developed. Forewing medius with furcation arising on central one-third of vein; cubital base usually arising distad, uncommonly proximad, on subcosta with distance between anal and cubital bases on subcosta usually relatively large, ca. 20–40 percent or more of anal vein length; medius, especially cubitus and anal veins usually distinct, except infrequently proximad 10–15 percent vague. Abdominal terga lacking irregular sclerites which engulf or join muscle attachment plates and dorsal hair bases or scleroites.

Oviparae, Males, Fundratrices—Unknown.

Diagnosis—*Essigella alyeska* requires the combination of all the following characters for identification, since the species may be confused with other pale *Essigella*: 8 dorsal and 2 marginal hairs on abdominal terga 2–4; 6, probably rarely to 8, hairs on abdominal tergum 8; presence of (usually) small, often asterisk-like, (instead of always large, sub elliptical) ventral abdominal sclerites on segments 2–4; absence of a lateral fusion of the meso- and metathoraces; absence of an exceptionally protuberant primary rhinarium; small non-invasive mesonotal muscle attachment plates on later stadia nymphs of apterae.

Discussion—*E. alyeska* is an uncommon species ranging from the interior of Alaska, on *Picea glauca*, to lower eastern Canada, on *Pinus banksiana*. My sampling of *Pinus, Picea glauca*, and other *Picea*, over their ranges in western Canada and the western U.S. have not yielded the aphid; nor was it easily found sampling *Picea glauca* throughout central Alaska. Samples from Quebec and Ontario exist, however, on *Pinus banksiana*. I anticipate that *E. alyeska* will be found in the northern Rocky Mountains in the U.S., and across Canada, wherever the hosts occur. *E. alyeska* is a broad-shaped species (see: Sorensen, in prep. a), but body width characteristics are not suggested here because of the measurement error often associated with non-standardized (compressed) slides made by others; I have attempted to standardize my *Essigella* slides for non-compression (Sorensen, 1983). *E. alyeska* is related to the *E. knowltoni* complex (*E. knowltoni* and *E. braggi*, plus an undescribed member) that feed on the western members of *Pinus (Pinus)* Subsection Contortae (Sorensen, 1987), of which *P. banksiana* is an eastern member (Little and Critchfield, 1969). The limited collections of *E. alyeska* (4) preclude adequate understanding of probable variation over its range. The aphid's species name is the Athabascan Indian term for "Alaska."

Material Examined—*ALASKA*. 20 km N. of E. entrance Mt. McKinley Nat'l. Park, 15–vii–1979, J. T. Sorensen (JTS 79G1), *Picea glauca*, (apt.); (type series) College, (Univ. Alaska Campus), nr. Fairbanks, 24–vi–1979, J. T. Sorensen (JTS 79F1), *Picea glauca*, (apt.). *ONTARIO*. Perrault Falls, 17–vii–1963, G. A. Bradley (63–147–0–APV), *Pinus banksiana*. *QUEBEC*. St. Bruno, Lac St. Jean, 10–xiii–1985, A. St. Hilaire, *Pinus banksiana*.

Essigella kirki Sorensen, New Species
(Figure 3)

Type Series—USA, New Mexico, Santa Fe Co., ca. 30 km N.E. Santa Fe, Hwy. 475, 3100 m, 10 AUG 1978, J. T. Sorensen, *Pinus flexilis;* Sorensen 78H55. *Holotype*—vivip. apt.; on slide with 3 paratype vivip. apt., holotype at lower left (8 o'clock position). Paratypes—19 vivip. apt., same data, on 5 slides including holotype slide. Holotype retained in Sorensen collection, eventually to be deposited B.M.(N.H.), London; Paratype slides deposited: 1 slide in N.M.N.H., Washington DC, and 3 slides in Sorensen collection.

Vivparous Apterae—*Morphology* (n = 20): Body length: 1.73–2.13 (1.92 ± 0.13) mm. HEAD: Primary rhinarium on terminal antennal segment (V) not exceptionally distad, distance from tip of processus terminalis to distal face of rhinarial rim greater than 0.5 times diameter of rhinarium; distal face of rhinarial rim usually oblique to longitudinal axis of antennal segment; rhinarial membrane not conspicuously protuberant. Length of antennal segment V: 95–133 (117 ± 10) μ, processus terminalis: 28–45 (37 ± 5) μ; IV: 70–91 (82 ± 7) μ; III: 141–188 (157 ± 15) μ; II: 63–73 (68 ± 3) μ. Longest frontal hairs: 10–43 (28 ± 9) μ, tips incrassate. Width of head: 245–316 (285 ± 19) μ. Length of stylets: 530–694 (608 ± 55) μ; ultimate rostral segment: 68–83 (76 ± 5) μ, rostral tip reaching metathorax to abdominal segment 1. Length of head + pronotum: 367–439 (399 ± 24) μ. THORAX: Length of mesothorax: 296–388 (347 ± 28) μ; metathorax: 112–163 (138 ± 15) μ. Meso- and metathorax not fused. ABDOMEN: Maximum distal width of flange on siphunculi: 45–55 (50 ± 4) μ; siphunculi nearly flush to truncated conical, protruding to 1.0 times maximal distal width. Ventral abdominal sclerites on segments II-IV subquadrate, subcircular to subelliptical;

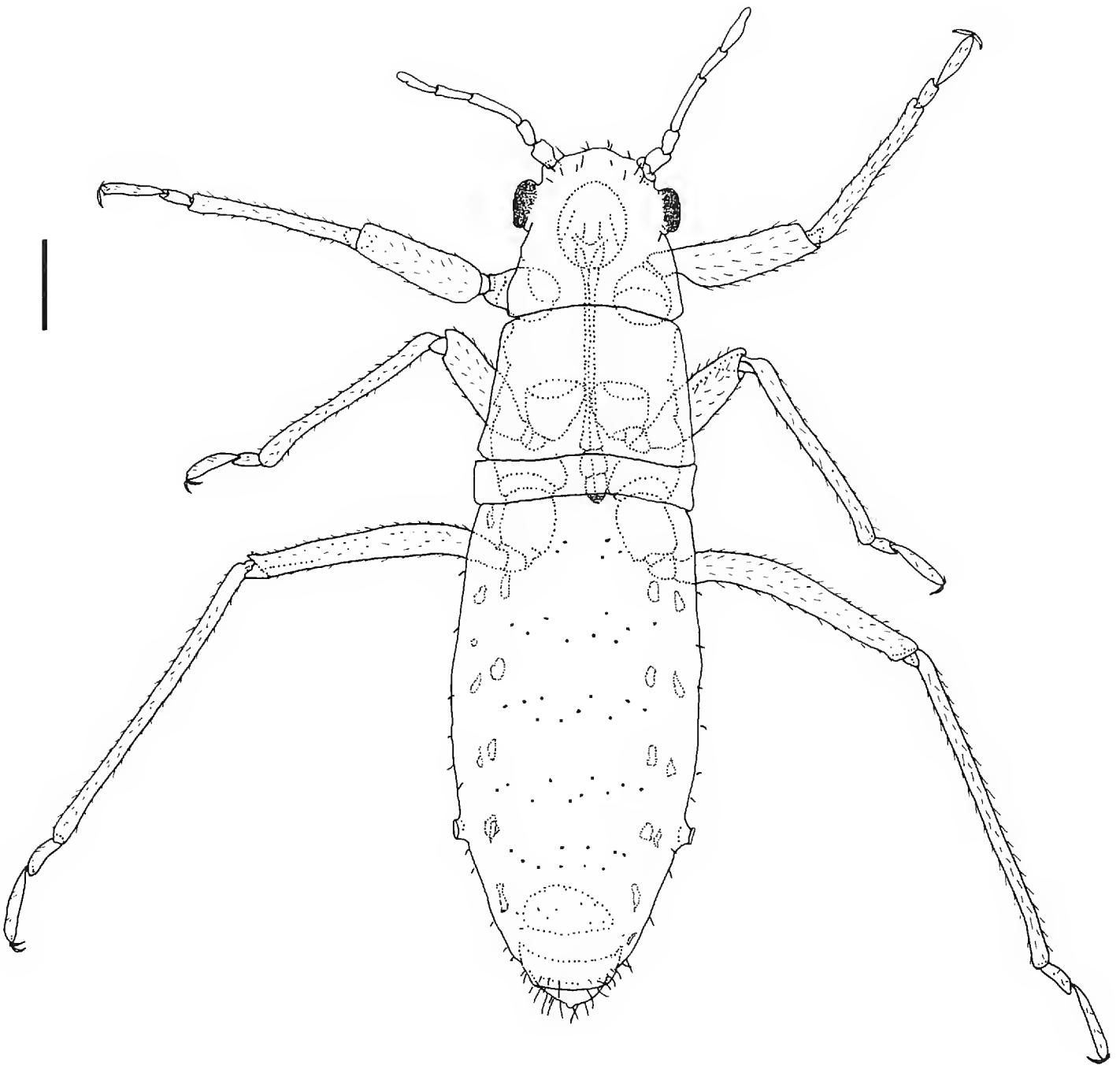

Figure 3. *Essigella kirki* n. sp. (viviparous aptera), type locality, 10 Aug 1978 on *Pinus flexilis* (JTS 78H55). Body setae omitted except frontals and setal positions on dorsum of abdomen. Measurement reference bar (upper left) = 0.2 mm.

length: 50–68 (59 ± 6) μ,. 1.2–2.0 times diameter of metatibiae. Dorsal hairs on abdominal terga II-IV: 10–14 (11 ± 1), tips sharp, in 2 irregular rows, lateral-most hair usually in anterad row; marginal hairs 4–6 per segment each side. Hairs on abdominal tergum VIII: 10–14 (11 ± 1), length: 5–43 (23 ± 11) μ, tips incrassate to rarely sharp, in 2 irregular rows. Cauda rounded; caudal protuberance moderately developed to frequently nearly absent; length of longest caudal hairs: 70–103 (86 ± 10) μ, tips sharp. LEGS: Length of metafemora: 500–663 (578 ± 53) μ; metatibiae: 622–900 (755 ± 70) μ; longest dorsal hairs on central one-third of metatibiae: 20–30 (24 ± 3) μ, 0.1–0.6 times diameter of metatibiae, tips incrassate, approximately equal or very gradually increasing distally, no hair length dimorphism; longest ventral hairs on metatibiae: 13–28 (23 ± 4) μ, tips sharp. Length of metabasitarsus: 93–118 (104 ± 7) μ; metadistitarsus: 165–213 (188 ± 13)

μ. Ratio of metadistitarsus to metabasitarsus averaging 1.81:1, usually less than 1.9:1, rarely reaching 2.0:1 or slightly more.

Pigmentation: Color in life: Gray-green, occasionally pale yellow throughout. Prepared specimens: Background of body dorsum pale (to 10 percent pigment density), unicolorous. Frontal hair bases and dorsal hair bases of abdomen concolorous with surrounding terga. Thoracic muscle attachment plates pale, inconspicuous to conspicuous. Dorsal muscle attachment plates of abdomen conspicuous, pale, infrequently dusky. Spiracular plates and ventral abdominal sclerites usually light brown, slightly darker than background of abdominal terga, to pale. Siphunculi concolorous with surrounding terga. Cauda, anal and subgenital plates concolorous with abdominal terga. Antennal segments V and IV slightly to moderately dusky over entire segment, to moderately brown distally; III pale; II and I concolorous with frons. Pro-, meso- and metatibiae usually pale, concolorous, equivalent to body dorsum; frequently tibiae subtly dusky at distal tip, rarely entire tibiae moderately dusky, slightly darker than body dorsum. Distitarsi usually subtly dusky distally to moderate brown, varying with antennae, infrequently entirely dusky with tibiae.

Ultimate Stadium Nymphs of Viviparous Apterae—Prepared specimens: Non-morphometrics as described for viviparous apterae except lacking body dorsum pigmentation syndrome; abdominal terga membranous with dorsal hairs, between muscle attachment plates, arising from distinct scleroites. Mesonotum with 2 sclerotized plates extending from muscle attachment sites to engulf neighboring hair bases; plates usually vague, faintly pigmented, diameter approximately equaling eye length.

Oviparae—Prepared specimens: Non-morphometrics as described for viviparous apterae except abdominal terga 1–6 fused, lightly to moderately sclerotic, including pleural areas, while 7 and 8 free; dorsal demarcations of anterad terga not evident; siphunculi usually incorporated into sclerotic dorsum, to free; dorsal abdominal muscle attachment plates pale, unicolorous except those between terga 6–7 darker. Pseudorhinaria on metatibiae irregular, difficult to distinguish, 7–11.

Viviparous Alatae, Males, Fundatrices—Unknown.

Diagnosis—*Essigella kirki* can easily be confused with other pale individuals of *Essigella* and requires the following character combination for identification: 10 or more dorsal hairs on abdominal terga 2–4 in 2 rows with (usually) the lateral-most hair in the anterad row; usually 10 or more hairs on the dorsum of abdominal tergum 8; lacking a protuberant, exceptionally distad primary rhinarium; having a metadistitarsus to metabasitarsus ratio of usually less than 1.9:1, but rarely to 2.0:1 (mean: 1.81:1 for *E. kirki*, 2.05:1 for *E. kathleenae*). Even with these attributes, *E. kirki* can still be confused with pale specimens of *E. fusca* and *E. braggi* (as well as other undescribed *Essigella* [Sorensen, in prep. a]). Most pale *E. fusca* and some pale *E. braggi* separate by having the longest dorsal hairs on the central part of the mesotibia more than 0.7 times tibial diameter, and usually less than 10 hairs on the dorsum of abdominal tergum 8. All observed *E. braggi* with 10 or more dorsal hairs on abdominal terga 2–4 and 8 differ from *E. kirki* by having the longest dorsal metatibial hairs in excess of 1.0 times tibial diameter. Rare confusing *E. braggi* are anticipated, and could be separated by their broad head on non-compressed slides, and by usually longer frontal hairs (see: Sorensen in prep. a, 1983).

Discussion—*E. kirki* is a common, very nearly monophagous species, which feeds on *Pinus flexilis* and *P. strobiformis*. It ranges with these hosts throughout the Rocky

Mountains, from Montana to Arizona and New Mexico; southern Sierra Nevada (east slope) and White Mountains of California; presumably into Mexico. *E. kirki* is closest in relationship to *E. kathleenae*, but differs in bivariate plots of (a) head width between the outer antennal socket rims vs body length and (b) metadistitarus vs metabasitarsus lengths, and in discriminant function and principal component delimitations employing the 26 characters used by Sorensen (in prep. a, 1983) to circumscribe all *Essigella* species. *E. kirki* is relatively homogenous morphologically, and always pale unlike several other *Essigella* species which can grade from pale to fully pigmented syndromes; in this respect it resembles *E. kathleenae*. *E. kirki*'s only apomorphy, a bipartite sclerotic dorsum of the oviparae differs from more fused oviparae shield of *E. kathleenae*, and appears to be a homoplasy with the *Essigella fusca* complex (see: Sorensen in prep a, 1983). The species is named for my son Kirk H. Sorensen.

Material Examined—*ARIZONA*. APACHE Co.: Lake Harney Rd. (Hwy. 473), nr. McNary, 2440 m, 11–ix–1978, J. T. Sorensen (JTS 78I14), *P. strobiformis*, (apt.). COCHISE Co.: nr. Rustler Park, Chiracahua Mts., 2500 m, 16–ix–1978, J. T. Sorensen (JTS 78I50), *P. strobiformis*, (apt.). *CALIFORNIA*. INYO Co.: Lake Sabrina, nr. Bishop, 2750 m, 1–viii–1977, J. T. Sorensen (JTS 77H2), *P. flexilis*, (apt.). INYO Co.: Onion Valley Cmpgd., 24 km W. Independence, 2770 m, 4–viii–1978, J. T. Sorensen (JTS 78H13), *P. flexilis,* (apt.). *COLORADO*. SAN JUAN Co.: 20 km N. Purgatory, 3020 m, 8–viii–1978, J. T. Sorensen (JTS 78H47), *P. flexilis,* (apt.). *MONTANA*. CARBON Co.: Red Lodge, 1770 m, 20–viii–1978, J. T. Sorensen (JTS 78H115), *P. flexilis,* (apt.). *NEVADA*. WHITE PINE Co.: Wheeler Peak, 3140 m, 26–viii–1978, J.T. Sorensen (JTS 78H147), *P. flexilis*, (apt., ovip.). *NEW MEXICO*. OTERO Co.: 3 km W. Cloudcroft, Hwy. 82, 2560 m, 13–ix–1978, J. T. Sorensen (JTS 78I22), *P. strobiformis*, (apt., ovip.). SANTA FE Co.: (type series) 30 km N.E. Santa Fe, Hwy. 475, 3100 m, 10–viii–1978, J. T. Sorensen (JTS 78H55), *P. flexilis,* (apt.). SIERRA Co.: Emory Pass, Hwy. 90, W. Kingston, 2470 m, 14–ix–1978, J. T. Sorensen (JTS 78I34), *P. strobiformis*, (apt.). *UTAH*. DUCHESNE Co.: 19 km N.E. Castle Gate, Hwy. 33, 2770 m, 25–viii–1978, J. T. Sorensen (JTS 78H144), *P. flexilis,* (apt.). *WYOMING*. ALBANY Co.: 5 km S.W. Woods Landing, Hwy. 230, 2560 m, 15–viii–1978, J. T. Sorensen (JTS 78H92), *P. flexilis*, (apt.).

Essigella Relationships and Nomenclatural Clarification

As noted Sorensen (in prep. a) revises *Essigella*, and details relationships discussed in Sorensen (1983, 1987). While Sorensen (1983) circumscribed all *Essigella* species using multivariate statistical treatments, I consider that work (a thesis) as unpublished for taxonomic nomenclatural purposes under I.C.Z.N. rules (1985: Articles 8–A1, 8–A3, 8–B presently, 8–C, 9–2, 9–3, 9–4 and 9–6). I have thus avoided publishing nomens which could be considered valid under applicable I.C.Z.N. rulings to this point. To clarify matters, however, it should be noted that the new species described here are referred to by the following manuscript names in Sorensen (1983): (1) *"E. kathleenae"* [acronym "KATH"], (2) *"E. alyeska"* [acronym "ALYE"] and (3) *E. kirki* as *"E. hottesi"* [acronym HOTT]. Sorensen (1987) details the proposed phylogeny for the genus, and treats *E. kathleeni* as "sp. J", *E. kirki* as "sp. K" and *E. alyeska* as "sp. D".

Acknowledgments

I thank: R. Foottit (Biosystematics Research Institute, Canada Agriculture, Ottawa, Ontario) and F. W. Quednau (Laurentian Forest Research Centre, Environment Canada, Ste. Foy, Quebec) for providing eastern Canadian samples of *E. alyeska;* K. W. Philip (Institute of Arctic Biol., Univ. Alaska, Fairbanks, Alaska) for making my sampling of *Picea*, north of Fairbanks, possible for *E. alyeska*; D. J. Voegtlin (Illinois Natural History Survey, Champaign, Illinois) for help during the discovery of *E. kathleenae*; Kathleen H. Sorensen for constant aid in field research; S. Sawyer and T. Kono (Insect Taxon. Lab., C.D.F.A.) for the illustrations, and for comments on the manuscript, respectively; and D. Hille Ris Lambers (Bennekom, The Netherlands), V. F. Eastop (British Museum [Natural History], London) and J. A. Powell (Dept. Entomol. Sci., Univ. Calif., Berkeley) for guidance during research on *Essigella*. The patient tutoring of Dirk Hille Ris Lambers in Berkeley and Bennekom is especially appreciated.

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PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 127–130

Winter Arthropods in Selected Habitats of Northern Mixedgrass Prairie

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Abstract.—Arthropods were collected from February through April in southeastern Wyoming using pitfall traps set under cattle dung pats in open habitats and near snow fences. Arthropods were active throughout the winter months. Only adults were collected; beetles were the predominant organisms and spiders were the most numerous predators. Greater arthropod activity occurred near snow banks than in open grassland habitat. Predator abundance increased, while prey abundance decreased, with time. Thus, predator:prey ratios increased from early to late winter.

Studies of arthropods in adverse conditions have been conducted in several ecosystems. There is considerable information concerning arthropod fauna in arctic and high altitude habitats (Laws, 1984; Gottingen, 1968) and chronic cold is perhaps the most intensively studied adverse condition. Several insects have evolved physiological or behavioral mechanisms for protection against cold temperatures. Antifreeze agents, like those in polar fish, accumulate in the hemolymph of various species of insects, particularly overwintering beetles (Duman, 1979; Patterson and Duman, 1979). A variety of insects engage in behavioral thermoregulation in order to function in both excessively hot and cold habitats (Casey, 1981). However, many insects, such as ants and termites, are not well adapted for the cold conditions associated with high latitudes and elevations (Jeanne and Davidson, 1984). While frost resistance and tolerance are taxonomically incongruous (Heinrich, 1981), cold hardiness manifests some ecological consistency. For example, arthropod predators tend to have thermal activity thresholds higher than their prey (Campbell, 1974). Indeed, ecologically stable communities apparently exist and function throughout the winter in subnivean habitats (Aitchison 1984a, b).

Despite a substantial amount of literature on insect ecology in chronically cold habitats, relatively little data are available on the arthropods of periodically cold habitats, such as winter fauna in temperate zones. Specifically, there appears to be no information concerning arthropod activity during winter months in the western rangeland of the United States. This study was undertaken to determine which, if any, arthropod taxa were active during the winter in selected habitats of Wyoming rangeland and to examine the quantitative relationships between predators and prey.

MATERIALS AND METHODS

Forty pitfall traps were randomly placed under individual cattle dung pats, on northern mixedgrass prairie, 14 km northwest of Laramie, Wyoming. Twenty traps

were placed 3 m apart along two intersecting transects in: 1) an open area which was fully exposed to environmental conditions and 2) an area which was protected from wind by an adjacent snow fence and associated snow banks. Traps placed in an open area were subjected to more wind and less snow accumulation than traps placed near snow fences/banks. Pitfall traps were checked every two weeks beginning February 5 and ending April 31. Specimens were placed into vials of 70% ethanol and brought to the laboratory for identification. Thus, the degree of influence of specific habitat conditions on arthropod abundance and overwintering behavior was determined.

Results and Discussion

The winter of 1987 was sporadic in terms of temperature and snowfall (Fig. 1). Temperatures ranged from –15 to 9°C and were above freezing for a number of days. Snowfall was irregular and the exposed areas were clear of snow for long periods of time. However, snow banks formed around snow fences in February and did not melt until mid-April.

In the course of the study, 106 adult arthropods, representing four orders and five families and species were collected from pitfall traps (Table 1). Coleoptera was the most abundant order, followed by Araneae, Homoptera and Acarina. The greatest number of arthropods collected was in March, followed by February and April. The curculionid, *Hyperodes macuicolli* (Kby), was found only in February; the cicadellid, *Cuerna alpina* Melickar, occurred in February and March; the tenebrionid, *Eleodes extricatus* (Say), was found only in April, and the spider, *Schizocosa* sp. and the elaterid, *Anthracopteryx hiemali* Hern, were present February through April. Acari and Coleoptera (Carabidae, Cantharidae and Staphylinidae) are known to be winter-active in subnivean habitats (Aitchison 1979a, b), although this appears to be the first report of winter-active Homoptera, Elateridae and Curculionidae on western rangeland. Lycosid spiders were the only predators found throughout the course of this study. These spiders have also been found to be winter-active in subnivean habitats (Aitchison, 1983, 1984).

Arthropods were ca. 12 times more abundant in protected habitats (n = 98) than in exposed habitats (n = 8), with the greatest differences occurring in February and March. Thus, it appears that the presence of snow banks increased the local abundance of arthropods; the climate in this microhabitat may have been less severe than that of exposed areas. The role of snow banks in increasing arthropod abundance is further supported by the corresponding decrease in arthropod numbers and snow banks in April, despite an increase in the daily mean temperature. *A. hiemali* and *E. extricatus* were the only arthropods found in both exposed and protected habitats. *A. hiemali* was collected from traps placed near snow banks 97% of the time, indicating a strong predilection for protected habitats. *E. extricatus* was found near snow banks only 57% of the time. The apparent lack of preference for protected habitats by *E. extricatus* is reasonable given the decreasing availability of snow banks in April, the time at which this species is active. The remaining arthropods, *H. macuicolli, C. alpina* and *Schizocasa* sp., were found only in protected habitats.

The predator:prey ratio was heavily biased towards prey in February and March (1:12) but reversed to favor predators (2:1) in April. The change in the ratio was due to both an increase in the abundance of *Schizocosa* sp. (from an average of two in

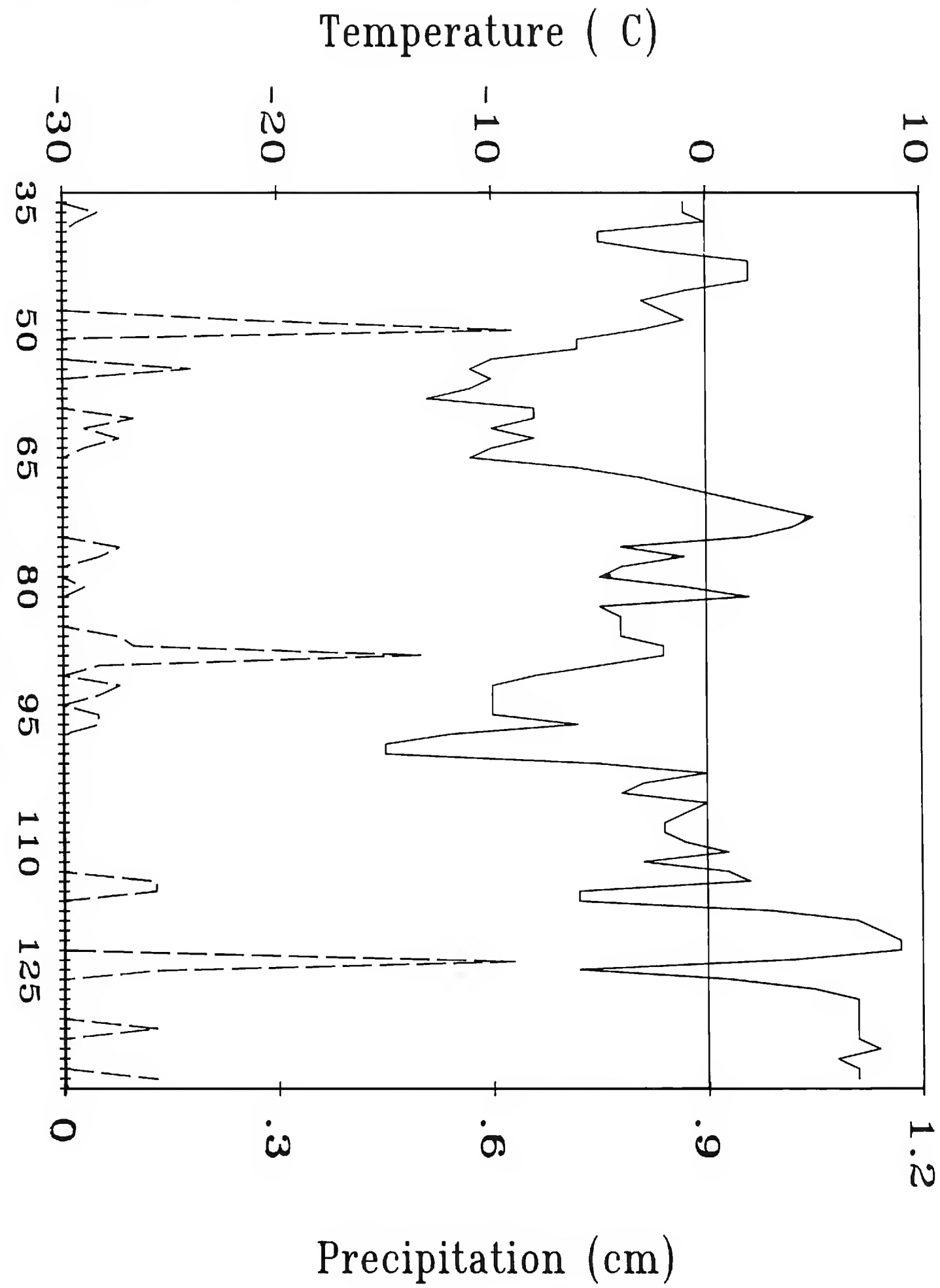

Fig. 1 Mean daily temperature (solid line) and precipitation (broken line) from February through April, 1987 in Albany County, Wyoming.

Table 1. Abundance and predator:prey ratios of rangeland winter adult arthropods collected from selected habitats in Wyoming.

Month	Habitat	Predator: Prey	Taxa present: Order	Family	Genus and Species	No.
Feb.	Exposed	0:1	Coleoptera	Elateridae	*Anthracopteryx hiemali* Hern	2
			TOTAL			2
	Protected	1:16	Coleoptera	Elateridae	*Anthracopteryx hiemali*	20
			Coleoptera	Curculionidae	*Hyperodes macuicolli* (Kby)	2
			Homoptera	Cicadellidae	*Cuerna alpina* Melickar	10
			Araneae	Lycosidae	*Schizocosa* sp.	2
			TOTAL			34
Mar.	Exposed	0:0	TOTAL			0
	Protected	1:10	Coleoptera	Elateridae	*Anthracopteryx hiemali*	36
			Homoptera	Cicadellidae	*Cuerna alpina*	2
			Araneae	Lycosidae	*Schizocosa* sp.	2
			TOTAL			40
Apr.	Exposed	0:1	Coleoptera	Tenebrionidae	*Eleodes extricatus* (Say)	3
			Acari			3
			TOTAL			6
	Protected	2:1	Coleoptera	Elateridae	*Anthracopteryx hiemali*	3
			Coleoptera	Tenbrionidae	*Eleodes extricatus*	4
			Araneae	Lycosidae	*Schizocosa* sp.	15
			TOTAL			22

February and March to 15 in April) and a decrease in the abundance of prey species (from an average of 36 in February and March to seven in April). This shift in predatory:prey ratio is consistent with the general trend of predators having higher thermal activity thresholds than their prey (Campbell, 1974).

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PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 131–137

Macrocephalic Male Bees as Functional Reproductives and Probable Guards

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Abstract.—In the Australian halictine bee *Lasioglossum (Chilalictus) erythrurum,* males are dimorphic; both typical males and large, disproportionately shaped, flightless males occur. The large, macrocephalic males fight with one another for exclusive occupancy of a communal nest and mate with females contained therein. They may also guard against predatory ants, and appear to be fed via oral trophallaxis by females.

More or less isometric size variation among male bees occurs in thousands of species (e.g., Bego and de Camargo, 1984; Alcock et al., 1977). In males of some ground-dwelling, halictine and andrenid bees, however, size variation is accompanied by striking variation in shape (Sakagami et al., 1966; Knerer and Schwarz, 1978; Houston, 1970; Rozen, 1970; Hirashima, 1965). The extreme morphs are on one hand a typical male bee and, on the other, a morph with a disproportionately large head and mandibles, reduced wings, and a broad thorax (Sakagami et al., 1966; Houston, 1970). In some species, such as *Lasioglossum (Chilalictus) erythrurum*, variation in shape takes the form of two discrete morphs and only the extremes are found. In these cases the large, flightless, macrocephalic morph dwells in the nest.

Speculation concerning the function of these unusual males has suggested several hypotheses: (a) the presence of flightless, macrocephalic males is due to a behavioral "mistake" whereby a female places an unfertilized (male-producing) egg on a large, female-sized provision mass (Knerer and Schwarz, 1976, 1978), (b) these males represent a "soldier caste" (Houston, 1970), or (c) macrocephalic males are functional reproductives similar to those found in fig wasps (Hamilton, 1979). Here we present evidence concerning the role of the flightless, macrocephalic morph in nests of *L. erythrurum.*

METHODS

We excavated 10 colonies of *L. erythrurum*. Each consisted of 10 or more adult females, female pupae, and zero (n = 1), one (n = 8), or two (n = 1) macrocephalic males. No larvae or male pupae were present. One nest (containing a single macrocephalic) also contained the only normal male excavated. Presumably, many are present earlier in the season (a single, large nest excavated by M. S. in Nov. 1981 contained 15 adult females, 17 female pupae, 61 normal male pupae and 7 macrocephalic male pupae, 7 prepupae, and 63 larvae). Similarly, within the same species complex, Knerer and Schwarz (1978) report that for *L. (Chilalictus),* sp. 1,

one nest contained 19 female pupae, 13 normal male pupae and 10 macrocephalic pupae and a second nest contained 44 female pupae, 23 normal male pupae and 17 macrocephalic male pupae). For this study, nests were taken from a loose aggregation on the Monash University campus near Melbourne, Australia during late February and March 1985, the time of year when mating and preparations for winter normally occur. The adults and pupae from these field colonies were used to establish artificial colonies in the laboratory, to provide a sample of females for dissection and as subjects in simple experiments.

Seven artificial nests (Michener and Brothers, 1971) were constructed to house colonies consisting of 10 females and a single macrocephalic male all from the same field nest. Two similar nests constructed of plaster-of-paris were used to obtain photographs upon which the line drawings in Figures 1, 2 and 3 are based.

After 10 days for equilibration, four nests were scan sampled every half hour from 9:00 a.m. to 4:00 p.m. for 5 days, and the first seen activity and location was recorded for each macrocephalic male. Continuous observation of 7 nests was carried out for a total of 27 hours over a three-week period.

Two experiments were conducted involving introduction of intruders into laboratory nests (see methods cited in Bell et al., 1974). First, macrocephalic males were introduced into nests already containing a resident macrocephalic male (n = 5) and the interactions observed for 5 minutes. In one case, a male intruder was allowed by the experimenter to remain in the nest. Second, heterospecific intruders, female ants of the genus *Rhytidoponera*, were introduced into nests containing macrocephalic males (n = 3) to determine if macrocephalic males would guard the nests against them. Interactions between macrocephalic males and ants were terminated after one minute to prevent injuries.

Virgin females (collected in the field as pupae and reared in the laboratory) were marked with LPC Office Products correction fluid and introduced into each of 3 nests that contained one macrocephalic male each (total = 6 females, two per nest). After 24 hours they were removed and dissected to determine the contents of the spermathecae. These dissections were conducted on freshly frozen females in Ringer's solution using a stereomicroscope. In addition, up to 10 females from each of 5 natural colonies were dissected (n = 37) and the contents of the spermatheca recorded; similarly, the reproductive system of two adult macrocephalic males was examined (see also Houston, 1970).

Results

Scan samples of macrocephalic male behavior within nests revealed that they spent most of their time sitting at a location where females or intruders entering or leaving the nest could be encountered, that is 3–5 cm below the nest entrance at the junction of the main tunnel with the first main side branch, but only 6% of their time at the nest entrance (see Table 1), the typical station for a female guard in other halictine species (Bell et al., 1974). Continuous nest observation and simple experimentation revealed qualitative information concerning male-male interactions and male-female interactions.

Encounters between macrocephalic males always resulted in fighting (Fig. 1). One intruder was allowed to remain in the nest, it was forced by the occupant to the bottom of the nest, and died within two days. Both macrocephalic males taken from a single field nest were placed in the same laboratory nest where they fought

Table 1. The percentage of time spent at particular locations in the nest and the percentage of time spent performing specific activities for macrocephalic male *Lasioglossum (Chilalictus) erythrurum* in artificial nests.

Location in Nest	%	Behaviors	%
Feeding chamber	4	Sitting	79
Nest entrance	6	Walking	9
Main tunnel	32	Interacting with females	5
Intersection of main tunnel with upper branch	45	Tunneling	5
Side tunnel containing females	6	Grooming	2
Side tunnel not containing females	1		
Not seen	6		

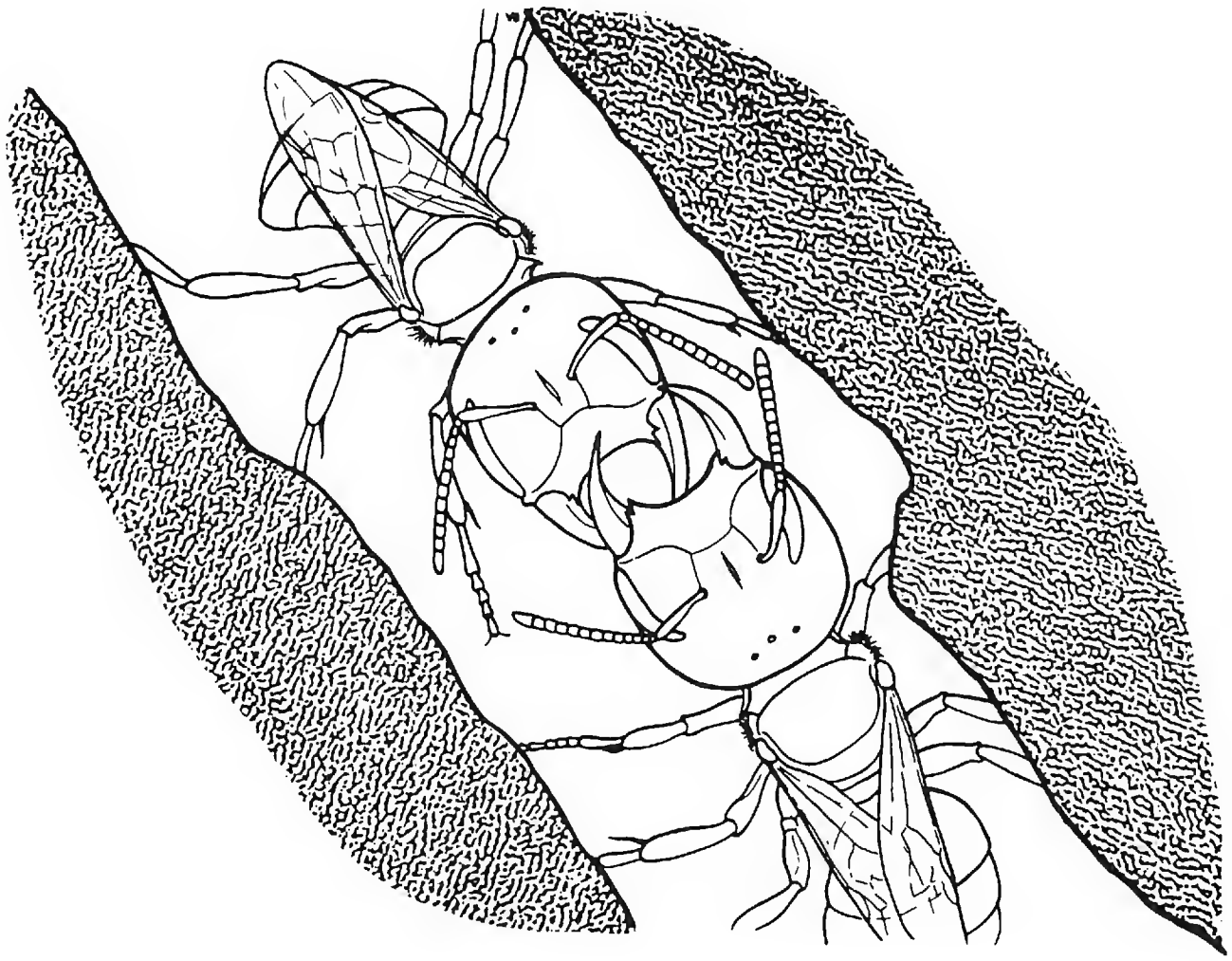

Figure 1. Macrocephalic *Lasioglossum (Chilalictus) erythrurum* males fighting within the nest.

repeatedly until one finally left the nest. These interactions explain why only one macrocephalic male was found in most field nests even though many are produced in each nest, and why dead macrocephalics were frequently found in nests during excavation. Macrocephalic males fight each other, apparently to the death, for the exclusive occupancy of a communal nest.

Observations of male-female interactions suggested that macrocephalic males are fed within the nest by females via oral trophallaxis (n = 3; Fig. 2). More importantly, we observed mating taking place within the plaster nests (n = 2; Fig. 3). Sperm was

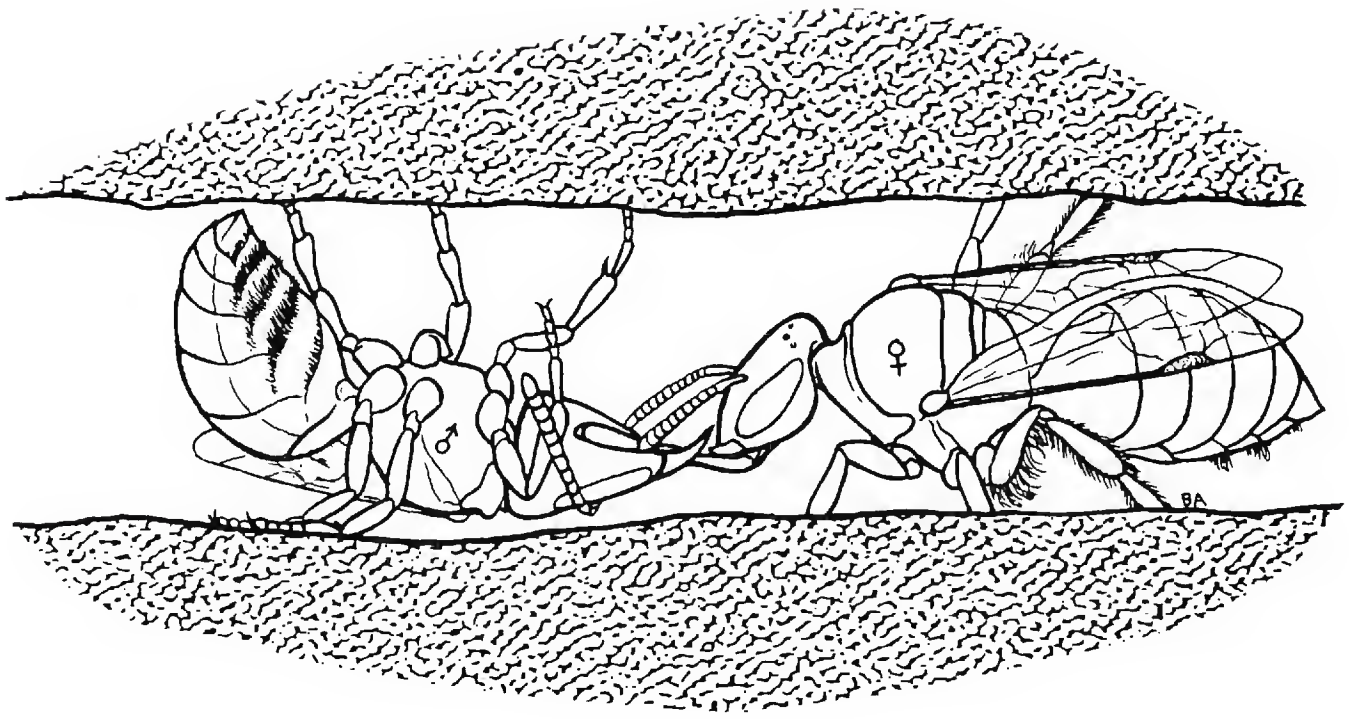

Figure 2. Apparent food exchange between male and female *Lasioglossum (Chilalictus) erythrurum* in the nest.

transferred during such matings. Of the 6 virgin females that were introduced into observation nests containing macrocephalic males, sperm was present in the spermathecae of all fully sclerotized (adult) females. Two teneral females with soft cuticles and very soft wings remained uninseminated. Most adult females collected from field nests occupied by a macrocephalic male contained sperm in their spermathecae (73%, n = 14), while none from the field colony lacking a macrocephalic male were inseminated (n = 8). Dissection of 2 macrocephalic males showed that they have normal-appearing reproductive systems containing motile sperm. This evidence shows that macrocephalic males of *L. erythrurum* are reproductively active within the nest.

There is also evidence that males may contribute to the welfare of the colonies with which they share a nest. They do a small amount of maintenance work within the next. A small proportion of their time (5%) is spent in tunnel repair, both tamping earth into the side wall or moving it toward the entrance. More importantly, they may act as guards against heterospecific intruders. Macrocephalic males fought with intruding ants (n = 3). On two occasions, macrocephalic males were seen to move toward intruding ants with open mandibles before contact was made.

Discussion

In light of these results, the previously stated hypotheses can be evaluated. The first hypothesis set forth to explain this unusual situation is ontogenetic, asserting that the presence of flightless, macrocephalic males is due to a "mistake" whereby a female places an unfertilized (male-producing) egg on a large, female-sized provision mass, thus producing a morph for which no function exists. Since allometric growth patterns also occur in female halictine bees (Sakagami and Moure, 1965; Sakagami and Wain, 1966) and many highly social Hymenoptera (Wilson, 1953, 1985; Houston, 1976), the potential for developmental polymorphism appears

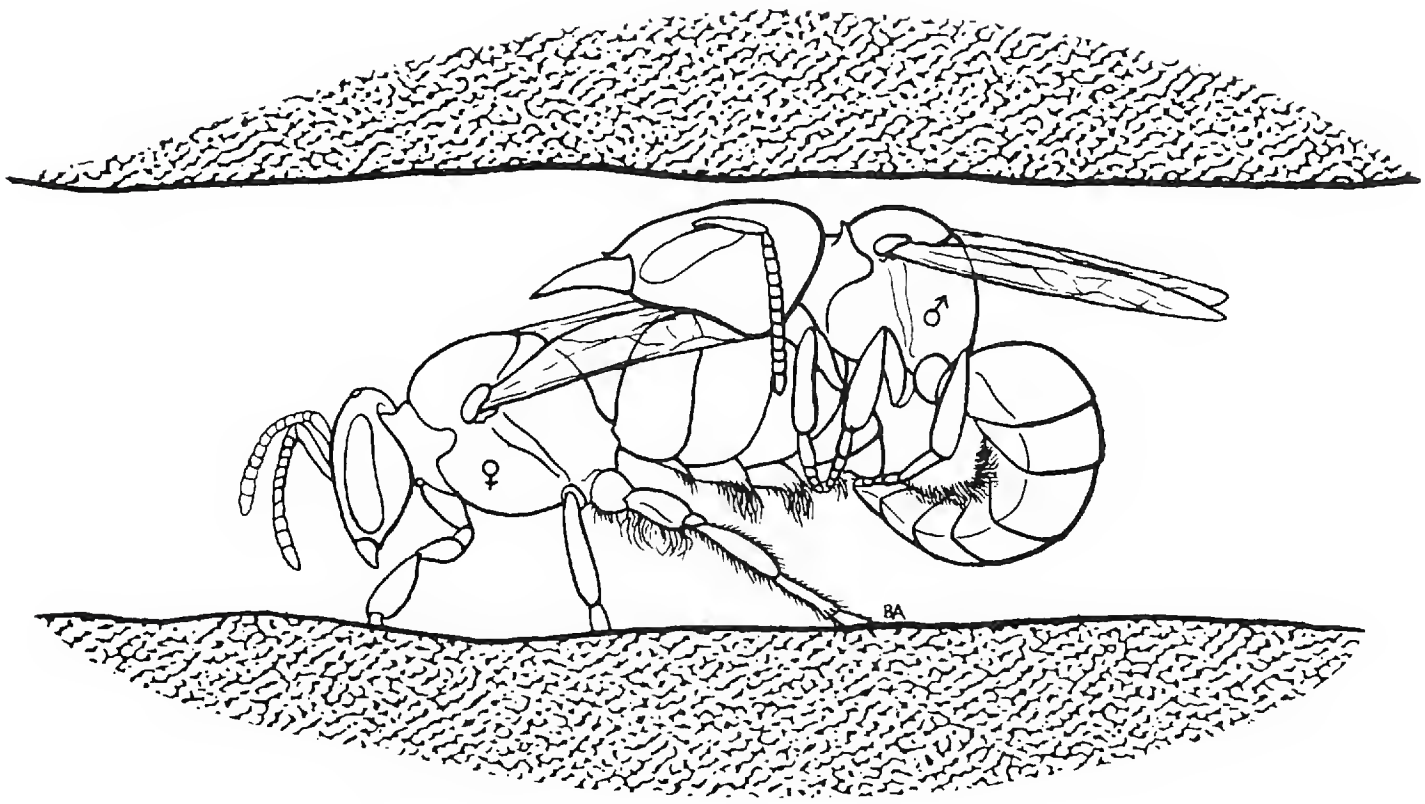

Figure 3. *Lasioglossum (Chilalictus) erythrurum* mating within the nest.

to be widespread. The mechanisms involved have received considerable attention, and studies support the hypothesis that allometric polymorphisms are due to environmental influences (e.g., nutrition) on development (Wilson, 1985).

Halictine bees are mass provisioners; within a brood cell a female prepares a provision mass from pollen and nectar upon which she deposits a single egg. Each cell contains only one individual, and the provision mass is completely consumed by the developing larva. The size of the provision mass and its composition determine larval nutrition and therefore control the size and perhaps morphology of the developing individual (Kamm, 1974).

Thus, this explanation is plausible at the mechanistic level. However, the presence of the extreme macrocephalic morph in certain species and its absence in closely related species (congeners) with similar sexual size dimorphism, plus the occurrence of intermediate forms in other halictine species (Sakagami et al., 1966) strongly suggest that the behavioral "mistake" hypothesis is not a full explanation.

The second, evolutionary-level, hypothesis suggests that the large morph persists because these males with large, powerful mandibles are an altruistic "soldier" caste, acting as "guards" for the communal nests they inhabit. This implies that such males are selected for via kin selection (Hamilton, 1964a, 1964b, 1972) through enhanced reproductive output of their relatives. Recent population genetics theory suggests that male altruism could evolve in the Hymenoptera under certain circumstances (Pamilo, 1984). However, in this case the evidence suggests that the contributions of flightless macrocephalic males to colony life through guarding behavior may be mate guarding, or a form of parental investment that provide individual fitness benefits with secondary benefits due to inclusive fitness. If a macrocephalic male has mated with females in the nest, he could be protecting his mates and through them his

offspring. Guarding by males occurs in solitary wasps in the genera *Oxybelus* (Peckham, 1977) and *Trypoxylon* (Brockman, 1980), and it reduces cleptoparasitism and appears to be associated with a direct reproductive role on the part of the guarding male. On the other hand, if females in the nest are relatives of the macrocephalic male, perhaps even mated to other males, he also could be increasing his inclusive fitness by protecting them.

Thus, it appears that the macrocephalic male morph gains in individual and inclusive fitness. It is of interest to note that extreme macrocephalic males are often found in the nests of other communal species such as *L. dimorphum* and *Perdita portalis* (Knerer and Schwarz, 1976, 1978; Houston, 1970; Rozen, 1970). A communal colony consists of a large number of females, not necessarily close relatives, each of which mates and produces brood. Perhaps mating is taking place within the nests of all these species and macrocephalic males are functional reproductives. With the possible exception of certain species of meliponine bees (Michener, 1974), and one halictine (Plateau-Quénu, 1959), it is commonly held that bees only mate outside their nests, a view that is supported by a large body of literature concerning the mating behavior of bees (Eickwort and Ginsberg, 1980; Alcock et al., 1978).

Flightless macrocephalic males in the communal nests of *L. erythrurum*, and perhaps other species of halictine and andrenid bees, are not "mistakes"; rather they are functional reproductives and perhaps also guards within their communal nests. Speculation concerning the evolution of this complex adaptation must wait until more information is available. Clearly, it involves selection acting on females who must allocate their reproductive effort. In *L. erythrurum,* females must produce an advantageous mixture of macrocephalic males, normal males and females. The role of normal males is not clear at present. Perhaps they obtain matings with females from nests that do not contain macrocephalic males or with females that remain unmated even from a nest occupied by a macrocephalic male. If there is a "penalty" for inbreeding, such as diploid male production, production of normal males might remain advantageous on the part of a female. In the halictine species *Lasioglossum zephyrum* diploid males are known to occur (Kukuk, unpublished data).

An additional question arises concerning the evolution of altruism in females. If many of the females in a single nest are inseminated by the same male, their offspring would be paternal half-sisters or full sisters and the relatedness among them would be at least 0.5. Since these females apparently then occupy and are reproductively active in the same nest, one might expect that a more hierarchical social system involving reproductive altruism would evolve under some cost/benefit situations; for example, if the costs of independent colony initiation are high. Detailed studies of the reproductive and social biology of communal species with intranidal mating are needed.

Acknowledgements

We thank R. H. Crozier, Y. C. Crozier, and G. C. Eickwort for their support of this research; B. Alexander, R. H. Crozier, J. Dickinson, G. C. Eickwort, Y. Maeta, C. D. Michener, M. Raveret, S. F. Sakagami, W. Wcislo and J. Wenzel for reading the manuscript; Y. Maeta and S. F. Sakagami for providing important information concerning macrocephalic male bees found in Japan; and R. J. McGinley for identification of vouchers. The line drawings were prepared by B.

Alexander. Funded in part by the National Science Foundation grant #BSR–84059792 (P. F. Kukuk and G. C. Eickwort, Principal Investigators).

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PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 139–145

New Species of Alticinae (Coleoptera: Chrysomelidae) from South India in the Genera *Taizonia* and *Longitarsus*

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Abstract.—Three new species of Alticinae, *Taizonia obrieni, Taizonia indica,* and *Longitarsus gilli* are described from South India. *Taizonia* is recognized for the first time from India, and a key to the species of *Taizonia* of the Indian subcontinent is given. *Chabria minima* Scherer and *Schereria martensi* Medvedev are transferred to the genus *Taizonia* from *Schereria* Medvedev 1984, which is newly synonymized with *Taizonia.* An existing key to genera of Alticinae of the region is modified to include *Taizonia.*

Abstract.—Drei Alticinen—Arten, *Taizonia obrieni, T. indica,* und *Longitarsus gilli* aus Südindien werden neu beschrieben. Erstmals wird ein Vorkommen von *Taizonia* in Indien berichtet. Wir stellen hier einen Bestimmungsschlüssel für die *Taizonia* Arten des indischen Subkontinentes vor. *Chabria minima* Scherer und *Schereria martensi* Medvedev werden zur Gattung *Taizonia* versetzt, aus *Schereria* Medvedev 1984, die hier neu als Synonym zu *Taizonia* gestellt wird. Ein Bestimmungsschlüssel der Alticinen-Gattungen des indischen Subkontinentes wird modifiziert, um *Taizonia* aufzunehmen.

INTRODUCTION

In 1986, ISA sent to BG some Alticinae of India for determination. Among these specimens, BG found two new species, one each of *Taizonia* and *Longitarsus.* Subsequently, ISA obtained additional material from C. W. O'Brien, among which was found another undescribed species of *Taizonia.* Dr. Gerhard Scherer informed ISA that *Chabria minima* Scherer also belongs in *Taizonia,* and that *Schereria* Medvedev (type species *C. minima*) must therefore be a junior subjective synonym of *Taizonia* Chen 1934 (type species *T. bella* Chen). *Schereria martensi* Medvedev must also be transferred to *Taizonia.*

With description of two new species, and transferral of two others, *Taizonia* is recorded for the first time from India. *Taizonia uenoi* Kimoto (1970) and *T. bella* Chen (1934) from Taiwan, *T. maculata* Gressitt et Kimoto (1963) from China: Fukien, *T. andreevi* Gruev (1985) from Nepal, and *T. minima* Scherer (1969) from Nepal and India, have elytral maculations (see Gressitt et Kimoto, 1963:836,

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Kimoto, 1970:299, Gruev, 1985a:42, Scherer 1969:217–218, and Medvedev 1984:58 for illustrations). Three other species, *T. ochracea* Gressitt et Kimoto (1963) (China: Kiangsi), *T. castanea* Gruev (1985b) (China: Da-laen-saen), and *T. martensi* (Medvedev 1984) (Nepal) lack elytral markings. Description here of *T. indica* and *T. obrieni,* without and with elytral markings, respectively, brings the total known species of the genus to 10. A key to separate the species of the Indian subcontinent is presented, and an existing key to the genera of Alticinae of the Indian subcontinent is modified to include *Taizonia.*

Additionally, a new species of *Longitarsus, L. gilli,* is here also described as new, and compared with similar species.

Taizonia Chen 1934:182

TYPE SPECIES: *Taizonia bella* Chen 1934, Taiwan.

Schereria Medvedev 1984:60. (TYPE SPECIES *Chabria minima* Scherer 1969) **New Synonymy**

Scherer (1969) gave keys for identification of genera and species of Alticinae of the Indian subcontinent, which were known to him. Since *Taizonia* is now newly known from this region, it will be useful to future students of Alticinae to be able to recognize this interesting genus. The key to genera given by Scherer was in both English and German, but only an English addition to this key is presented here. The genus *Taizonia* keys to couplet #46 in Scherer (1969, p. 15), and the following couplet should be inserted immediately thereafter:

46′(46″) Metasternum with anterior margin produced, fitting between mesocoxae; first abdominal sternite similarly produced, fitting between metacoxae ..... *Taizonia*

46″(46′) Meso- and metasternum normal 47

Key to species of *Taizonia* of the Indian subcontinent, with all known non-maculate species of the genus included:

1a. Elytra and pronotum unicolourous (pronotum at most laterally slightly paler) 2

1b. Elytra with yellow markings at least laterally, the disc at least in part, but not entirely, black or blackish brown; pronotum at least basally black or dark brown, laterally and anteriorly yellow 5

2a. Dorsal surface metallic, "dark pitchy bronze," sides of pronotum "a little lighter" (based on Medvedev 1984:61, specimens not seen) .... *T. martensi* Medvedev)

2b. Dorsal surface pale yellow-brown, or pale ochraceous, not metallic, entirely unicolourous 3

3a. Dorsal surface extremely finely punctured, most punctures of elytra 0.05 or less the size of intervening spaces 4

3b. Dorsal surface deeply and densely punctured, the elytral punctures larger in diameter than intervening spaces. Body yellow-brown; tarsal segments slightly darkened; seven apical segments of antennae blackish. Length 2.1 mm, width 1:45 mm ..... *T. indica* Gruev & Askevold

4a. Larger (length 3.0 mm, width 2.2 mm). Pale ochraceous above, except anterior portion of head; labrum and anterior portion of frontoclypeus chestnut-brown; antennae with segments 1–3 ochraceous, 4–5 slightly tinged with brown, 6–10 pale brown, 11 brown, with apex slightly paler; ventral surface ochraceous; legs evenly pale ochraceous ..... *T. ochracea* Gressitt and Kimoto.

4b. Smaller (length 1.7–2.0 mm, width 1.3–1.4 mm). Chestnut-brown dorsally and ventrally; margins of pronotum paler in some specimens; apical five segments of antennae brown, the basal ones pale; legs yellow-brown ... *T. castanea* Gruev
5a. Elytra yellow, with large oval black macula almost exactly in the middle of each elytron (based on Scherer 1969:217, specimen not seen) . *T. minima* (Scherer)
5b. Elytra yellow laterally, black along suture and basally, this extending onto pronotum at least basally 6
6a. Disc of elytra not uniformly dark, yellow colour enlarged onto disc, triangularly at humerus and at midlength, and as vitta posteriorly, and with sickle shaped macula near scutellum; pronotum with dark area extending to near anterior margin ..... *T. andreevi* Gruev
6b. Disc of elytra uniformly dark, laterally with yellow band enlarged triangularly only at apex; pronotum with dark area only along basal margin .....
..... *T. obrieni* Gruev & Askevold

Taizonia obrieni New Species
(Figures 3, 6–8)

Type material.—Holotype female, India, Tamil Nadu, 32 km E Kodaikanal, 1050 m, 29.ix.1985, C. W. and L. B. O'Brien, collectors, deposited in Zoologische Staatssammlung, Münchhausenstrasse 21, D-800 München 60, West Germany.

Diagnosis.—*T. obrieni* is distinguished from other known *Taizonia* species by the lateral yellow vitta on elytra, basal band of pronotum, labrum and 10 apical antennomeres black, apical antennomere broad, with apex oblique.

Description.—(of female) body hemispherical, shiny. Elytron black with epipleuron and broad lateral band yellow, the yellow band uniformly wide from inside humerus to apex, where it abruptly widens, basally as wide as epipleuron. Thorax yellow, with basal black band not extending past black area of elytra; disc imperceptibly shagreened medially; punctulae very fine, less distinct than those of elytra; anterior pronotal bead entire and distinct; surface of anterolateral tubercles finely and irregularly wrinkled; posterolateral corner of disc slightly swollen and smooth, separated from disc by fine sinuate groove. Antennae black except basal segment piceous; apical segments distinctly widened, compressed, apical segment uniformly wide. Head shiny, yellow, labrum black; vertex distinctly punctulate, without microsculpture; frontoclypeal suture indistinct between eyes; occiput near eyes with longitudinal grooves or costae. Legs light brown, except tarsi piceous. Elytra without humeral tubercles, punctures fine, confused, smaller in diameter than intervening spaces. Metasternum pentagonal, margined laterally and anteriorly. Metatibiae strongly curved in dorsal view, outer dorsal edge with 3–4 distinct teeth, each bearing a stout, short seta; outer surface with strong, elongated microsculpture, the meshes in same direction as axis of metatibia. Size: length, 2.68 mm, width, 2.04 mm.

Taizonia indica New Species
(Figures 7, 8)

Type material.—Holotype female, India, Karnataka, 12 km S.W. of Yellapur, 500 m, 7.vii–14.viii.1984, leg. B. Gill. The specimen is deposited in Zoologische Staatssammlung, Münchhausenstrasse 21, D–8000 München 60, West Germany.

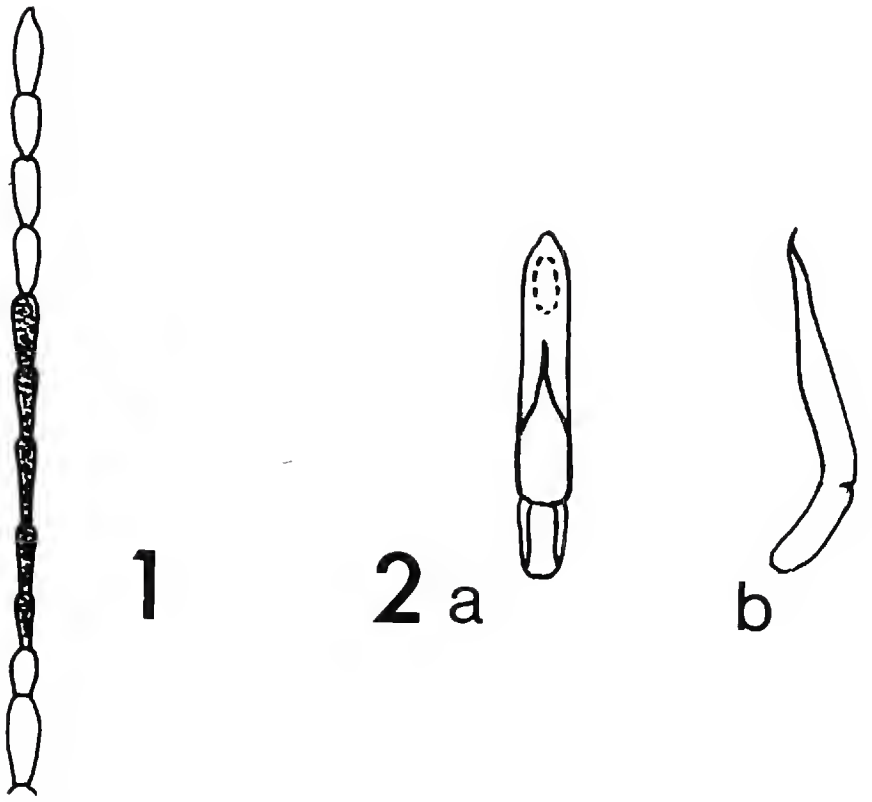

Figure 1. Antenna of *Longitarsus gilli.* Figure 2, a & b, ventral and lateral views, respectively, of median lobe of *Longitarsus gilli.*

Diagnosis.—T. indica is distinguished from other described species by the relatively deeply and densely punctured dorsal surface, and by the entirely yellow-brown color of the body, head, and legs, without any markings.

Description.—(of female) Body hemispherical, shining, yellow-brown. Tarsal segments slightly darkened. Antennae with apical seven segments blackish (assumed, apical 3 segments missing in type). Head, including eyes, narrower than prothorax, vertex convex, its surface finely shagreened and finely but indistinctly punctulate; frontoclypeal suture between eyes a ^-shaped transverse furrow, above which are four large punctures; frontal tubercles indistinct; interantennal space about three times transverse diameter of antennal socket; labrum deeply, narrowly, triangularly emarginate medially; clypeus with anterior margin slightly rounded-emarginate; antennae less than half body length, segment 2 shortest, thick, nearly as broad as segment 1, segment 3 longer than 2. Pronotum 2.5 times as broad as long, broadest basally, disc shagreened, densely punctured, anterior pronotal bead indistinct medially, not entire, surface of anterior tubercles smooth, not with fine wrinkles. Elytra without humeral tubercles, punctures of disc deep and dense (deeper than those of pronotum), larger in diameter than the intervening spaces, and distinct to the apex. Scutellum broader than long, triangular. Metasternum pentagonal, margined anteriorly and laterally. Metatibiae strongly curved, spur long, as long as first antennal segment, dorsal outer edge of tibia not toothed, at most slightly irregular, microsculpture of outer surface oblique to axis of tibia, the meshes elongate, appearing as fine incised lines. Length 2.1 mm, width 1.45 mm.

Longitarsus gilli New Species
(Figures 1 & 2)

Type material.—Male holotype and five male paratypes, India, Kerala, Munnar area, Eravikulam, 2100 m, 26–30.vii.1984, leg. B. Gill. Holotype deposited in

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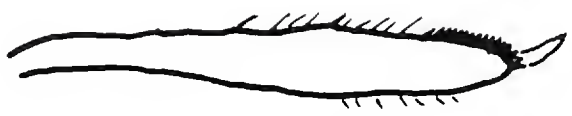

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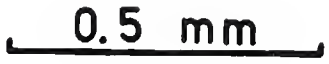

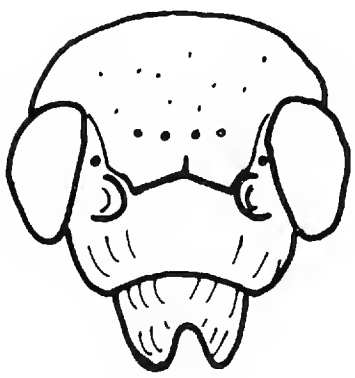

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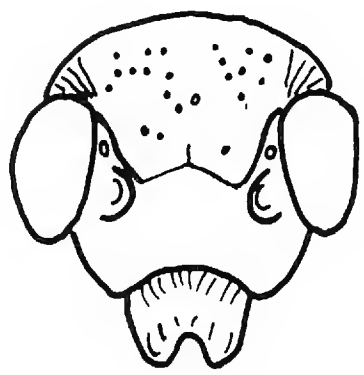

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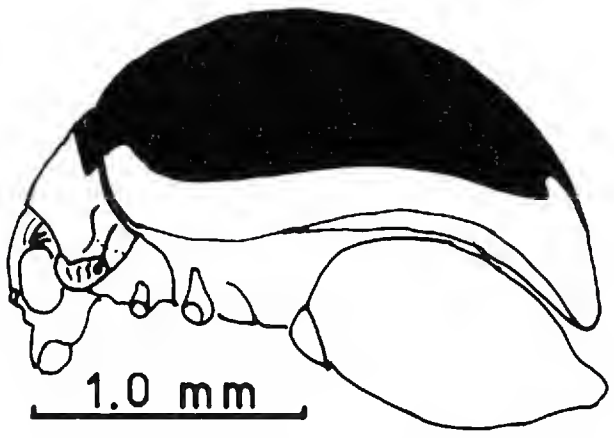

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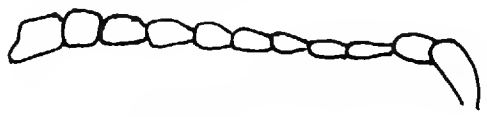

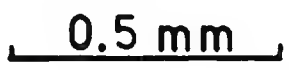

Figure 3. *Taizonia obrieni,* left metatiba. Figure 4. *Taizonia indica,* left metatibia. Figure 5. Head of *Taizonia indica. Figure 6. Head of Taizonia obrieni. Figure 7. Taizonia obrieni,* left side of pronotum and elytron. Figure 8. *Taizonia obrieni,* antenna.

Zoologische Staatssammlung, Münchhausenstrasse 21, D-8000 München 60, West Germany. Two paratypes retained by B. Gruev, one by I. S. Askevold, and one paratype each deposited in Zoological Survey of India, Calcutta, and British Museum, London.

Diagnosis.—This new species belongs to the group of small brown species of *Longitarsus,* but no other oriental species has the following combination of characters: body apterous, pronotum almost quadratic, frontal tubercles distinctly delimited, middle antennal segments (3–7) dark, antennae nearly as long as body with segments much elongated (4–7 mostly 4 times as long as wide), and its unique aedeagus shape.

The only other species with dark middle antennal segments is *L. ochraceicornis* Maulik (1926), which differs from *L. gilli* in having indistinct frontal tubercles and antennal segment 2 not much shorter than 1, and somewhat longer than 3.

Description.—Body apterous, small, convex, brown. Legs yellow. Antennae with the four apical and two basal segments yellow, clearly contrasting darker segments (3–7) between them. Head dark chestnut-brown, mouth area light brown, with vertex shining and impunctate, frontal tubercles narrow and clearly delimited, interantennal ridge narrow and sharp. Antennae almost as long as body, segment two shortest, half as long as 1, 3 a little longer than 2, segments 4, 6–10 almost equal in length, longer than 3, segments 5 and 11 equal in length, longest; antennal segments from 7 to apex slightly broadened (Figure 1). Pronotum about 1.2 times as wide as long, broadened in front, narrowed behind, sides nearly straight, surface finely shagreened and finely punctured, the basal punctures larger and more distinct. Elytra convex, without humeral tubercles, strongly rounded, widest in the middle, surface indistinctly shagreened, densely punctured, the punctures larger than those of pronotum. Length 1.4 mm, width 0.7 mm.

Male.—Basal protarsomere moderately broadened. Apical abdominal sternite with depression indistinct. Median lobe of aedeagus with apex triangular, underside behind the middle raised medially, with two convergent ridges (Figure 2a).

Female.—unknown.

Acknowledgments

ISA is grateful to Dr. Bruce Gill, Department of Entomology, Carleton University, Ottawa, Ontario, and to Drs. Charles W. and Lois B. O'Brien, Department of Entomology, Florida A. & M. University, Tallahassee, Florida, for collecting the Chrysomelidae upon which this paper is based, and especially Dr. Gerhard Scherer for sharing his knowledge of *C. minima* and allowing us to publish this information here. BG prepared illustrations of *L. gilli,* and descriptions of *L. gilli* and *T. indica,* ISA prepared description of *T. obrieni,* figures of *Taizonia,* and key to *Taizonia* species. Work on the part of ISA leading to this publication has been supported by NSERCC grant #AO428 held by Dr. Robert E. Roughley of the University of Manitoba, and by NSERCC PGS scholarship held by ISA.

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PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 147–157

Melipona yucatanica New Species (Hymenoptera: Apidae: Meliponinae); Stingless Bee Dispersal Across the Caribbean Arc and Post-Eocene Vicariance

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Abstract.—The second insular continental species of *Melipona* north of Panama is described. Its similarity to workers of the *M. favosa* group and the single meliponine species restricted to Caribbean islands, *M. variegatipes* of the Lesser Antilles, is analyzed in conjunction with the male genital capsules described here. The South American species *favosa* differs slightly but very clearly from *variegatipes: yucatanica* differs greatly from both, and also from all *Melipona* of Central America. Such features in the *favosa* group, and current distributions of *Melipona* in Central America, suggest that *Melipona* occupied South America and Yucatán before the late Pliocene connection via Panama. The Panamanian land bridge was crossed by other *Melipona* found both in Colombia and Costa Rica, but an ecological barrier between Costa Rica and Panama has prevented movement by competing species pairs that we suggest share common ancestors—*M. favosa—M. yucatanica* and *M. beecheii—M. compressipes*. We propose that ancestral meliponines of these and other taxa dispersed across the Caribbean arc and cannot colonize territories of their sister species. After bee dispersal, tectonic activity in the Caribbean separated populations and led to insular species in Central America and the Caribbean. Miocene fossils of Trigonini from the Greater Antilles and southern Mexico, and the broken distribution of *Ptilotrigona,* also suggest dispersal across the proto-Antillean archipelago prior to the Panama land bridge.

The colonial bee described here, *Melipona yucatanica,* is known by the Mayan inhabitants of the Yucatan peninsula as "Ts'ets" (González 1983). It is one of the smaller bees of the genus, about 8 mm in length, and its colonies are very small (<200 workers). Here we propose this bee is a member of the *M. favosa* group and demonstrate that bees from the Lesser Antilles and thought to be a geographic race of *M. favosa* are an insular species. We review biogeography of neotropical meliponines and show why current species ranges, the distribution of Miocene fossils, and parapatry in sister species of *Melipona* each suggest dispersal across a proto-Antillean archipelago between South America and Mexico before the Panama landbridge existed.

Schwarz (1932) characterized *M. favosa* as distinguishable from congenerics by the relatively large inter-orbital distance, notably greater than the length of the eye. He

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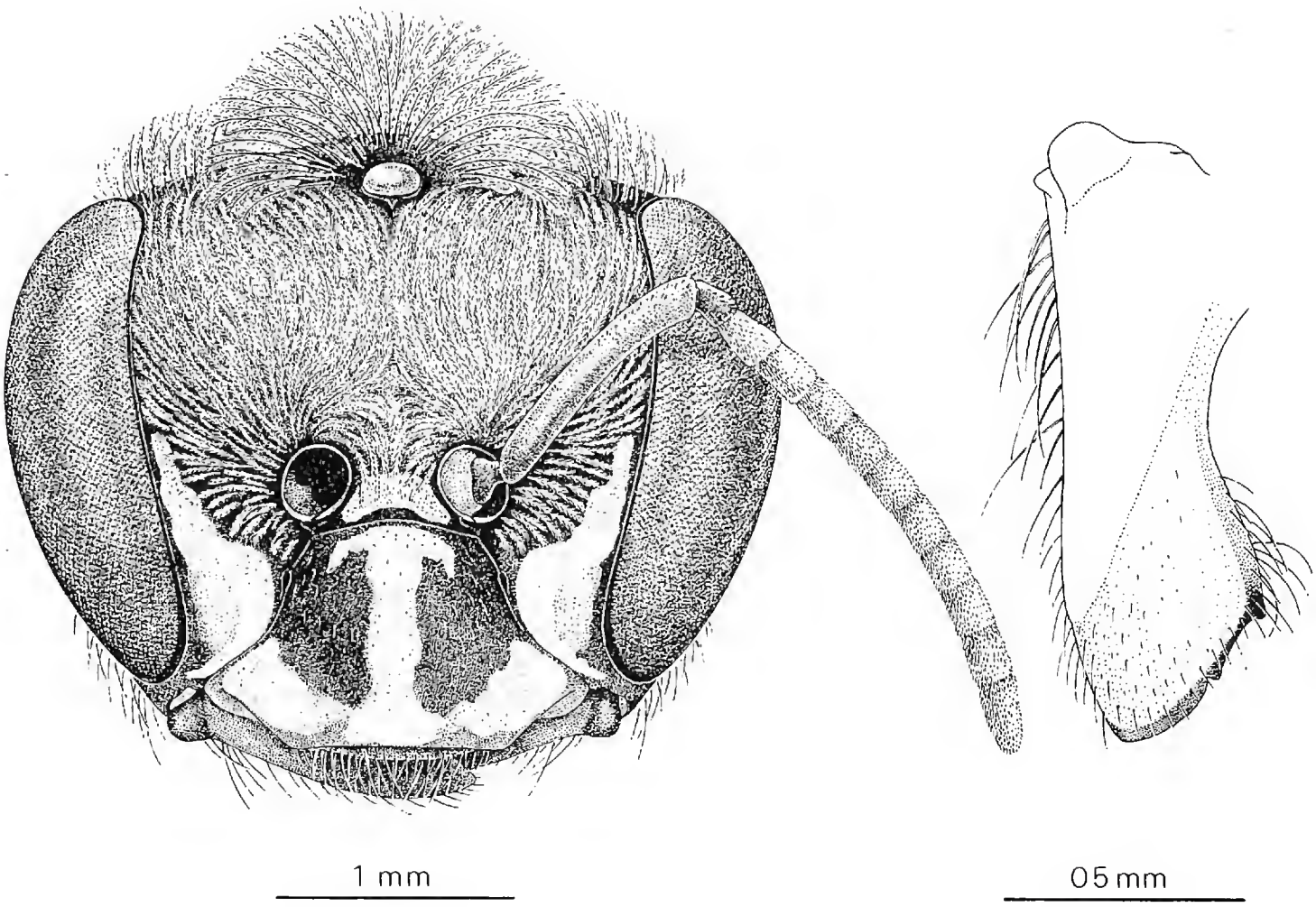
indicated a wide distribution of *M. favosa,* from Argentina to Panama. No related species was known from Central America or Mexico. Typical *Melipona favosa* (Fabricius) was described from French Guiana and occurs in the Guianas, Venezuela, Colombia and Trinidad; *M.f. orbignyi* (Guérin) was described from Chiquitos, Bolivia and occurs also in Paraguay and Brazil (Mato Grosso, Maranhão and Ceará); *M.f. phenax* Cockerell is known from Ecuador and Panama; *M.f. baeri* Vachal exists from Tucumán, Argentina to northern Bolivia, *M.f. lunulata* Friese is known from Yungas, Bolivia (Espia Rio Bopi and Canamina), and *M.f. peruviana* was described from Huancabamba, Perú. The systematic treatment of *M. favosa* by Schwarz may be in need of some modification. The northeastern Brazilian *Melipona subnitida* Ducke should be included, since it too has an unusually wide superior interorbital area. Three of the subspecies mentioned above, *orbignyi, baeri* and *lunulata,* probably are sympatric in Bolivia. If more intensive collecting in Bolivia reveals no hybrids, then these bees, like many geographic races recognized by Schwarz, are likely distinct species. Although the distribution of *M.f. phenax* appears anomalous, this may be due to lack of collection between Ecuador and Panama.

An insular species, *M. variegatipes* Gribodo, is known only from Guadeloupe, Dominica and Montserrat, of the Lesser Antilles. It is one of the two native species of *Melipona* in the Caribbean, and it appears closely related to *M. favosa* (Schwarz 1932; Moure 1960). Schwarz (1932) synonomized *variegatipes* with *favosa* and made it a subspecies of this taxon. We examined the male and genital capsule of *variegatipes* from Montserrat and find differences from *favosa* of Colombia (Figs. 10–23, and Discussion). The other Caribbean *Melipona* is *M. beecheii fulvipes* (sensu Schwarz 1932), which is slightly smaller than *M. beecheii beecheii* and is found in Belize, Yucatán, Jamaica and Cuba. Michener (1982) suggests that *M. beecheii fulvipes* has been brought to the islands from the mainland by indigenous inhabitants of the Caribbean, which seems to us reasonable in light of its mainland distribution and the extensive beekeeping with this species practiced by the Maya.

Description of Melipona yucatanica sp.n. Melipona fulvipes; Wille, 1976, *Rev. Biol. Trop.,* 24(1):134–135, *nec.* Guérin, 1835 *Melipona* sp. Mayan name "Ts'ets", González 1983:193.

Worker (Figs. 1, 2); total length approximately 7.9 mm, wing length from apex to costal scelerite 6.04 mm; maximum head width 3.36 mm; maximum abdominal width 3.05 mm.

Integumental coloration.—For the most part dark brown to almost black. Mid and hind femora and tibiae light ferruginous or reddish with black markings on lower face of femora, variegately on mid tibiae, and lower third of posterior tibiae. Tarsi dark, having small light brown-ochraceous spots on posterior basitarsus; mid basitarsus bicolorous. Sterna dark. Mandible largely yellow, slightly brown and darkened in apical fifth, and having a black spot near the internal basal articulation (Fig. 2). Labrum bright yellow. Face displaying large yellow maculation in the form of an inverted 'T' on clypeus; supraclypeal maculation crescentic; paraocular maculations large, widest at tentorial foveae and narrowing along orbit, terminating slightly above the level of the superior alveolus. Antennae brownish, basal flagellomere slightly yellow. Scutellum and axillae yellow. Mesoscutum displaying fine yellow striation laterally, beginning at the level of the mid tegula and broadened backwards. Tergites 1 to 5 displaying yellow marginal bands, bordered by fine translucent areas



Figures 1–2. *Melipona yucatanica,* holotype worker from Mérida, Yucatán, México; head and mandible.

but lacking typical lateral spots of *favosa (seusu stricto)*; width of bands approximately equal to diameter of mid ocellus. Tegulae ferruginous-light yellow; wing staining the same color, slightly more pronounced in the marginal and radial cell.

Vestiture.—Densely plumose, branched hairs on the head, terminating at facial maculations below the alveoli, becoming almost glabrous on paraocular areas below tentorial foveae and extremely short and sparse on most of the clypeus, and interspersed on genae with longer hairs on the basal fifth. Hairs on labrum shorter than more yellow hairs on mandibles. Hairs yellowish on mesoscutum, scutellum, pronotal lobes and basal area of porpodeum; branched on mesepisternum, ventral portion of thorax, femora, pro- and mesothoracic tibiae and basal two-thirds of the anterior and all of the posterior marger of the metatibiae; light yellow-ferrugineous on tarsi and anterior margins of pro- and mesothoracic tibiae and distal anterior third of metathoracic tibiae. Yellow on the metathoracic tergites, sparse in the basal two and progressively longer and denser on following segments, black hairs also appearing on last tergite.

Punctation.—Face dull due to a very dense micropunctation; intercalating, sparse piligerous punctures on clypeus, slightly sparser on genae, primarily found within lower one-third; the same large punctures near orbit; microreticulation replacing punctation toward the hypostoma. Mesoscutum having sparse piligerous punctures (5 to 6 per ocellar diameter), separated by slightly more than their width;

micro-punctation dull, except small area on disc where punctures are more separated and the integument is slightly shiny. Mesepisternal piligerous punctures slightly larger than those of mesoscutum. Scutellar punctures wide, twice as large as those of mesoscutum, separated by 2 to 3 diameters, smooth and shiny; basal area of propodeum having similar punctures, some wider than those of scutellum but not separated, slightly shining, and progressively dull microtessellated toward sides. Tergites displaying micropunctation similar to that of clypeus, although smooth at the base of the second tergite, piligerous punctures less distinct. Legs having superficial microreticulation, slightly more shining and punctures more evident.

Form and proportions.—(measurements given in mm) Head broader than long (3.36: 2.68); eyes longer than twice width (2.04: 0.88), slightly shorter than superior interorbital distance and strongly convergent below (2.13: 2.24: 1.78). Clypeus shorter than two-thirds its width and this slightly larger than clypeo-ocellar distance (0.98: 1.48: 1.40). Interalveolar distance subequal to diameter of alveolus and smaller than alveorbital, the lateral alveocellar distance a little more than twice this (0.30: 0.32: 0.50: 1.10). Lateral interocellar distance over twice diameter of median ocellus, ocellorbital distance smaller (0.66: 0.26: 0.52). Malar space equal to half the distance from the inferior lower edge of the clypeus to the orbit and barely two-fifths diameter of the median ocellus (0.10: 0.20: 0.26). Length of scape little more than six times its diameter and greater than the lateral alveo-ocellar distance (1.16: 0.18: 1.10); length of first three flagellomeres 0.20, 0.24, 0.24, diameter of the third 0.18. Mandibles having narrow incision on apical border, approximately at three-fifths from external apex, followed by a tiny denticle greatly separated from the inner edge by a simple emargination. Forewings having marginal cell five times longer than wide, narrowly open at apex; first submarginal cell well defined; veins M and M1 extending almost to wing margin, first m-cu almost complete. Mesotibia longer than its basitarsus (2.00: 1.20); metatibia 2.5 × longer than greatest width (2.56: 1.02), terminating in a sharp angle but not forming tooth; anterior penicillus weak; metabasitarsus twice as long as wide (1.32: 0.68), having slightly convex posterior border, ending in a prominent downward-projecting angle.

Male.—(Figs. 3–9). Total length approximately 8.13 mm; fore wing length from apex to costal sclerite 6.32 mm; maximum head with 3.08 mm; maximum abdominal width 3.36 mm.

Integumental coloration.—Present material callow and incompletely pigmented; yellow maculation scarcely evident, particularly on clypeus and paraocular area. Axillae and margins of mesoscutum clearly lacking yellow markings. Metasomal bands and predominant dark body color similar to that of worker.

Vestiture.—Density and color patterns like that of workers except at the superior margins of the clypeus and inferior paraocular areas, where the dense, plumose gray pubescence is well developed.

Punctation.—Similar to that of worker.

Form and proportions.—Head wider than long (3.08: 2.44); eyes slightly longer than twice their width (1.90: 0.92), subequal to superior interorbital distance and very convergent below (1.92: 1.80: 1.36). Clypeus slightly shorter than three-fourths its width and this slightly greater than distance between the clypeus and median ocellus (0.96: 1.32: 1.12). Interalveolar distance little less than diameter of antennal alveolus and near five-sevenths that of the alveorbital distance; lateral alveocellar distance 2.6 times longer than this (0.24: 0.32: 0.34: 0.88). Distance between lateral

ocelli more than twice diameter of median ocellus and little less than the ocelloorbital distance (0.60: 0.24: 0.46). Malar space very short, one-fourth diameter of median ocellus (0.06: 0.24). Length of scape 3.8 times greatest diameter and slightly less than lateral alveocellar distance (0.84: 0.22: 0.88); length of first three flagellomeres 0.08, 0.32, 0.32 and diameter of third 0.18. Mandibles edentate. Wings similar to those of workers, fore wing 2.8 × longer than width (6.32: 2.28). Metatibia 3.4 × longer than wide (2.04: 0.60) with the apex evenly rounded and narrowed posterior and anteriorly. Metabasitarsi 2.5 × longer than wide (1.20: 0.48). Eighth sternite very elongate and narrow (1.20: 0.32); hooks of valve almost straight and shorter than gonostylus (1.00: 1.40). Further details and comparison with *M. f. favosa* are given in Figs. 3–9 and 10–16.

Variation.—In several specimens the clypeus presents a yellow marking along the median line and one on each inferior edge, not completing the inverted "T" of the holotype worker. In some workers the band of the first metasomal tergite is slightly interrupted medially. Metric variation is indicated in Table 1.

Types and type locality.—Holotype worker and two paratypes of the same caste with labels "Mérida, Yucatán, México, 16.XII.80, J. G. Acereto leg.," 26 additional paratypes from the same collector and locality, II. 1987 and 4 with the labels "Mérida, Yucatán, México, XII. 1981, Camargo leg.," the holotype and paratypes labelled "Mérida" were taken from a nest carried to Mérida from Baxac, 20 km southwest of Tzucacab, Yucatán (Michener and J. González Acereto, personal communication), 8 paratype workers, the allotype and an additional male also taken from a nest from Yucatán collected by J. González A. bearing the labels "Mexico, Quintana Roo, F. Carrillo Puerto, 10 km N, 10 Oct. 86, D. Roubik coll.; nest from Yucatán, J. González." Additional paratype workers (4) housed in the Snow Entomological Museum, University of Kansas, from the University of Kansas Mexico expedition; Guerrero State, 42 km N. Acapulco, and Oaxaca State, 49 km W Tehuantapec; and from Costa Rica, Puntarenas Province, 7 mi. S. Platanares. Holotype bearing red label and paratypes with yellow labels deposited in the collection of the Department of Biology of the Faculty of Philosophy, Science and Letters at the University of São Paulo in Ribeirão Preto. Allotype bearing red label and paratypes deposited with the Instituto de Biologia, Universidad Nacional Autónoma de México (UNAM) in Mexico city. Paratypes also deposited at the Smithsonian Institution, Washington, D.C.; the Smithsonian Tropical Research Institute, Balboa, Panama, the collection of the Department of Zoology of the Federal University of Paraná, and the Snow Entomological Museum at the University of Kansas, Lawrence.

Distribution and bionomic notes.—According to González (1983:193) this bee is found in the southern portion of the Yucatán peninsula, in forest remaining in the border region of Yucatán, Quintana Roo and Campeche. Its total distribution is considerably larger, as was probably its distribution in Yucatán before massive deforestation. Specimens in the collection of DWR and the University of Kansas Snow Entomological Museum are from Puntarenas, Costa Rica; Oaxaca, Mexico, and Guerrero, Mexico.

Discussion.—Considering its pronounced facial maculation, *M. yucatanica* is similar to the typical form of *M. favosa* but shares no part of its range (Schwarz 1932). The former differs principally in displaying yellow markings at the supralar margins of the mesoscutum and axillae, continuous yellow bands from the first to fifth

Table 1. *Melipona yucatanica,* morphometrics (in mm) of worker hologype, paratypes and allotype male from Mérida, Yucatán, México and male morphometrics of *M. variegatipes* from Montserrat, Lesser Antilles.

variable.*	*n*	*range*	*mean*	*s.d.*	*holotype*	*allotype*	*variegatipes*
1	10	3.12–3.36	3.27	0.090	3.36	3.08	2.82
2	10	2.00–2.16	2.09	0.046	2.12	1.92	1.80
3	10	2.14–2.28	2.2	0.049	2.24	1.80	1.60
4	10	1.68–1.80	1.75	0.043	1.78	1.36	1.32
5	10	1.88–2.04	1.97	0.047	2.04	1.90	1.64
6	10	0.82–0.88	0.85	0.023	0.88	0.92	0.78
7	10	1.28–1.40	1.33	0.049	1.40	1.12	1.12
8	10	0.88–0.98	0.93	0.034	0.98	0.96	0.90
9	10	1.24–1.50	1.44	0.076	1.48	1.32	1.20
10	10	0.30–0.36	0.32	0.020	0.30	0.24	0.26
11	10	0.48–0.52	0.5	0.015	0.50	0.34	0.36
12	10	0.34–0.40	0.38	0.022	0.34	0.44	——
13	10	0.50–0.56	0.53	0.021	0.52	0.46	0.46
14	10	0.64–0.68	0.65	0.016	0.66	0.60	0.52
15	10	1.02–1.10	1.07	0.030	1.10	0.88	0.80
16	10	0.24–0.26	0.24	0.007	0.26	0.24	0.26
17	10	0.10–0.12	0.11	0.009	0.10	0.06	0.10
18	10	2.24–2.48	2.36	0.069	2.42	3.20	3.04
19	10	1.12–1.20	1.15	0.025	1.16	0.84	0.78
20	10	1.28–1.38	1.34	0.030	1.36	1.04	0.92
21	10	5.76–6.28	6.02	0.159	6.04	6.32	6.24
22	10	2.04–2.32	2.21	0.086	2.22	2.28	2.20
23	10	2.24–2.56	2.44	0.107	2.56	2.04	2.04
24	10	0.96–1.06	1.00	0.036	1.02	0.60	0.60
25	10	1.16–1.32	1.25	0.049	1.32	1.20	1.24
26	10	0.64–0.72	0.69	0.025	0.68	0.48	0.48
27	10	2.14–2.42	2.31	0.096	2.36	2.44	2.20
28	10	2.36–2.64	2.49	0.105	2.64	2.52	2.28
29	10	0.64–0.72	0.68	0.031	0.72	0.68	0.76
30	10	1.40–1.60	1.52	0.072	1.56	1.60	1.52
31	10	9–11	10	——	10	10	10

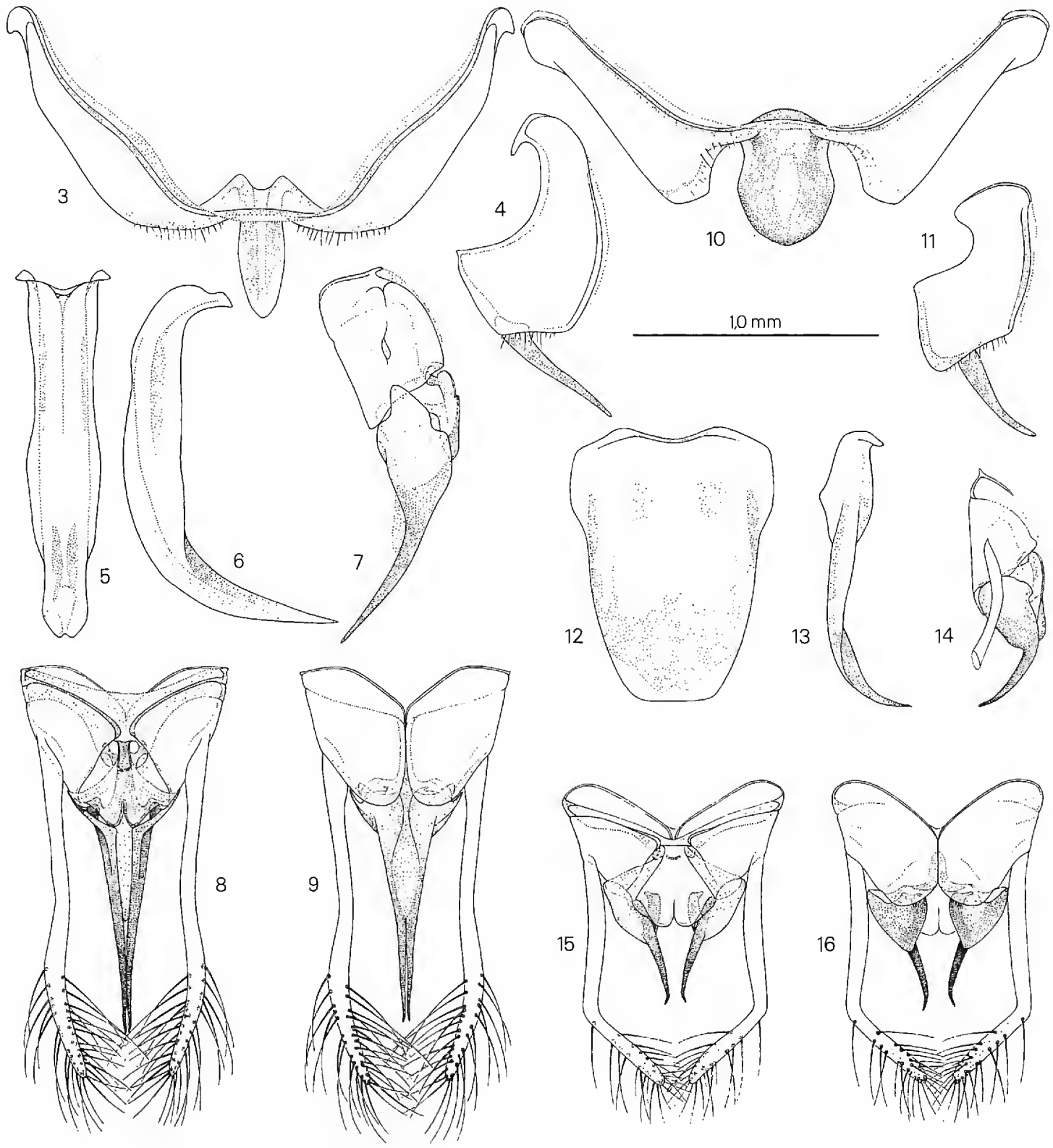
*variables: 1) maximum head width; 2) superior inter-orbital distance; 3) maximum interorbital distance; 4) inferior interorbital distance; 5) compound eye length; 6) compound eye width; 7) distance from clypeus to median ocellus; 8) clypeus length; 9) clypeus width; 10) interalveolar distance; 11) alveorbital distance; 12) ocelloccipital distance (measured from median ocellus in dorsal view); 13) oxellorbital distance (lateral ocellus to orbit); 14) distance between lateral ocelli; 15) distance from alveolus to lateral ocellus; 16) median ocellus diameter; 17) length of malar area; 18) length of flagellum and pedicel; 19) length of scape; 20) length of mandible; 21) fore wing length; 22) fore wing width; 23) metatibia length; 24) maximum metatibial width; 25) metabasitarsal length; 26) metabasitarsal width; 27) length of mesoscutum; 28) width of mesoscutum; 29) length of scutellum; 30) width of scutellum; 31) number of hamuli.

metasomal tergites, gray pilosity on the mesepisternum and the dull micro-punctation of the discal area of the mesoscutum. *Melipona favosa* lacks yellow maculations on the mesoscutum and axillae, as do other forms of this group; the yellow band across the first metasomal tergite is largely interrupted medially; the mesepisternum and mesoscutum are covered with fulvous hairs, and the discal area of the mesoscutum is faintly lustrous. Structure of the male metasomal sternites and

genitalia are very distinct (Figs. 3–16). The male of *M. yucatanica* is unique among the known *Melipona* in possessing the elongate, narrow eighth metasomal sternite (Figs. 5, 6). The corresponding sternite of *M. favosa* is about 2.2 × as long as wide, while that of *M. yucatanica* is over 4.3 × its width. This marked difference may represent a very long separation from the *favosa* group and even a separate origin. Following the key in Schwarz (1932), *M. yucatanica* could be confused with *M. variegatipes* due to the shared characteristic of extensively yellow-ferruginous hind legs, but this bee has no yellow maculations on any part of the body.

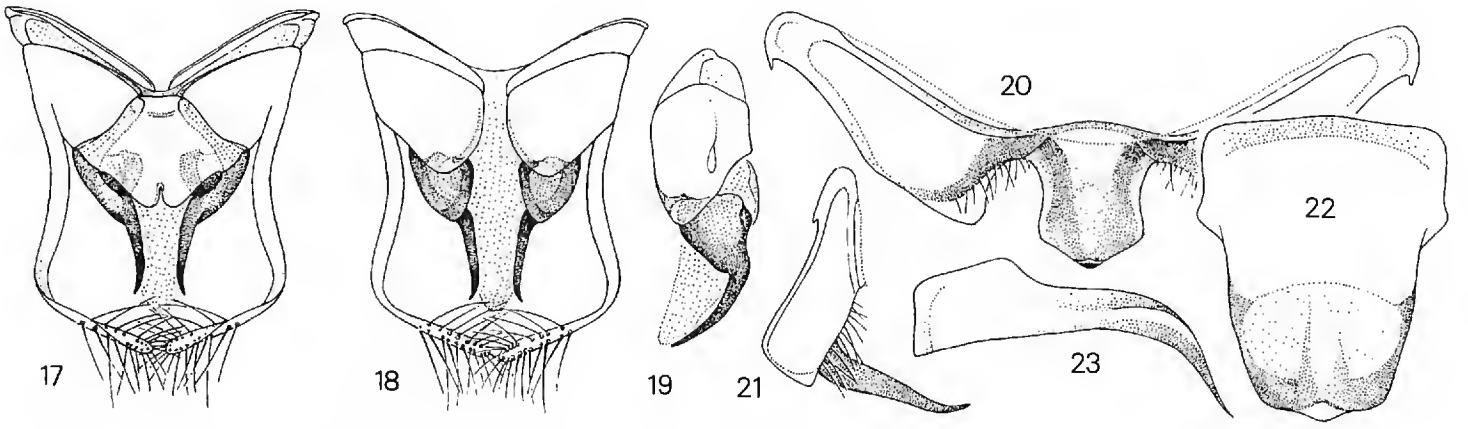
It is now clear that *M. beecheii beecheii* and *M. b. fulvipes* are distinct from *M. yucatanica* and their continental ranges appear to overlap with it completely. Both forms of *M. beecheii* are larger than *M. yucatanica,* and both possess whitish-gray plumose hairs on the clypeus, lacking in *M. yucatanica.* The type specimen of *M. b. fulvipes,* described from Cuba, is supposedly in the Paris Museum. We have only examined two worker bees of the collection of the Portici Museum, Italy. They are labelled Santiago, Las Veras, Cuba, April 10, '26 (interpreted by Schwarz [1932] as 1926). We also examined specimens determined by Schwarz from Cabanas, Cuba; all are very similar to *M. b. fulvipes* from Yucatán and Quintana Roo, Mexico, and also Belize. Typical *M. b. beecheii* is larger than *M. b. fulvipes* (Schwarz 1932), corresponding to bees we have examined from Costa Rica, Nicaragua, Honduras, and Nayarit and Jalisco States in Mexico. Wille (1976: 135) provides a detailed morphometric comparison of Costa Rican *M. b. beecheii* with what he thought to be *M. fulvipes*; its size corresponded closely to those of *M. yucatanica* and it is thus very likely the same bee that we describe. Although Wille states that its distribution ranges from Mexico to Costa Rica and also includes the islands of Cuba and Jamaica, neither he nor we have evidence of its presence on these islands. Wille (1976) reports collecting workers along the Panamerican Highway between Rio Térraba and Palmar Norte. Palmar Norte is approximately 100 km from the Pacific border with Panama.

Comparative distributional data of meliponines and evidence provided by amber meliponine fossils suggest Meliponinae occupied the Caribbean islands and Mexico well before the land bridge of Panama was completed at 3 mybp (Simpson and Neff 1985). Many modern groups of meliponines are certain to have moved across the Isthmus of Panama; some may have crossed during the initial formation for the isthmus in the upper Pliocene (Raven and Axelrod 1975), and there is a suggestion, with little evidence, that some dispersal of contential fauna may have occurred across the Panama gap during the Oligocene-Miocene, 22 to 27 mybp (Halffter 1978). On the other hand, there is substantial geological and biological evidence that an archipelago dispersal route was available in the early Eocene between northwestern South America and Yucatán; sometime in the upper Eocene this connection was broken by the movement of Cuba away from the mainland (Rosen 1985). Fossil evidence definitively attests to the presence of meliponines north of Central America before the Miocene. The modern supraspecific group *Nogueirapis* was described from middle Miocene amber of Chiapas, southern Mexico (Wille 1959, 1962, 1964). The *Nogueirapis* group now occurs from Brazil to Costa Rica. *Proplebeia dominicana* (Wille and Chandler) is known from the Greater Antilles in amber of the Oliogocene-Miocene (Michener 1982). This extinct genus has not been found elsewhere and was first described as a modern *Hypotrigona-Liotrigona* or a *Plebeia* (Wille and Chandler 1964; Moure and Camargo 1982a). The related *Plebeia* group exists from southern Brazil to north central Mexico.



Figures 3–9. *Melipona yucatanica,* allotype male from Mérida, Yucatán, México. (3, 4): 7th metasomal sternite, ventral view and profile; (5, 6): 8th metasomal sternite, ventral view and profile; (7–9): genital capsule, profile, dorsal and ventral views. Figures 10–16. *Melipona f. favosa,* male collected in Santa Marta, Magdalena Department, Colombia by G. E. Bohart. (10, 11): 8th metasomal sternite, ventral view and profile; (12, 13) 9th metasomal sternite, ventral view and profile; (14–16): genital capsule, profile, dorsal and ventral views.

The above information could signify that certain meliponine groups were common to Africa, Central and South America in Cretaceous times. Little or no dispersal by island-hopping across the Caribbean is necessary to explain this, and it is one of a number of predictions from cladistic analysis of Caribbean geohistory (Rosen 1985). However, almost no supraspecific groups of meliponines below tribal level occur both in Africa and the neotropics. Despite some close resemblances between



Figures 17–23. *Melipona variegatipes,* male from "Mntserrat, 3.3 WI, H. G. Hubbard Collector." (17–19): genital capsule, profile, dorsal and ventral views; (20–21): 7th metasomal sternite, ventral view and profile; (22, 23): 8th metasomal sternite, ventral view and profile.

African *Hypotrigona* and the neotropical *Trigonisca* group, and certain groups related to *Plebeia* in southern Brazil and in Africa, meliponine evolution of higher taxonomic groups proceeded independently on the two continents after the upper Cretaceous. Eocene or Miocene exchanges across an archipelago between North and South America seem to better explain the dispersion patterns of *Melipona.* Exchanges by this route are reasonably well established for other organisms, including narrowly specialized solitary bee species and their host plants (Moure and Camargo 1982b; Michener 1982; Simpson and Neff 1985; Graham 1985; Gentry 1985). Furthermore, speciation by another bee group, *Bombus* seems to have been too extensive in South America to result from dispersal across the Panama land bridge. The isthmus was a filter that excluded the passage of species native to xeric or highland habitats, which should have included *Bombus* (Simpson and Neff 1985). The presence of meliponine fossils from the Greater Antilles and the insular existence of *M. variegatipes* in the Lesser Antilles imply an ancient connection between North and South America. The relationship to South America is demonstrated by similarities in *M. variegatipes* and *M. favosa* genitalic structure and worker morphology (Figs. 10–23, Table 1 and Moure 1960, 1971).

The second part of our general argument is that vicariance, the splitting up of previously contiguous populations, led to mutually exclusive distributions of sister species of *Melipona* in Panama and Costa Rica. There are no major vegetational or climatic differences setting these regions apart. All of the *Melipona* of the isthmian area live in lowland forest and build their nests in cavities in living trees (Roubik 1983 and in press). Their foraging habits are broadly similar, but detailed information exists only on the pollen utilization by three species (Roubik and Moreno, unpublished data). We propose that *Melipona* were separated from parent populations during the Eocene or Miocene, diverged ecologically and also specifically in Central America and South America, yet now retain sufficient similarity to competitively exclude their sister species in the isthmian region. The sister species were geographically separated until the late Pliocene. Considering *Melipona* of the region, eight species in all, only one extends from Mexico to South America, *M. fasciata.* Two more range from Costa Rica to Brazil *(M. fuliginosa* and

M. marginata). One bee, *M. crinita,* is restricted to eastern Panama and western South America. The other four species form two closely-related pairs, *M. compressipes—M. beecheii* and *M. favosa—M. yucatanica.* The first two species have similar male genitalia and their workers are strongly similar in appearance (Schwarz 1932). The ranges of each pair are mutually exclusive in Panama and Costa Rica. Furthermore, a clearly distinct form of *M. compressipes* is found on the large Pacific Panamanian island of Coiba, and *M. favosa* exists on numerous small islands in the Bay of Panama (Roubik in press). These two taxa have several races in South America (Schwarz 1932). Both are certainly adapted to living on islands, some very small, isolated from mainland Panama since the upper Pleistocene.

Only 3 of the more than 40 *Melipona* species are not South American, and it seems likely that a northward dispersal of bees took place across the Caribbean arc. However, the state of our knowledge does not allow recognition of the relatively more primitive or derived taxa, thus does not exclude the possibility of southward dispersal.

Other meliponines indicate wide distribution of bee fauna before formation of the isthmus. Similar vicariant speciation has likely occurred in Central and South American populations. Many supraspecific groups of the Trigonini and certain individual species are distributed throughout the neotropics and probably also inhabited the proto-Antillean archipelago. These include *Lestrimelitta, Partamona, Nannotrigona, Scaptotrigona, Plebeia, Paratrigona, Trigonisca, Dolichotrigona, Tetragonisca, Frieseomelitta, Trigona* and *Cephalotrigona.* Since their distributions range from southern Brazil to Mexico and at least *Cephalotrigona capitata, Tetragonisca angustula (= T. jaty)* and *Lestrimelitta limao* are found throughout this range, it seems that relatively few neotropical meliponine species spread widely after the Panama gap was bridged. The timing of their dispersal may have allowed speciation but not the initiation of insular supraspecific groups. Alternatively, many of the supraspecific groups might have crossed the isthmus only after the formation of the Panama land bridge. As mentioned earlier for *Bombus,* a few dozen of which are restricted to South America, such a high degree of speciation seems unlikely to have occurred since the Pleistocene. So far as we know, at least one or two insular Trigonini in each of the abovementioned supraspecific groups are found north of Panama, making their rate of speciation similar to that of *Melipona.* Therefore, higher Trigonini may have existed in South America and along the proto-Antillean archipelago during the Eocene. Fossil amber *Nogueirapis* of southern Mexico (a bee that generally builds nests in the ground and cannot disperse by rafting or transport in logs) and its current absence north of Costa Rica suggest some regional extinctions of higher meliponine groups. In addition, another South American group having several species there but only one north of Panama, *Ptilotrigona,* is found in southeastern Costa Rica but is absent in the rest of Central America and Panama. These continental taxa trace the demise of previously wide-ranging groups. The distinct distributions of four isthmian *Melipona* provide further evidence of dispersal between North and South America, and subsequent vicariance, preceding formation of the Panamanian land connection.

Acknowledgments

We wish to acknowledge the field support and generous contributions of bee colonies by Jorge González Acereto of the University of Yucatán, and also the information supplied by Charles D. Michener and Ricardo Ayala. The first authors

acknowledge Brazilian grants from CNPq 406235/84 ZO and CNPq 30.0014/84 BM, respectively; the first author also appreciates funding from FAPESP, project 85/2842-7 Bot. We are especially pleased to contribute this paper in honor of E. Gorton Linsley, whose work on island biogeography and many aspects of bee biology opened paths for others to follow.

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PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 159–172

Notes on Tabanidae (Diptera) of the Oriental Region III. New and Little-Known Tabanidae from Borneo[1]

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Abstract.—Fourteen species of Tabanidae were examined in three small collections from Sabah, Malaysia (North Borneo) and southeastern Borneo (Indonesia). Five new species, *Haematopota quadrifenestrata, Tabanus atratoides, Tabanus atropilosus, Tabanus samawangensis,* and *Tabanus transversus,* are described from Sabah, and one new species, *Tabanus atristylatus,* is described from southeastern Borneo. Two species, *Tabanus brevicallus* and *T. stantoni* are recorded from northern Borneo (Sabah) for the first time. *Chrysops translucens,* known from Sarawak and Brunei in northern Borneo, is here recorded from Sabah. Collection records are summarized, and observed variation in taxonomic characters is discussed.

The tabanid fauna of peninsular Malaysia and Borneo has remained unstudied since the review by Philip (1960a, 1960b). A recent small collection of 33 specimens from Sabah, Malaysia, in northern Borneo, by scientists from the National Museum of Natural History, Washington, D.C., yielded 11 species of Tabanidae, 5 of which proved to be undescribed, and an undescribed genus in the Pangoniini, the first representative of this tribe known from the Oriental Region. An additional 11 specimens from Sabah in the Museum of Comparative Zoology, Harvard University, and a specimen from southeastern Borneo in the Cornell University collection, yielded 3 additional undescribed species of *Tabanus*. Two species in the new genus of Pangoniini are treated in a separate paper. The notes and descriptions provided here supplement the review by Philip.

The relatively large number of undescribed species in these small collections suggests that the tabanid fauna of Borneo is more diverse than presently realized, and that a significant percentage of the fauna remains to be discovered. This is probably true for most of the Oriental Region, as suggested by Burton (1978). Unless a major effort is made to adequately sample the horse fly fauna of Malaysia and Indonesia, it is unlikely that we will attain a good understanding of many species groups in Tabanidae before destruction of tropical forests and other natural habitats extirpates the indigenous fauna.

Chrysops translucens Macquart, 1838

Material examined.—MALAYSIA: Sabah; Weston, 11 August 1983, G. F. Hevel & W. E. Steiner (1 ♀).

[1]Scientific Contribution Number 1509 from the New Hamphsire Agricultural Experiment Station.

This is the first record of this species from Sabah, but the site of collection on the northwestern coast is near Brunei and Sarawak, where *translucens* has been recorded (Philip, 1960b). The female seen here is 7.6 mm long, and agrees well with published descriptions. Philip states that *translucens* is a "larger" species (9 mm), but other characters, particularly the reddish yellow frontoclypeus, swollen dark brown tibiae, posteriorly divided crossband of the wing, and the yellow basal bands on abdominal terga 1 and 2 will separate this species from other *Chrysops* in the Oriental Region.

Haematopota pendleburyi Stone & Philip, 1974

Material examined.—MALAYSIA: Sabah; 1 km. s. Kundasang, el. 1530 m., 26 Aug. 1983, G. F. Hevel & W. E. Steiner (3 ♀), 22 Aug. 1983 (1 ♀), 25 Aug. 1983, (1 ♀); Kinabalu National Park, Headquarters area, el. 1560 m., 7 Sept. 1983, (1 ♀), 9 Sept. 1983 (3 ♀), G. F. Hevel & W. E. Steiner.

The specimens examined here agree well with the original description by Stone & Philip (1974). Length of specimens 8–9.6 mm, width of the front at vertex 0.6–0.8 height, and the apical palpomere of the maxillary palpi gray to brown tomentose. One female from Kundasang has a narrower frontal callus than usual and lacks a dorsal extension. Stone & Philip did not mention the rather strikingly bicolored abdomen. Terga 1–3 are light brown, terga 4–7 are black, the transition usually occurring abruptly at the apex of tergum 3. The ventral surface is similar, except the anterior sterna are more yellowish. The posterior margins of all terga are narrowly gray, slightly wider at the lateral margins. The gray bands on the ventral surface are narrow medianly, abruptly widened laterally, especially on posterior segments. Specimens from Mount Kinabalu average slightly larger than those from Kundasang.

Haematopota quadrifenestrata Burger, New Species

(Fig. 1)

Holotype Female.—Length 9.6 mm; wing length 9.2 mm; antenna 2.2 mm. Front parallel-sided, taller than wide, width at vertex 0.7 height, dark gray tomentose, bearing large paired irregular velvety black spots laterally, broadly contiguous with eye margins, narrowly separated from upper margins of callus, submedian paired subshining black spots below vertex, and small pale grayish spot at apex of dorsal extension of callus; callus about 2.5 times broader than tall (excluding dorsal extension), narrowly contiguous with eye margins at ventrolateral corners, upper margin evenly convex, with broadly triangular median dorsal extension extending nearly two-thirds distance to vertex; interantennal spot large; face and parafacials gray, except for sharply delimited velvety black transverse stripe beneath antennae that extends along ventral margin of eyes; scape of antenna shining dark brown, cylindrical, four times longer than thick, densely clothed with semi-erect black setae, flagellum slender, black, 1.5 times longer than scape; maxillary palpi gray-black, apical palpomere relatively stout, bearing black setae and scattered pale hairs along ventral margin.

Mesonotum dark brown tomentose, except postpronotal lobes and area behind head gray, bearing paired slender sublateral gray stripes expanding to strong spots at transverse suture, and paired gray crescentic spots anterior to scutellum, mostly black pilose with some silvery hairs intermixed laterally and posteriorly; scutellum wholly brown tomentose and black setose; pleuron gray tomentose and white pilose except dark brown along lower margin of mesanepisternum and upper margin of

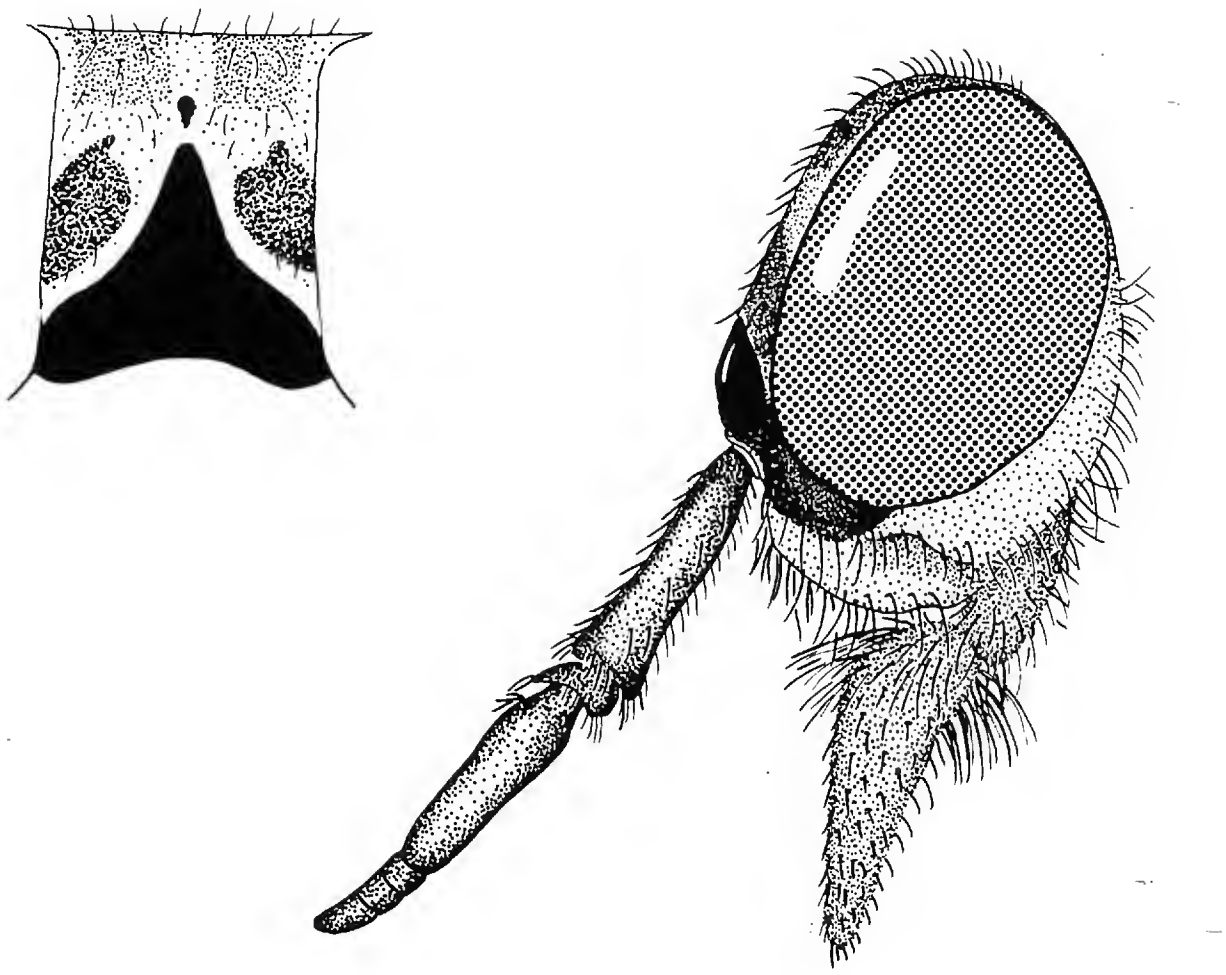


Figure 1. *Haematopota quadrifenestrata* Burger, female. Front, lateral view of head, wing.

katepisternum; coxae gray basally, blackish apically, femora black, fore and hind tibiae white on basal one-third, otherwise black, mid tibiae white on basal half, tarsi black, pale and dark areas of legs white and black pilose respectively; wings dark brown, except paler in radial and medial cells, normal pattern of rosettes reduced to four hyaline spots, three occurring anteriorly, medianly, and posteriorly in line just past middle of wing, and subapical streak in first submarginal cell, anterior spot in middle of marginal cell, narrowly extended into first submarginal cell, median spot elongate-oblique, extending from middle of first posterior cell through apical fourth of discal cell, narrowly extending into upper part of fourth posterior cell, posterior triangular spot in fifth posterior cell at hind margin of wing; halteres white, except base of stalk brownish.

Abdomen dark shining brown, all terga with narrow apical gray tomentose bands, that of tergum 1 broader than those on remaining terga, tergum 1 entirely gray tomentose laterally; sternum 1 entirely gray tomentose and white pilose, remaining sterna with conspicuous apical gray tomentose bands that are widened laterally, broadest on sterna 2–3, progressively narrower on posterior segments.

Holotype Female.—MALAYSIA: Sabah; Kinabalu National Park, Poring, el. 570 m., 18 Sept. 1983, G. F. Hevel & W. E. Steiner. Deposited in the National Museum of Natural History, Washington, D.C., U.S.A.

This species would key to *Haematopota bizonata* Schuurmans Stekhoven, from North Borneo [Sabah], in Stone & Philip (1974). It differs from *bizonata* in having the callus darker and more broadly convex above, more attenuated laterally and with a broadly triangular median dorsal extension, larger paired spots above the callus and conspicuous submedian black spots below the vertex, silvery hairs across the hind margin of the mesonotum, scutellum entirely dark brown tomentose and black pilose, wing pattern with four isolated hyaline spots, halteres white, mid- and hind tibiae white on basal half and one-third respectively, all abdominal terga bearing narrow apical gray tomentose bands, and sterna 2–7 dark brown basally, bearing apical gray tomentose bands.

H. quadrifenestrata appears to be a montane species, and may be restricted to the higher elevations of the Crocker Range in western Sabah. *H. bizonata* is recorded from the southeastern part of Sabah, near the coast. *H. pendleburyi* also occurs in montane habitats, but is immediately recognizable by the normal pattern of rosettes on the wing.

Tabanus atratoides Burger, New Species

(Fig. 2)

Holotype Female.—Length 12.8 mm; wing length 10.8 mm. Front narrow, strongly diverging toward vertex, index 10.5, index of divergence 2.0, dark gray tomentose; basal callus black, inverted V-shaped, separated from eye margins along lower border; subcallus and frontoclypeus dark brown, black pilose; beard black; scape and pedicel black, gray tomentose, basal flagellomere brown, dorsal angle obtuse, 2.5 times longer than height, terminal annulations black, combined length one-half that of basal flagellomere; maxillary palpi black, wholly black pilose; eyes bare, without color pattern (revived).

Mesonotum, pleuron and scutellum black with bluish pruinose tones, entirely black pilose, except a tuft of white hairs on upper posterior margin of mesanepisternum; legs black; anterior third of wing brown tinted, extending into basal half of first posterior cell, rest of wing subhyaline, R_4 without spur; halteres dark brown.

Abdomen entirely black, black pilose, concolorous with thorax.

Holotype Female.—B. N. Borneo [Sabah, Malaysia], Mt. Kinabalu, Kenokok, 3300 ft., 22 April 1929, H. M. Pendlebury coll., F. M. S. Museum. Deposited in the Museum of Comparative Zoology, Cambridge, Massachusetts, U.S.A.

T. atratoides is close to *Tabanus stekhoveni* Philip (= *T. elegans* Schuurmans Stekhoven), originally described from western Sarawak by Schuurmans Stekhoven (1926). It differs, however, in having a less abruptly tapered dorsal extension of the basal callus, stouter palpi, infuscated anterior part of the wing strongly contrasting with the posterior hyaline area, and the femora not paler apically.

Tabanus atristylatus Burger, New Species
(Fig. 3)

Holotype Female.—Length 16 mm; wing length 12.8 mm. Front relatively narrow, slightly diverging toward vertex, index 8.5, index of divergence 1.5, yellowish gray tomentose, black pilose, with small irregular denuded brown spot at vertex, basal callus brown, narrowly triangular, well-separated from eye margins, with a broad dorsal extension; subcallus and adjacent frontoclypeus yellowish tomentose, otherwise frontoclypeus light gray tomentose, beard white; antennal scape, pedicel and basal flagellomere brown, terminal flagellomeres black, basal flagellomere length twice height, dorsal tooth strong; maxillary palpi light brown tomentose, apical palpomere rather slender basally, blunt apically, pale pilose at extreme base, remainder black pilose.

Mesonotum and scutellum brownish gray tomentose, black pilose, with scattered pale hairs intermixed, notopleural lobes reddish tinged, anterior half of mesonotum with indistinct brown median and sublateral stripes (best seen from behind); pleuron light gray tomentose, white pilose except scattered black hairs dorsally on posterior half of mesanepisternum; coxae light gray tomentose, white pilose, fore femora black, gray tomentose on outer surface, mid- and hind femora brown, gray tomentose, tibiae brown, except apical half of fore tibiae and extreme apices of mid- and hind tibiae darkened, fore tarsi black, mid- and hind tarsi brown basally, apical tarsomeres black; costal cell of wing yellow-brown tinted, rest of wing pale brown tinted along wing veins, subhyaline in interior of cells and along apico-posterior margin; halteres with base of knob dark brown, apex yellowish.

Abdomen brown dorsally, with terminal 3 segments slightly darkened, yellow-brown ventrally, all terga black pilose except white pilose on lateral margins, pale yellowish spot of hairs medianly on tergum 1, and small median yellow pilose triangles on terga 2–5 not underlain by pale integument; sterna 2–5 with large median dark-haired patches, sterna 6–7 entirely black.

Holotype Female.—S. E. BORNEO: 17–46 km. W. Batulitjin, 28 June–2 July 72, lowland rainforest, W. L. Brown. Deposited in the Cornell University Collection, Ithaca, New York, U.S.A.

T. atristylatus is in the *Tabanus malayensis* group, and is closest to *T. angustitriangularis* Schuurmans Stekhoven, known from Malaya, Sumatra and Java. It differs from *angustitriangularis* in being slightly larger, the wholly brown basal flagellomere, black fore femora, paler abdominal terga, smaller median triangles on terga 2–5, lateral borders of all terga broadly pale pilose, and sternum 6, as well as 7, wholly black. Precise definition of species limits for taxa related to *T. malayensis* Ricardo, and those of the *Tabanus immanis/fumifer* groups, is difficult. These groups need a thorough review to determine limits of variation within and between described species from Malaysia and Indonesia.

Tabanus atropilosus Burger, New Species
(Figs. 4, 5)

Female.—Length 11.2–12.4 mm; wing length 9.6–10.8 mm. Front narrow, diverging toward vertex, index 7.0, index of divergence 1.7–1.8, dark grayish brown tomentose and black pilose, basal callus brown, rectangular, about twice as tall as wide, contiguous with eye margins, median callus black, narrowly lanceolate to oval, widely separated from basal callus; subcallus denuded, shining brown; frontoclypeus

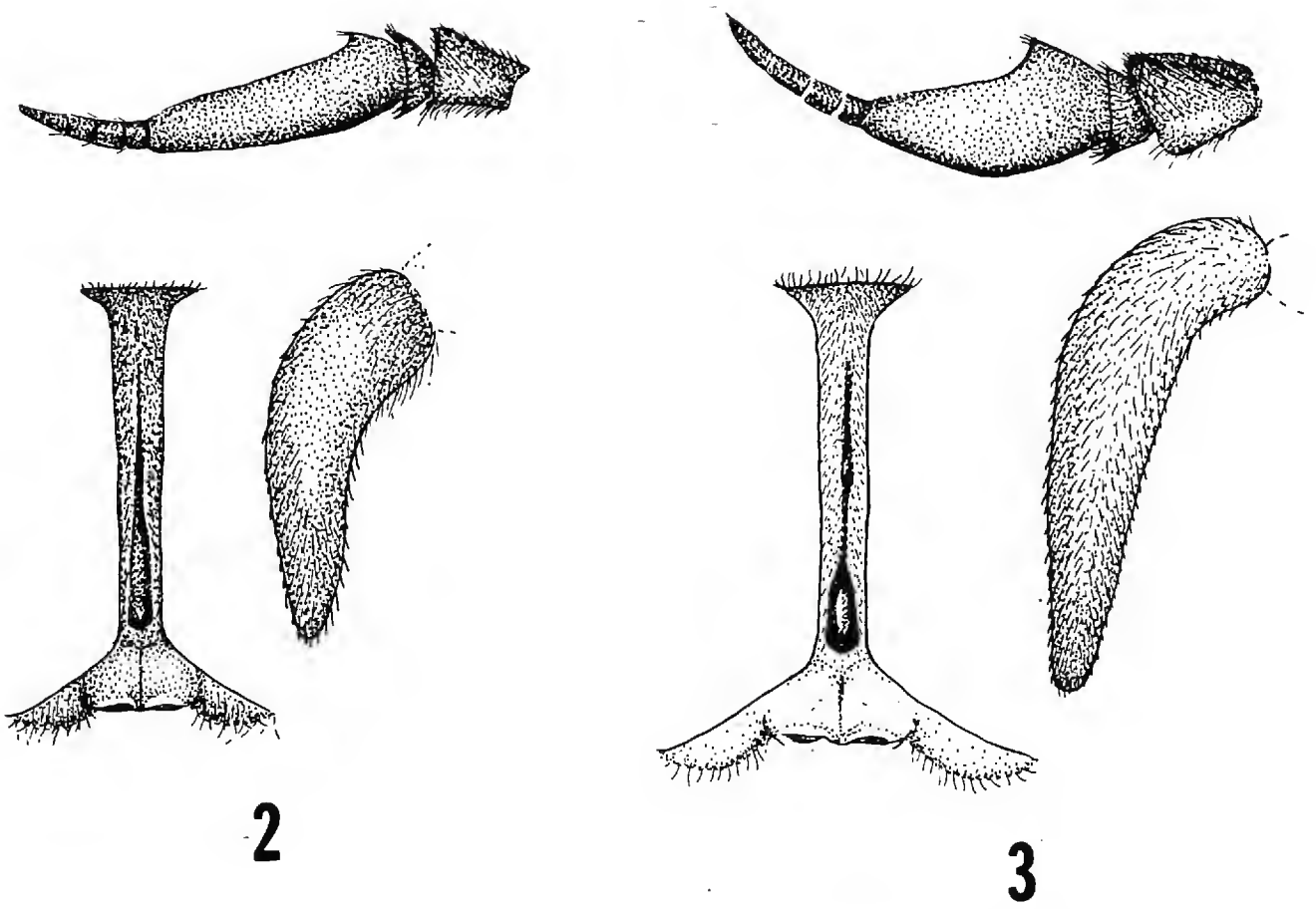


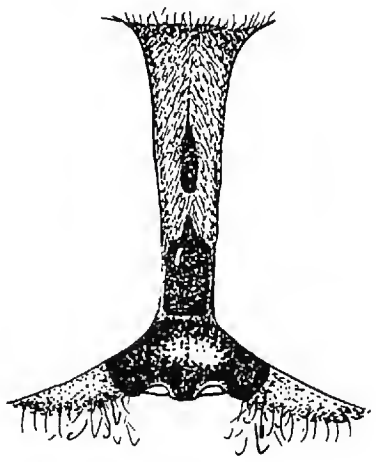
Figure 2. *Tabanus atratoides* Burger, female. Antenna, front, apical palpomere. Figure 3. *Tabanus atristylatus* Burger, female. Antenna, front, apical palpomere.

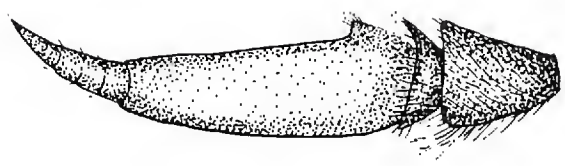
gray tomentose, white pilose, parafacials brownish tinged and black pilose laterad of subcallus along ventral margin of eyes, beard white; antennae brown, scape enlarged dorsally, shining, basal flagellomere elongate, with obtuse dorsal tooth, length twice height, and twice length of terminal flagellomeres; maxillary palpi light gray tomentose with some bluish gray tones, apical palpomere stout basally; eyes bare, pattern (revived) a narrow median transverse purple stripe on bright green ground.

Mesonotum brown tomentose with some grayish tones anteriorly and laterally, black pilose, scutellum concolorous, postpronotal lobes gray tomentose, notopleural lobes reddish gray; pleuron gray tomentose, white pilose, with some black hairs intermixed on mesanepisternum. Coxae gray tomentose, fore femora black, gray tomentose on outer surface and mixed black and white pilose, mid- and hind femora brown, gray tomentose, tibiae yellowish white basally, white pilose, apical one-third of fore tibiae and apical one-fourth of mid- and hind tibiae contrastingly black, tarsi black; anterior part of wing brownish tinged, sometimes concentrated in the marginal and first submarginal cell along veins R_{2+3} and R_4, remainder of wing subhyaline, R_4 without spur, basal half of Cu vein forming lower margin of median cell with row of setulae; halteres yellowish to dark brown.

Abdomen reddish brown anteriorly, progressively darkened on posterior segments, black pilose, ventral surface light brown with a poorly-defined dark grayish tomentose, black-haired median stripe, paler areas yellowish pilose.

Male.—Length 10.4–11.6 mm; wing length 9.6–10 mm. Apical palpomere elongate-oval, gray tomentose, bearing mixed black and pale hairs; large and small





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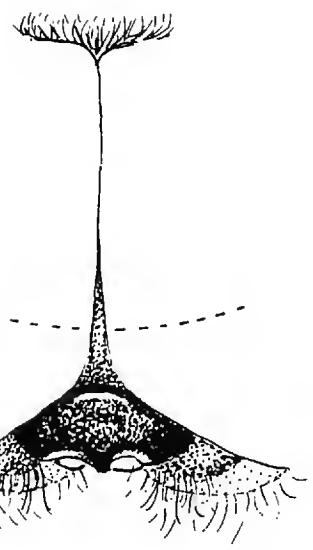

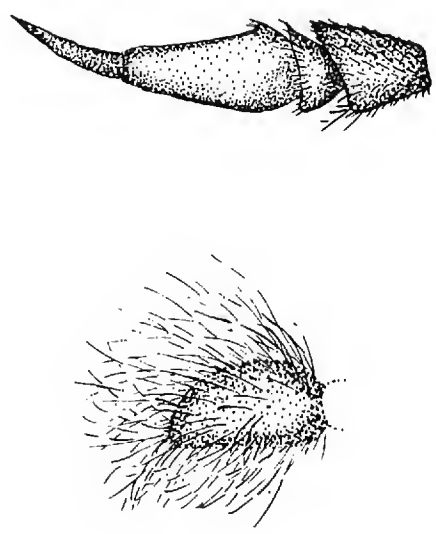

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Figure 4. *Tabanus atropilosus* Burger, female. Front, antenna, apical palpomere. Figure 5. *Tabanus atropilosus* Burger, male. Front of head, antenna, apical palpomere.

eye facets sharply differentiated along lower one-third of eye, area of small facets continuing around posterior margin of eye nearly to vertex; postocular fringe of black hairs very long and curved forward over eyes, otherwise similar to female.

Holotype Female.—MALAYSIA: Sabah; Kinabalu National Park, Headquarters area, el. 1560 m, 9 Sept. 1983, G. F. Hevel & W. E. Steiner. Deposited in the National Museum of Natural History, Washington, D.C., U.SA.

Paratypes.—2 ♀, 4♂; 1♀, same data as holotype; 7 Sept. 1983 (1 ♀), 5 Aug. 1983 (2 ♂); Poring, 8 Sept. 1983 (1 ♂); Mt. Kinabalu, Marei Parei, 5000 ft, April 27, 1929, F. M. Pendlebury Coll., F. M. S. Museums (1 ♂).

One female has a trace of a spur on the R_4 vein of the right wing only. The male from Marei Parei is darker than the others, with pale tibial markings very indistinct, and the ventral surface of the abdomen entirely black pilose. In all other respects, however, it is similar to the other males and thus is considered conspecific.

T. atropilosus is in the *ceylonicus* group, based on the narrow front, greatly elongate basal flagellomere, bare subcallus, strongly bicolored legs, and absence of contrasting markings on the mesonotum and abdomen. It also has a row of setulae on the basal portion of the Cu vein (most species in the *ceylonicus* group have at least 2–4 scattered setulae on the cu vein). I agree with Burton (1978) that although the *ceylonicus* group has some features in common with the *biannularis* group of *Tabanus,* they are distinct entities, based on present knowledge.

Tabanus brevicallus Philip, 1959

Material examined.—MALAYSIA: Sabah; Tanjung Aru Beach, 29 August 1983, G. F. Hevel & W. E. Steiner (1 ♀); N. Borneo, Labuan Is., June 30, 1927, C. B. K. & H. M. P. [H. M. Pendlebury] (1 ♀).

This species has been recorded from the islands of Palawan and Mindanao, adjacent to Sabah, as well as other islands of the Philippine Archipelago. The records listed here are the first from Malaysia.

The female from Tanjung Aru Beach is in excellent condition. It agrees well with the original description of *T. brevicallus* (Philip, 1959), except for the narrower front (index 5.0), smaller size (length: 10 mm), the apical palpomere with more white hair mixed with black, and the entirely hyaline wing. The female from Labuan Island is somewhat rubbed and discolored but agrees closely with the Tanjung Aru Beach specimen.

Tabanus brunnicolor Group

Four species of *Tabanus* related to *T. brunnicolor* Philip (= *T. brunneus* Macquart) were separated by Philip (1960b) from other Malaysian species of the *Tabanus fumifer-malayensis* groups in his key by the blackish brown legs and abdomens, dark "antealar tubercles" (= notopleural lobes), broader fronts (index: 7.0–8.5), eyes green on lower half, and size (length at least 16 mm). Included in this group of species are *Tabanus audyi* Philip, *T. brunnicolor, T. parabrunneus* Schuurmans Stekhoven, and *T. parallelifrons* Schuurmans Stekhoven. Philip used the color of the basal callus, color of tibial pilosity, size of median abdominal spots, extent of excision and tooth height on the dorsal margin of the basal flagellomere, the frontal index, color of the mesonotum, and color of the ventral abdominal vestiture to separate these taxa. Unfortunately, these characters have not proven satisfactory for accurate identification. Especially variable are the frontal indices (the index of the holotype of *audyi* is 9.7), color of the tibiae (black in Malayan specimens, variably reddish basally in most Bornean specimens), mesonotal color, and color of the ventral abdominal vestiture. The eye colors cannot always be revived, especially when specimens have been in spirit. Clearly, these taxa need additional study to define the limits of variation in Malaya and in the northern part of Borneo. The

following identifications of specimens from Sabah are based on comparison with determined specimens, and from original descriptions in the literature.

Tabanus brunnicolor Philip, 1960

Material examined.—MALAYSIA: Sabah; 1 km. S. Kundasang, el. 1530 m, G. F. Hevel & W. E. Steiner, 21 Aug. 1983 (1 ♀), 11 Sept. 1983 (1 ♀).

T. brunnicolor can be recognized by the uniformly dark chocolate-brown mesonotum and concolorous scutellum, black-brown abdominal terga bearing conspicuous lemon-yellow median triangles not connected to incisural bands, and wings subhyaline to lightly brown tinted. The basal flagellomere of the antenna is wholly black, moderately excised, and bears a moderate-sized blunt tooth. Tergum 1 of the abdomen has a conspicuous spot of yellow hairs in the middle; terga 2–5 bear small equilateral lemon-yellow median triangles apically that extend about one-third the length of each tergum; tergum 6 has a small median spot of yellow hairs on the apical margin; the lateral margins of terga 1–6 are broadly yellow-brown and golden pilose. The ventral surface of the abdomen is bright yellowish brown with golden hairs and black half-moon-shaped median black patches of hair basally on sterna 2–6, that on sternum 3 largest, becoming progressively smaller on succeeding sterna. Sternum 7 is entirely black.

A specimen of *T. brunnicolor* from Perak, Malaya, has the tibiae entirely black and black haired. Both females from Sabah have the mid- and hind tibiae reddish and pale pilose ventrally on the basal two-thirds, entirely black elsewhere. The fore tibiae of one female is entirely black, with scattered pale hairs; the other female has the fore tibiae reddish on the basal one-fourth, and pale hairs on the basal half of the outer margin. The frontal index of both females is 8.0, as is the determined specimen from Perak.

Tabanus parabrunneus Schuurmans Stekhoven, 1932

Material examined.—B. N. Borneo [Sabah, Malaysia], Mt. Kinabalu, Lumu Lumu, 5,000 ft., 6.4.1929, H. M. Pendlebury coll. (3 ♀), 7.4.1929 (1 ♀); Kiau, 3,000 ft., 17.4.1929 (1 ♀).

I am not convinced that *T. parabrunneus* is specifically distinct from *T. brunnicolor* or *T. parallelifrons* Schuurmans Stekhoven. Characters previously used by Philip (1960b) and Schuurmans Stekhoven (1932) are too variable to be reliable. Pending additional study of more material, however, I tentatively recognize *parabrunneus* as distinct. The deeply excised basal flagellomere with a tall, acute dorsal tooth, lighter brown anterior abdominal terga contrasting with darker posterior segments, the pale median triangle on tergum 2 with a dark spot above the apex, and the paler segmentations of the abdominal terga are characteristic of *parabrunneus,* as presently defined.

The Mount Kinabalu specimens are 16.4–19.2 mm long, frontal indices 7.0–9.0, basal callus tall rectangular, not drop-shaped, basal flagellomere with a deep dorsal excision, mesonotum grayish brown, fore tibiae reddish on basal two-thirds of the outer margin, mid- and hind tibiae with basal two-thirds to nearly entire length reddish, darker at the apex. One female has the fore tibiae entirely black, and the mid- and hind tibiae reddish on the basal third of the ventral surface. The abdominal color and pattern is similar to *T. brunnicolor,* except for the basal 3 terga paler chestnut brown, contrasting with the blackish posterior segments, the paler

segmentations on terga 2–6, the narrower yellowish brown markings on the lateral margins of terga 1–5, and the paler yellow vestiture ventrally. One female has the pale segmentations of the abdominal dorsum overlain by yellow hairs; the others have only black hairs overlying the paler segmentations. The wings are more heavily tinted than in *T. brunnicolor,* but this feature may be variable.

Tabanus parallelifrons Schuurmans Stekhoven, 1926

Material examined.—MALAYSIA: Sabah; Kinabalu National Park, Headquarters area, el. 1560 m, G. F. Hevel & W. E. Steiner, 5 Aug. 1983 (1 ♀), 8 Sept. 1983 (1 ♀); B. N. Borneo [Sabah, Malaysia], nr. Kinabalu, Tenompok Pass, 4,700 ft., Mar. 18, 1929, H. M. Pendlebury coll. (1 ♀).

This species is very close to *T. parabrunneus.* Characters used by Philip (1960b) and Schuurmans Stekhoven (1926) to distinguish this species from relatives are too variable to be reliable, but pending a thorough review of this species and related taxa, I recognize it as a distinct species. The females examined here agree with descriptions of *parallelifrons* in having the excision of the basal flagellomere rather shallow, its dorsal tooth obtuse, and its extreme base reddish brown, the front paler grayish to gray-brown below, contrastingly darker above, and the mesonotum brown to reddish brown. For the specimens at hand, the frontal indices are 7.0–7.5, somewhat broader than cited by Philip and Stekhoven, the anterior abdominal terga are darker than in *parabrunneus,* with no trace of paler segmentations, the pale median triangles on terga 2–5 are smaller, the median dark markings on the ventral surface of the abdomen are larger than in *T. parabrunneus* and *T. brunnicolor,* extending the width of each segment, thus the individual sterna are blackish basally and pale yellowish brown apically. Leg markings are indistinguishable from *T. parabrunneus.* One female has white hairs overlying the median abdominal triangles instead of the usual yellowish ones. *T. audyi* also has relatively small abdominal triangles, but also has the legs entirely black, with no reddish traces, a much narrower front, with a drop-shaped basal callus, the basal flagellomere entirely black, with a very shallow dorsal excision and low dorsal tooth, and the basal segments of the abdomen dark chocolate brown, not paler than posterior segments.

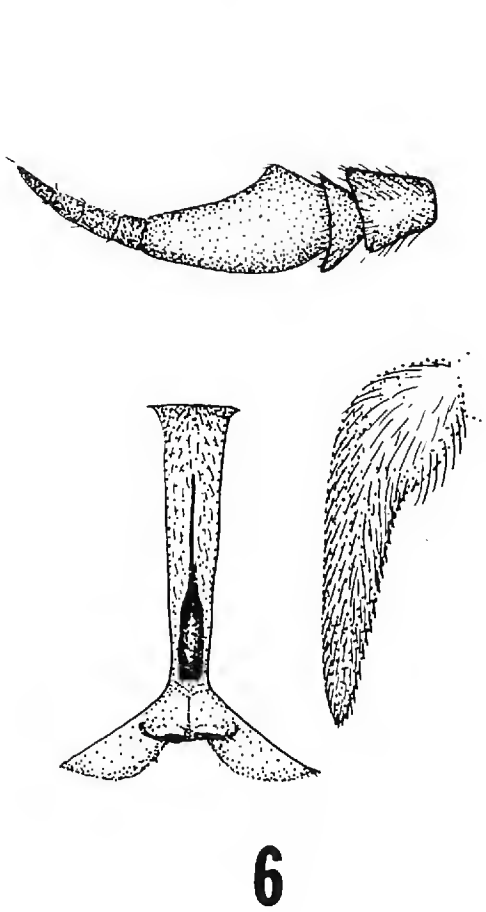
Tabanus partitus Walker, 1857

Material examined.—MALAYSIA: Sabah; Tanjung Aru Beach, 3–4 August 1983, G. F. Hevel & W. E. Steiner (1 ♂), 20 August 1983 (1 ♀); 1 km. S. Kundasang, el. 1530 m, Aug. 1983 (1 ♀).

These specimens agree well with the description of *T. partitus* by Burger & Thompson (1981). The female from near Kundasang has the outer margin of the median abdominal stripe more irregularly serrated than the specimen from Tanjung Aru Beach.

Tabanus samawangensis Burger, New Species
(Fig. 6)

Holotype Female.—Length 12 mm; wing length 9.6 mm. Front narrow, diverging toward vertex, index 8.0, index of divergence 1.6, reddish gray tomentose, basal callus brown, parallel-sided below, tapering to slender dorsal extension; subcallus and adjacent upper frontoclypeus yellowish gray tomentose, remainder whitish tomentose, beard white; antennae orange-brown, terminal flagellomeres dark



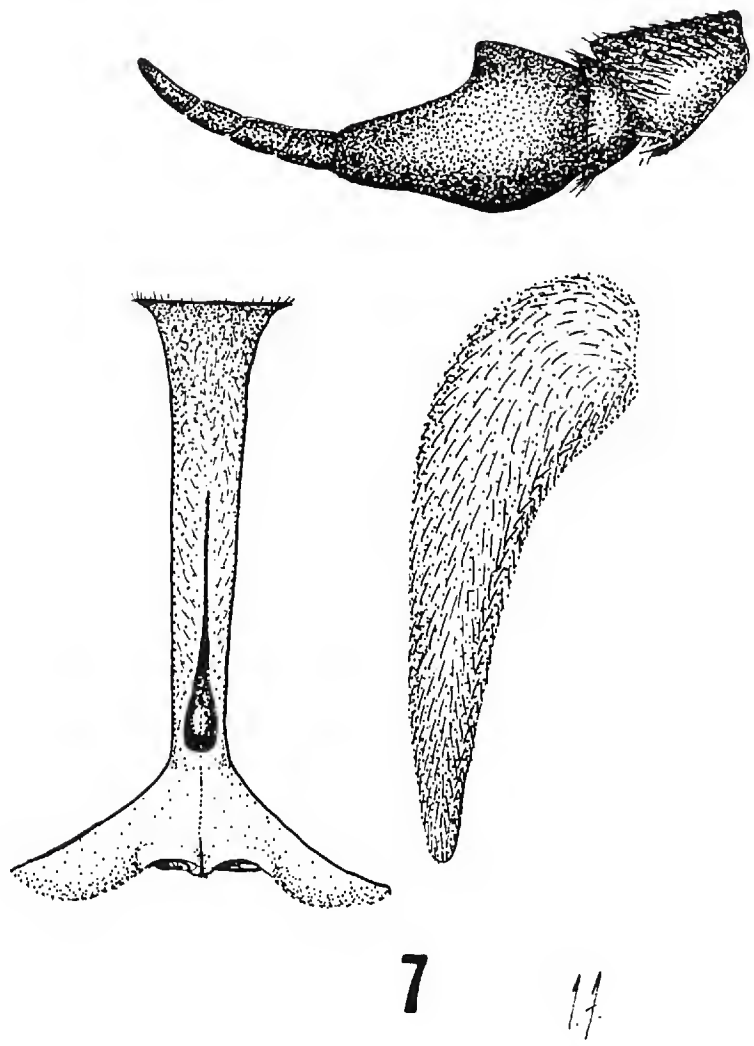


Figure 6. *Tabanus samawangensis* Burger, female. Antenna, front, apical palpomere. Figure 7. *Tabanus stantoni* Ricardo, female. Antenna, front, apical palpomere.

brown, basal flagellomere with moderate dorsal angle, about 1.5 times longer than broad; maxillary palpi pale yellowish gray, apical palpomere pale haired at base and on ventral surface, mostly black haired elsewhere; eyes bare, dark green (revived).

Mesonotum and scutellum light brown, gray tomentose, bearing mixed black and brassy yellow hairs, notopleural lobes reddish; pleuron gray tomentose, pale pilose, except posterior half of mesanepisternum with reddish tones; legs orange-brown except apical third of fore tibiae and the fore tarsi black, tibiae yellow haired ventrally, black haired dorsally, hind tibial fringe black; wings hyaline, R_4 without spur; halteres with knob yellow, stalk light brown.

Abdomen brown basally, gradually darkened apically, bearing mixed black and yellow hairs forming no discernible pattern, pale yellowish brown ventrally, gray pollinose and pale yellow pilose.

Holotype Female.—N. Borneo, Samawang, near Sandakan [Sabah, Malaysia], in jungle, 7th July 1927, C.B.K. & H.M.P. [H. M. Pendlebury], F. M. S. Museums. Deposited in the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, U.S.A. The type locality is situated at approximately 5° 50′N, 118° E, on the northeastern coast of Sabah.

Tabanus stantoni Ricardo, 1911
(Fig. 7)

Material examined.—Br. N. Borneo [Sabah, Malaysia], Papar, VI–7–51, Collr. G. W. Angalet (1♀).

A female in the Cornell University Collection agrees well with specimens from the British Museum collection, from Batu Tiga, except in having more extensive yellow hair on the hind femora and tibiae, and some golden hairs laterally on abdominal terga 1–3. Stone (1975) incorrectly synonymized this species with *T. immanis* Wiedemann. Since there has been some confusion about the identity of this species, and it has not been adequately figured, an illustration is provided.

Tabanus transversus Burger, New Species
(Figs. 8, 9)

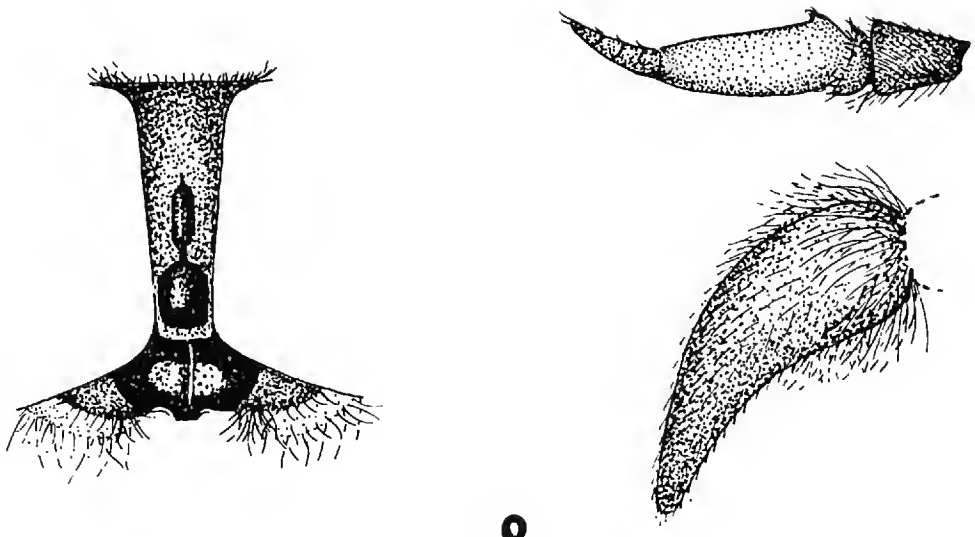
Holotype Female.—Length 9.6 mm; wing length 9.0 mm. Front relatively narrow, diverging toward vertex, index 6.0, index of divergence 1.6, yellowish gray pollinose near subcallus, blackish beyond level of median callus, basal callus rectangular, reddish brown below, black above, separated from denuded subcallus and from eye margins, median callosity black, nearly as broad as basal callus and narrowly joined to it; subcallus denuded, dark brown; frontoclypeus yellowish gray tomentose except dark brown from lateral margins of subcallus along lower margin of eyes, beard white. Antennae reddish brown, terminal flagellomeres slightly darker, basal flagellomere elongate, slender, dorsal angle low, length 1.6 times longer than terminal flagellomeres; maxillary palpi dark bluish gray tomentose, basal palpomere densely long yellow pilose, apical palpomere stout basally, densely black setose, except for some pale hairs at extreme base; eyes bare, pattern (revived) a broad green diagonal median stripe on a dark purple ground.

Mesonotum and scutellum yellowish gray tomentose, yellow pilose, a broad subshining black transverse band present between the wings extending from notopleural lobes to but not including prescutellum; pleuron gray tomentose and pale yellow pilose; coxae gray tomentose, white pilose, femora black, gray tomentose, mostly pale pilose, distal outer margin of fore femora black pilose, tibiae pale yellowish white basally, white pilose, distal one-fifth sharply black, tarsi black; wings lightly brown tinted in costal cell and along anterior margin of wing, otherwise hyaline, R_4 vein without spur; halteres light brown.

Dorsum of abdomen black, black pilose, terga 1–2 yellowish gray tomentose and yellow pilose laterally, terga 3–4 similarly colored only on posterolateral margins, terga 3–4 with conspicuous median half-moon-shaped spots on posterior margin of each segment, extending about half length of segments, tergum 6 with pale apical fringe of hairs; ventral surface yellowish gray tomentose, pale yellowish pilose except sterna 2–3 narrowly brown basally and sternum 7 wholly black.

Holotype Female.—MALAYSIA: Sabah; 1 km. S. Kundasang, el. 1530 m, 24 Aug. 1983, G. F. Hevel & W. E. Steiner. Deposited in the National Museum of Natural History, Washington, D.C., U.S.A.

T. transversus is in the *Tabanus biannularis* group. It keys to *Tabanus macdonaldi* Philip, from Selangor, Malaya (Philip, 1960b). It differs from *macdonaldi* in having a broader front, no flat, bare tubercle at the vertex, broader median callus, more grayish frontoclypeus that is sharply brownish laterad to the subcallus, pleuron gray



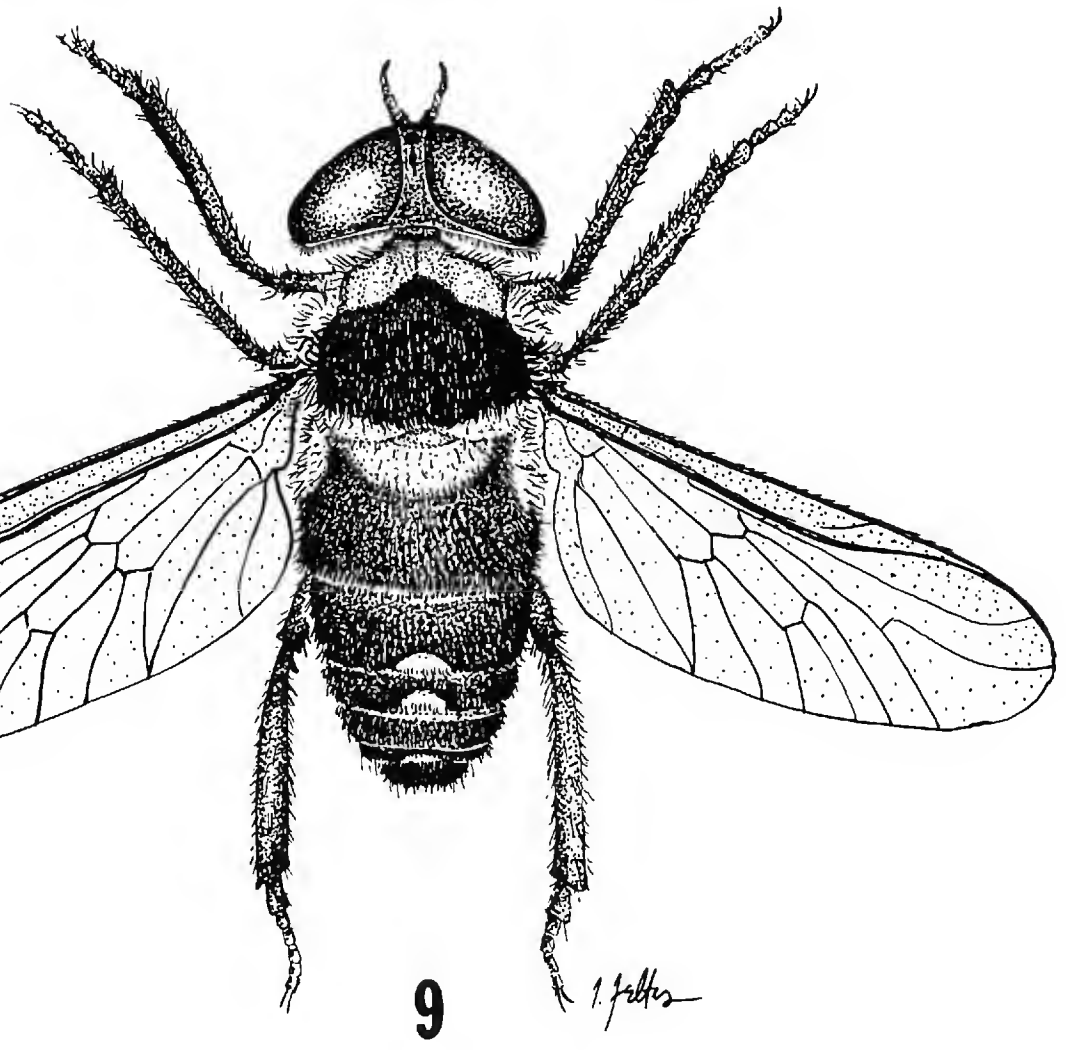


Figure 8. *Tabanus transversus* Burger, female. Front, antenna, apical palpomere. Figure 9. *Tabanus transversus* Burger, adult female, dorsal view.

tomentose, not yellow, yellow half-moon-shaped spots on terga 3–4 and a narrow apical yellow band of hair on tergum 6. *T. transversus* is quite distinct from *Tabanus auricircus* Philip, described from southeastern Sabah (Philip, 1979).

As indicated by Burton (1978), who described 6 new species of the *biannularis* group from Thailand and Laos, this is an extraordinarily diverse group of species that, despite considerable study, remains incompletely known. It is likely that many species remain to be described, since most species seem to occupy limited ranges. A thorough study of the interspecific variation in this group is needed.

Acknowledgments

I wish to thank Mr. John Chainey, British Museum (Natural History) for sending me specimens of Malaysian *Tabanus* for reference, and D. S. Chandler and Scott Sherman, University of New Hampshire for reviewing the manuscript. My special thanks to Tess Feltes, Portsmouth, New Hampshire, for her execution of the illustrations.

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PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 173–182

A New Species of *Goniozus* Foerster from India (Hymenoptera: Bethylidae) used in biological control of *Diaphania indica* (Saunders) (Lepidoptera: Pyralidae).

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Abstract.—*Goniozus sensorius* NEW SPECIES is described. The wasp parasitizes the Pyralid *Diaphania indica* (Saunders) in Chingleput District, Madras, India.

INTRODUCTION

Bethylids submitted for identification to Dr. Z. Boucek, CIE, by Mr. Clement Peter, Frederick Institute of Plant Protection, Chingleput District, Madras, India, represented a species of *Goniozus*. Boucek suggested that Mr. Peter send the material to me for study. The specimens from India represent another undescribed species of *Goniozus*. A name is made available for the wasp here so an account of its biology can be published by Mr. Peter in connection with his research.

Goniozus sensorius Gordh, NEW SPECIES

Female.—3.15 mm long (Holotype). Body black; antenna yellow with apical three segments very faintly infuscated in some plays of light. Mandible concolorous with antennal scape. Legs reddish brown with anterior face of forecoxa and forefemur somewhat darker; tarsal claws black. Wings hyaline; forewing veins pale colored, stigma blackish.

Head in dorsal (frontal) aspect about as long as wide with uniform, rather weak, reticulate microsculpture and numerous shallow, setigerous punctations (Fig. 02); setae along vertexal margin weakly (not strongly) recurved and not conspicuously larger than other setae on head (Fig. 01); vertexal margin acute. Shallow depression anteriad of median ocellus ill-defined but apparent when specimen rotated in diffuse or concentrated light; lateral ocellus at vertexal margin. Fronto-clypeal median longitudinal carina acute (Fig. 01, FC), and projecting above ventral margin of compound eye (Fig. 02, FC). Scrobal impression rather shallow and short, with dorsal margin broadly rounded and not well defined. Head in lateral aspect (Fig. 01) not strongly prognathous (Fig. 06). Compound eye minutely and very sparsely setose; setae evident only at high magnification (Fig. 03, S). Mandibles symmetrical, each four toothed with uppermost tooth truncate, remaining teeth apically pointed, third tooth longest (Fig. 04). Antenna as illustrated (Fig. 08); flagellar segments apparently lacking multiporous plate sensilla (rhinaria, tyloids) under light microscopy, ro vestigal with SEM (Fig. 09, MPS); club apically somewhat truncate (Fig. 08). Maxillary palpus five-segmented; labial palpus three-segmented.

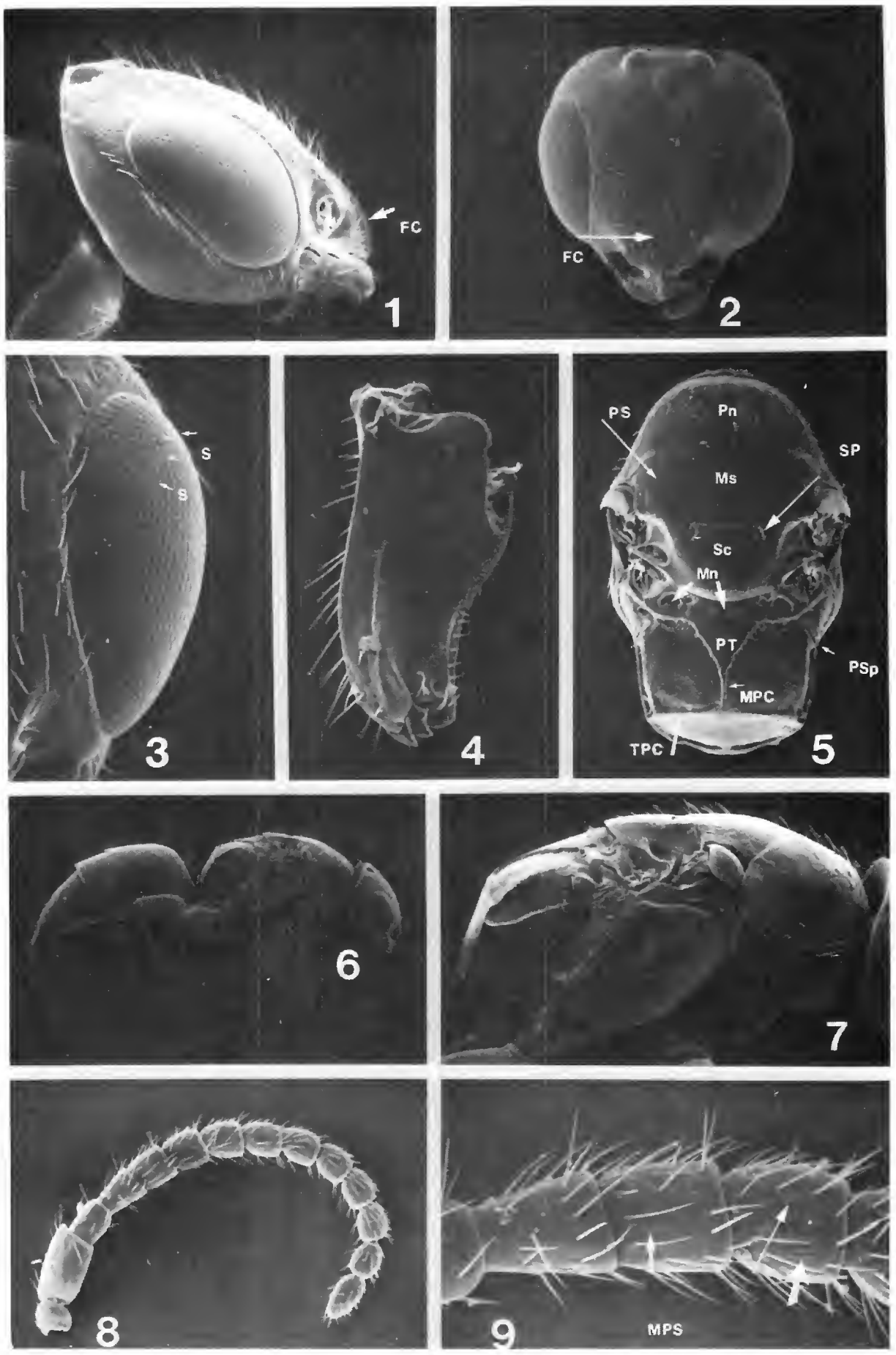


Figure 1. *Goniozus sensorius* n. sp., female head, lateral aspect (110X). (FC. Frontal Carina). Figure 2. *Goniozus sensorius* n. sp., female head, frontal aspect (94X). (FC. Frontal Carina). Figure 3. *Goniozus sensorius* n. sp., female compound eye, frontal aspect (180X). (S. Seta). Figure 4. *Goniozus sensorius* n. sp., female mandible, ventromedial aspect (320X). Figure 5. *Goniozus sensorius* n. sp., female mesosoma, dorsal aspect (66X). (Mn. Metanotum; MPC. Median Propodeal Carina. Ms. Mesoscutum; Pn. Pronotum; PT. Propodeal Triangle; PS. Parapsidal Suture; PSp. Parapsidal Spiracle; SP. Scutellar Pit; Sc. Scutellum; TPC. Transverse Propodeal Carina.) Figure 6. *Goniozus sensorius* n. sp., female mesosoma, lateral aspect (72X). Figure 7. *Goniozus sensorius* n. sp., female habitus, lateral aspect (26X). Figure 8. *Goniozus sensorius* n. sp., female antenna (130X). Figure 9. *Goniozus sensorius* n. sp., female antennal flagellar segments 1–3 (400X). (MPS. Multiporous Plate Sensilla).

Mesosoma in dorsal aspect (Fig. 05) with pronotum (Pn) moderately setose, weakly and uniformly reticulate except smooth along posteromedial margin. Mesoscutum (Ms) moderately setose (only sockets evident in micrograph) with sculpture less pronounced; parapsidal sutures complete but weakly developed (PS). Scutellum sparsely setose (only sockets evident in micrograph); polished, with very minutely and weakly reticulate sculpture between scutellar pits; scutellar pits (Fig. 05 SP) well developed along transscutal suture but transverse groove absent. Metanotum (Mn) with a few setae and weak reticulate sculpture in meson and well-developed pits in lateron. Anteromedial propodeal triangle large, polished and conspicuously elevated (Fig. 05 PT), continuing posteriad as a median carina (MPC) which reaches complete transverse carina (TPC) marking junction of dorsal and posterior faces; dorsal face predominantly reticulate; lateral face entirely reticulate (Fig. 07); posterior face reticulate with pattern evanescent medially. Propodeal spiracle exceedingly inconspicuous, obliquely slit-like, and positioned along anterolateral margin of propodeum (Fig. 05, PSp). Mesosoma in lateral aspect not conspicuously compressed (Figs. 06, 07); mesopleuron with conspicuous vestiture of pale setae along anterior surface (Fig. 07). Wings flat, not curved to form to the curvature of the metasomal dorsum; forewing with basal vein short and not forming an areolet.

Metasoma polished, weakly transversely reticulate along anterolateral margin of Terga II–V; respiratory spiracles on Terga II–VI; Terga III–IV with a few setae laterad; Tergum V with vestiture along posterior half; Tergum VI moderately setose. Sterna II–VI moderately setose with individual setae rather long; apical sternum conspicuously more setose than preceding sterna, when viewed in lateral aspect the setae are decidedly shorter than setae on other sterna and form an erect mat projecting from the integument.

Male.—2.22 mm long (Allotype) (Fig. 13). Similar to female in coloration and habitus. Taxonomically important details include: Head in dorsal aspect (Fig. 11) more transverse, sculpture and chaetotaxis similar to female, but ocelli allometrically (disproportionately) larger. Head in lateral aspect as illustrated (Fig. 10). Antenna (Figs. 19, 21, 23) similar in form to female antenna, with multiporous plate sensilla (Fig. 21 MPS) evanescent. Mandible shorter and wider than female mandible, but with similar sensilla (Fig. 12, third tooth broken).

Mesosoma (Figs. 13, 14) slightly shorter than female mesosoma. Scutellar and metanotal pits as female in shape, position and size (Fig. 16). Propodeal spiracles decidedly larger than female (Fig. 14 PSp). Pretarsal claws "bifid", each with a subapical tine apically truncate (Figs. 27, 28).

Subgenital shield conspicuously setose and with a medial notch along the posterior margin (Figs. 29, 30). Genitalia (Figs. 31, 32) as illustrated.

Etymology

The specific epithet, *sensorius,* refers to the curious atrophy of multiporous plate sensilla found on the flagellar segments of the antenna.

Variation

Female.—Body length ranges from 2.66–4.40 mm in the type-series. Specimens display variation in the coloration of the femora. Some specimens show a decidedly

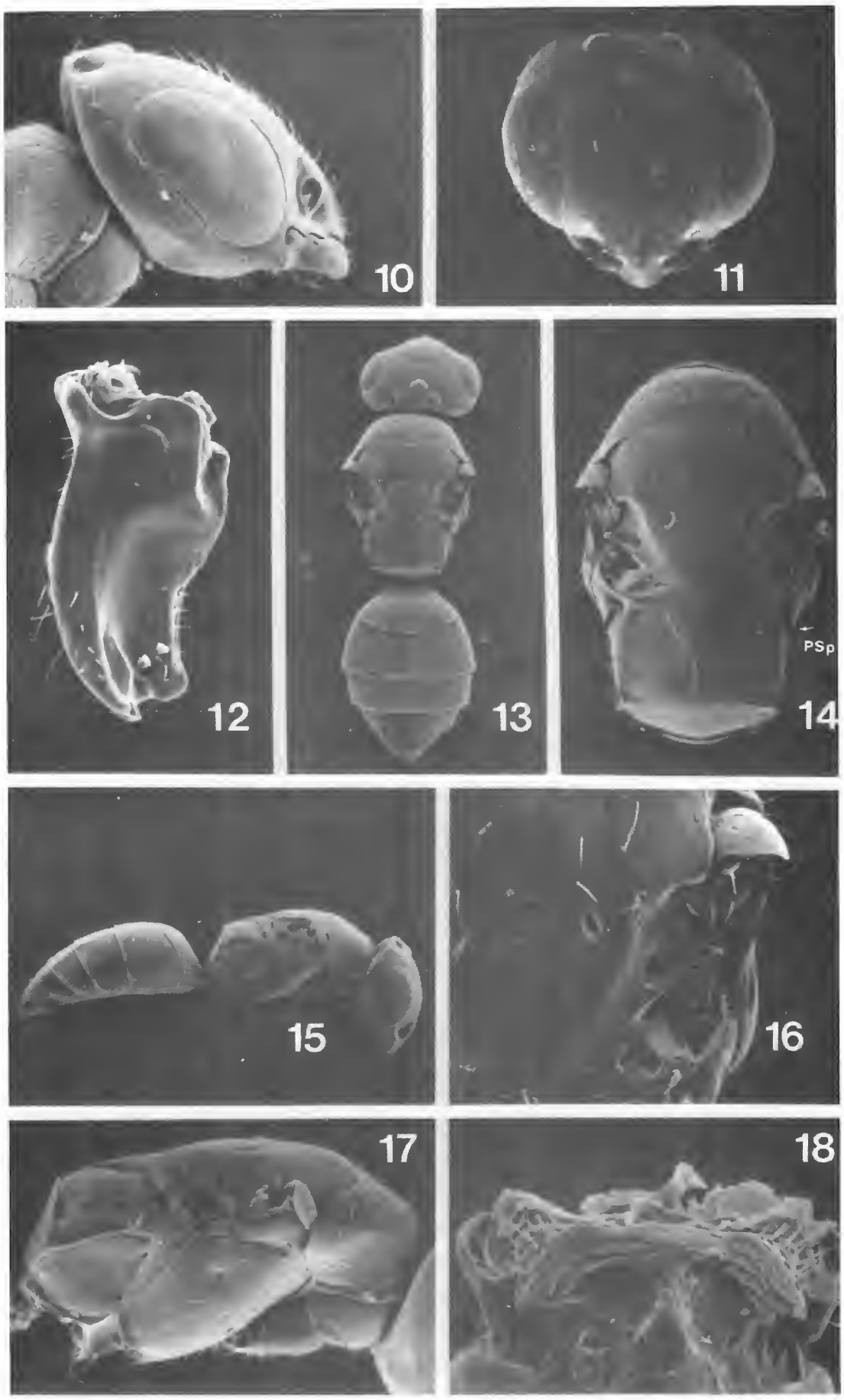


Figure 10. *Goniozus sensorius* n. sp., male head, lateral aspect (130X). Figure 11. *Goniozus sensorius* n. sp., male head, frontal aspect (100X). Figure 12. *Goniozus sensorius* n. sp., male mandible, ventromedial aspect (360X). Figure 13. *Goniozus sensorius* n. sp., male habitus, dorsal aspect (40X). Figure 14. *Goniozus sensorius* n. sp., male mesosoma, dorsal aspect (86X). (PSp. Propodeal Spiracle). Figure 15. *Goniozus sensorius* n. sp., male habitus, lateral aspect (44X). Figure 16. *Goniozus sensorius* n. sp., male mesosoma, enlargement of tegula, axillary region, scutellar pits, and metanotal pits (180X). Figure 17. *Goniozus sensorius* n. sp., male mesosoma, lateral aspect (110X). Figure 18. *Goniozus sensorius* n. sp., male petiole, ventral aspect (480X).

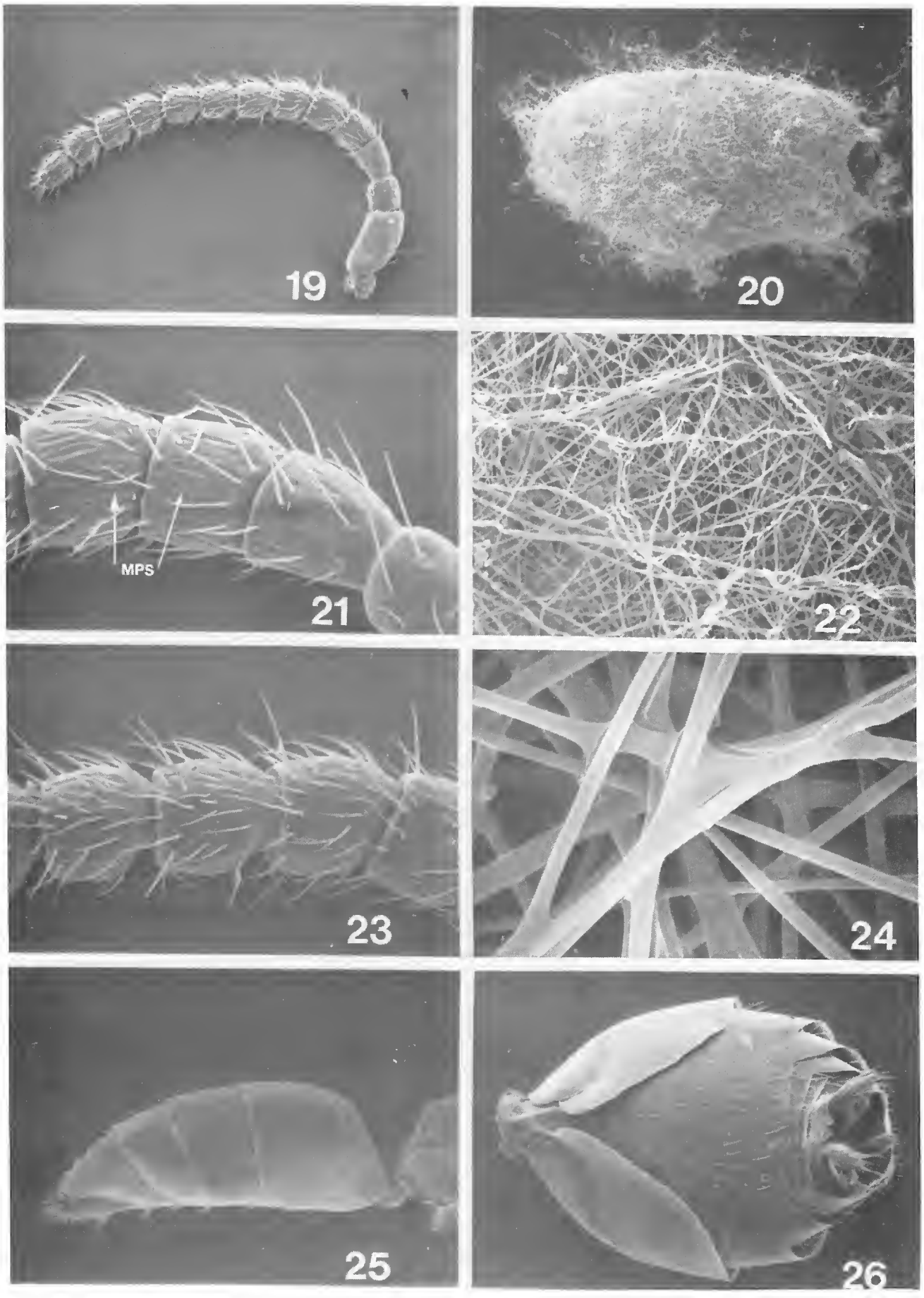
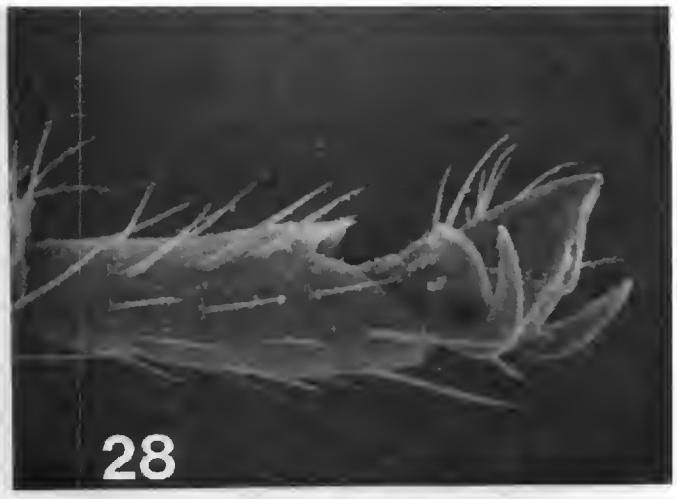
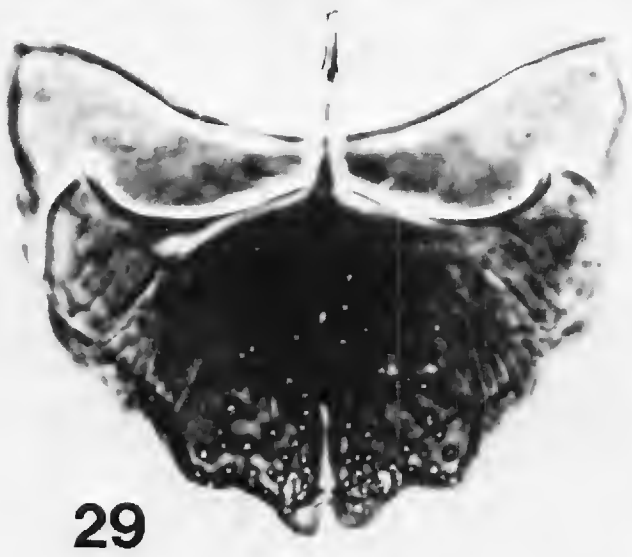
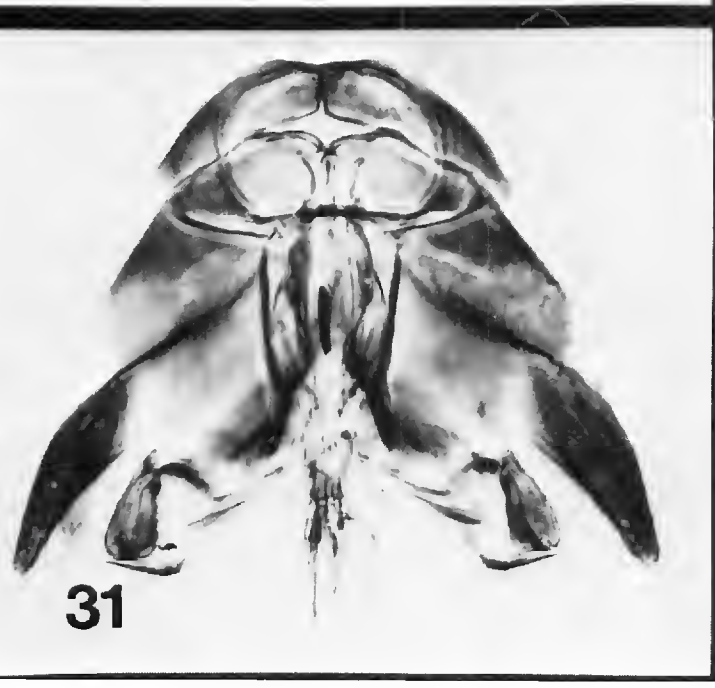


Figure 19. *Goniozus sensorius* n. sp., male antenna (150X). Figure 20. *Goniozus sensorius* n. sp., pupal cocoon (emergence hole at left) (20X). Figure 21. *Goniozus sensorius* n. sp., male antennal funicular segments 1–3 (540X). (MPS. Multiporous Plate Sensilla). Figure 22. *Goniozus sensorius* n. sp., pupal cocoon (magnification of threads) (200X). Figure 23. *Goniozus sensorius* n. sp., male antennal funicular segments 4–6 (480X). Figure 24. *Goniozus sensorius* n. sp., pupal cocoon (magnification of thread junction) (2000X). Figure 25. *Goniozus sensorius* n. sp., male metasoma, lateral aspect (78X). Figure 26. *Goniozus sensorius* n. sp., male metasoma, ventral aspect (86X).







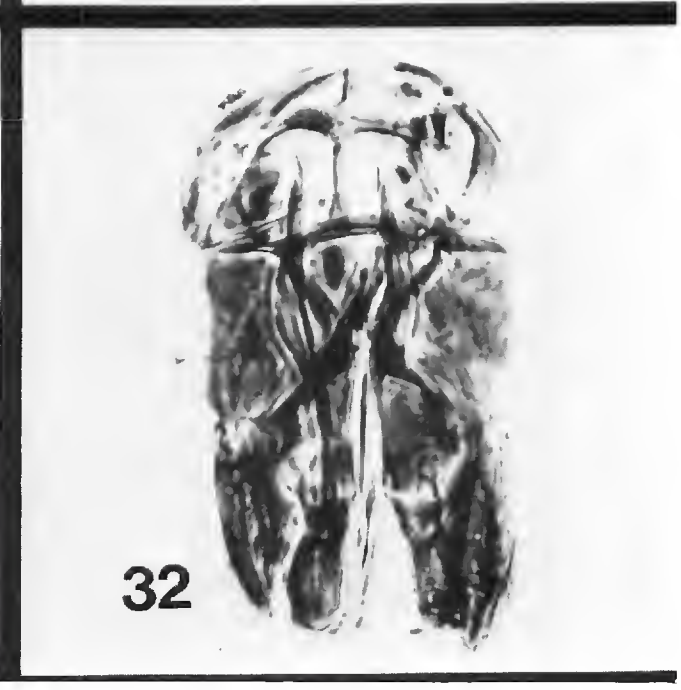


Figure 27. *Goniozus sensorius* n. sp. male hind leg pretarsus, frontal view (1000X). (Ar. Arolium; SaT. Subapical Tine. TC. Tarsal Claw). Figure 28. *Goniozus sensorius* n. sp. male hind leg pretarsus, lateral aspect (600X). Figure 29. *Goniozus sensorius* n. sp., male subgenital plate (sternum VII) and sternum VI (620X). Figure 30. *Goniozus sensorius* n. sp., male subgenital shield (sternum VII) (600X). Figure 31. *Goniozus sensorius* n. sp., male genitalia with parameters expanded (600X). Figure 32. *Goniozus sensorius* n. sp., male genitalia with parameters contracted (600X).

darker base of each femur, with the apical half yellow. All of the legs on a specimen show the same color pattern.

Male.—Body length ranges from 2.00–2.44 mm in the type-series. Some males display a flush of pale coloration behind the compound eye. The character appears correlated with a general castaneous coloration of the first and second metasomal terga, and bright yellow coloration of the legs. Such coloration differences sometimes motivated early bethylid taxonomists to propose new names, but in the present context, all of the type-material comes from a homogeneous series of lab-reared siblings.

Male *G. sensorius* are invariably smaller than conspecific females. That is, in the type-series there is no male larger than the smallest female. It is difficult to provide biometrical data on body length, the simplest measure of body size, because wasps of both sexes typically die in a flexed position.

Material Examined

Holotype.—Intact, point-mounted female with collection information reading: INDIA, Padappai, Tamil Nadu, Madras; 12–1–87, Coll. C. Peter; Ex. *Diaphania indica.*

Allotype.—Intact, point-mounted male taken at the same locality as the holotype, and pin bearing identical information.

Paratypes.—73 females, 34 males lab-reared by Mr. Clement Peter at Padappai from *Diaphania indica* (Saunders) taken on *Coccinia grandis* (L.) Voight (reported as *Coccinia indica* Wight and Arnott). All specimens are point-mounted and carry the same label information as the holotype. Additionally, three female and four male specimens from this series have been dissected and mounted in Canada Balsam. Six females and five males have been dissected and mounted on SEM stubs.

Numerous supplemental specimens have been supplied by Mr. Peter and examined by me. These have not been included in the type-series although they were collected from the same host plant and pyralid host. The type-series was restricted to exclude the inclusion of sibling species, and to provide a homogeneous series for subsequent morphometric analysis specifically addressing genetic variability in type-series.

Holotype, allotype, four female and four male paratypes deposited in USNM. Two male and two female paratypes each, deposited in the following institutions: Canadian National Collection, Ottawa; American Museum of Natural History, New York; California Academy of Sciences, San Francisco; Zoological Institute, Soviet Academy of Sciences, Leningrad; South African National Insect Collection, Pretoria; Australian National Insect Collection, Canberra; Entomological Laboratories, Ehime University, Matsuyama. The remainder of the type-series is deposited in the Entomological Collections at the University of California, Riverside.

Discussion

Goniozus is a cosmopolitan genus with nearly 150 nominal species. It is among the largest genera of Bethylidae, and clearly the largest genus in the Bethylinae. A world catalog has been developed which suggests all species are external parasites of Lepidoptera larvae (Gordh, unpublished).

Our knowledge of the Indian Bethylidae is limited to few studies, the most extensive by Kurian (1952, 1954a, 1954b, 1955), and a revised key prepared by Ram and Subba Rao (1967). More recent work has developed isolated descriptions of new species based on material taken in Pakistan and India (Ram 1969, Samad 1973, and Gordh 1984). Elsewhere I (Gordh, accepted) have summarized knowledge of *Goniozus* from the Indian Subcontinent and treated nomenclatural problems with *Goniozus* from India.

The species described here belongs to *Goniozus* in the restricted sense of earlier workers. Features in combination which I regard as most distinctive and diagnostic include: Pale colored mandible and coxae; head as wide as long; antenna with evanescent multiporous plate sensilla; scutellar pits not connected by a transverse sulcus; slit-like propodeal spiracles; propodeum with well-formed, polished, triangular antero-median elevation with continuous longitudinal carina to complete posterior transverse carina.

Comparing *G. sensorius* with other Indian species which may be closely related is difficult. Type-specimens are not available for study, many original descriptions lack adequate detail, and existing keys are misleading. Further, five described species are known only from the male. These males may be conspecific with females which stand under other names.

Kurian (1955) published a key to Indian *Goniozus*. This key was modified by Ram and Subba Rao (1967). The first couplet in both keys creates a dichotomy based on head width to length. *Goniozus sensorius* females display a head as wide as long. Among species with a non-elongate head, *G. sensorius* keys to *G. triangulifer* Kieffer. This species was described twice (Kieffer 1914a, 1914b) from Laguna, Los Banos, Luzon in the Philippines. The type-series cannot be located. I have identified material as such from Lae, New Guinea and Luzon. If my identification of this species is correct, then *triangulifer* has black coxae and dark femora, a comparatively long, thin longitudinal carina extending posteriad from the propodeal triangle, and the multiporous plate sensilla of the antennal funicular segments are more conspicuous. The name *triangulifer* has been comparatively frequently published in the literature (cf. Paine 1961, Paine 1964, Catley 1966). Hosts include *Cnaphalocrocis medinalis* (Guenee), *Marasima patnalis, Nacoleia octasema* (Meyrick), and a pyraustid leaf roller on rice.

Appendage coloration has been used to provide differentiae for species of *Goniozus,* but this is frequently an unreliable character. Coloration of the tagma and mandibles may be more reliable. Female *G. sensorius* may be distinguished from the female of *G. chatterjii* by the apparently reddish-brown abdomen (metasoma) of the latter species. Both species display a triangular elevation on the dorsal face of the propodeum which continues posteriad as a carina to the junction of the dorsal and posterior propodeal faces.

Bethylids frequently possess subapical claws, tines and setal modifications on the pretarsus of the legs. *Goniozus* females typically have "bifid" pretarsi and the males have trifid pretarsi. These features have been used taxonomically in some recent bethylid studies (vide Evans 1978; Krombein 1987), but have been generally ignored. These structures are sometimes striking or bizarre, but they have not been analyzed or carefully described in detail within *Goniozus*. The truncate subapical tine on the pretarsi of *G. sensorius* is not readily evident or appreciated with light microscopy, but it is similarly developed in the male and female. The tine appears to

develop from the unguis and not the arolium. The functional significance of this character state is not understood.

That females are invariably larger than conspecific males is a condition common among the Bethylidae, and parasitic Hymenoptera in general. The present example should provide data for morphologists interested in allometry, and biologists interested in resource allocation. Additionally, this species of *Goniozus* also skews its sex ratio in a female bias, with one to a few males produced per brood. This phenomenon has been discussed by Greene et al. (1982).

The subgenital shield (apical sternum) of male *Goniozus* must be studied comprehensively to determine its importance in the taxonomy of the genus. Many species, including *G. sensorius* exhibit a modified posterior margin. The notched surface probably serves as a guide for the intromittent portion of the aedaegus.

Features of the pupal cocoon have not been used in bethylid taxonomy, but this aspect of development is potentially rich in characters. The cocoon of *G. sensorius* is typically brown but occasionally white cocoons are produced. The difference in color probably is correlated with availability of tyrosine. The cocoon formed by *G. sensorius* is relatively tightly woven and brown (Figs. 20, 22, 24). Many species of *Goniozus* spin cocoons which are white. The significance of color is unknown, but study of the phenomenon should reveal an interesting, potentially important, aspect of the biology of these wasps. All members of a brood construct cocoons of the same color. Each individual constructs its own cocoon, but all members of a brood construct their cocoons in a compact mass with each individual contributing a few threads which bind all of the cocoons together. Each cocoon is about two times longer than wide (Fig. 20), with the strands loosely woven and of similar diameter at all levels of construction (Figs. 22, 24). Emergence by the adult is from the polar end nearest the head of the developing pupa.

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PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 183–184

Scaphandrena and *Elandrena* (Hymenoptera: Andrenidae)

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Ribble (1974) synonymized *Scaphandrena* and *Elandrena,* a pair of the fifty or so subgenera of North American bees of the genus *Andrena,* the former having page precedence. His version of the reasons for describing them as separate subgenera in the first place is not entirely accurate: he states that "*Elandrena* has been distinguished from *Scaphandrena* by the lack of abdominal fasciae and the presence of dark pleural hairs." The original description of the two subgenera (Lanham 1949) specifically sequestered them only on the basis of the females; in the diagnostic key the males were not separated. The strategy of the 1949 classification of *Andrena* into subgenera was (p. 194) to base it primarily on the females, and assumed that some useful and biologically significant subgenera would often not be distinguishable in the males. In fact, the true situation may be obscured by requiring that the males be diagnosed at the subgeneric level. Ribble intergrades the two subgenera by shifting from male to female characters as required.

An important difference lies in the conspicuous white appressed hair bands at the apices of the abdominal terga of female *Scaphandrena,* absent in females of *Elandrena.* Impressions gained from field collecting suggest that this banding functions as mimicry for several species of halictine bees which are similarly banded and about the same size. These sting readily with a fiery sting even when a hand is brushed lightly against them in the net. *Andrena* is unable to penetrate the human skin with its sting.

The European *Truncandrena* probably are *Elandrena; A.* (T.) *ferrugineicrus* Dours, abundant in North Africa is much like *Elandrena,* more robust than our *Scaphandrena,* and without conspicuous light tergal hair bands. The vestiture is predominantly long and red, shading to dark brown and black in places. Since *Elandrena* is in North America limited to the western half, it possibly had its origin in *Eurasia,* coming to America by way of the Beringian land bridge. *Scaphandrena* in the strict sense seems to be absent from the Old World, but is widespread in North America except the South East and the Great Plains. It has considerable morphological diversity, and includes a unique hybrid complex (Ribble 1973, Lanham 1974).

At one of the sites where *A. (Scaphandrena) montrosensis* Viereck and Cockerell was frequent (campground of the Colorado National Monument) it was in mid-May of 1985 a co-dominant on flowers of *Lepidium montanum* with *A. (Elandrena) bruneri* Viereck and Cockerell, a striking bee with all the hairs black, the midnight-blue integument coarsely punctate on the terga (black and dull in *montrosensis*), and more robust than *montrosensis.* It was interesting that the robust, red-haired, blue males of *bruneri* (first collected at this site on 5–6 May, 1987) had almost the same facial pattern of yellow cuticle as *montrosensis,* with the entirely yellow clypeus and large irregularly shaped parocular patches. It is possible that this

could provide a joint bi-specific recognition mark for the females for these two species, which are rather uncommon, so that pooling their resources would seem to be adaptive. On 6 May (mid-afternoon) at a small patch of *Cardaria* near the Monument Headquarters, kept alive in this dry area because it formed the edge of a sprinkled lawn, a small crowd of these species (5 male and 2 female *montrosensis* and a female of *bruneri* taken) was flying actively about over the flowers, with males hovering over the females and striking at them, knocking them to the ground and grappling. In this instance a lek (possibly bi-specific) was not well defined, but with the large dorsal field of vision provided by the compound eyes, the females might have been able to recognize males hovering above them as *Andrena* of interest by the wide yellow facial patches. Then final selection at closer range could be made on the basis of the color of the integument, presence or absence of dorsal light hair bands, or other stimuli, such as scent.

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PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 185–192

External morphology of a species of *Metajapyx* (Diplura: Japygidae) from Washington[1]

R. J. RATHMAN[2], R. D. AKRE[3] AND J. F. BRUNNER[2]

Abstract.—Scanning electron microscopy was used to aid in describing the external morphology of a species of *Metajapyx* collected in 1986 from southeastern Washington State. Specimens had extremely setaceous, 26 segmented antennae with trichobothria present on segments 4 and 5. Forcep-like cerci were armed with toothlike projections on the inner surface. Genital papillae were observed on the 8th abdominal sternum of a single specimen. Setose subcoxal organs were visible between the 1st and 2nd abdominal sterna. The mouth parts had several unusual modifications. The mandibles were elongate and toothed. The maxillae were composed of 3 segmented palps, lacinia with a strongly curved, sclerotized entire lamina, and 5 pectinate inner laminae; the galea was reduced. The mouth parts are probably specialized for feeding on soil micro-flora and fauna and for grooming the antennae and body surface.

INTRODUCTION

Few North American insects are as poorly known as those in the order Diplura. Diplurans have been found under stones, in dead wood, among fallen leaves, and in soil (Paelt 1957).

As of 1941 the family Japygidae was represented by less than a dozen species from the United States (Fox 1941). To date most studies on the family Japygidae have been either taxonomic descriptions or collecting records (Silvestri 1947, Young 1951, Chandler 1957, Smith and Bolton 1964). An extensive review of dipluran morphology can be found in Denis and Bitsch (1973) and Matsuda (1979), with frequent reference to the genera *Campodea* and *Japyx*. There are no records of specimens of the genus *Metajapyx* ever having been collected from the Pacific Northwest. Little information on biology has been published.

The purpose of this paper is to present a morphological examination of a *Metajapyx* species, family Japygidae, common to southeastern Washington.

MATERIALS AND METHODS

All examined *Metajapyx* specimens were collected 3.2 km north of Lower Granite Dam along the Snake River (Garfield Co.), Washington in loose soil (elevation 240 m). Collections were made on 23 January, 6 February, and 27 April 1986. Length of collected specimens from 23 January was 7.80 ± 0.01 mm (n = 20)[4].

[1]Scientific paper number 7746. College of Agriculture and Home Economics Research Center, Washington State University, Pullman, Washington. Work conducted under project number 1090.

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[4]Mean ± SE (N).

Ten specimens were examined with scanning electron microscopy (SEM) using an ETEC Autoscan U-1, and photographs were taken with 55 Polaroid P/N film. Live *Metajapyx* specimens were killed with ether or placed directly into boiling water, then preserved in 70% alcohol. Mouth parts were examined intact or dissected from the head prior to fixation. After rehydration for 24 hours, specimens were air-dried or fixed with 2% osmium tetroxide (OsO_4). Specimens were coated with gold (30 nm) using a Technics Hummer Sputter Coater.

Light microscopy was used to make morphometric measurements on *Metajapyx* specimens collected 6 February and preserved in 70% alcohol. Head width was measured from the base of the diverging frontal sutures, and head length was measured from between the antennal scapes to the base of the coronal suture (Figs. 1a-a and 1a-b). Mandibles dissected from specimens collected 6 February were mounted on microscope slides in Hoyer's solution. All measurements were made using either a Wild M 5A binocular microscope or an Olympus BH2 compound microscope connected to a Houston Highpad digitizer and Apple IIe microcomputer.

Laboratory observations of *Metajapyx* behavior were made to support interpretations of the functional morphology revealed by SEM. Specimens were obtained 21 February 1987, along the Snake River and kept in the laboratory at room temperature in 1 liter glass containers filled with loose soil.

Results and Discussion

Head and Antennae.—The head capsule of *Metajapyx* is without compound eyes or ocelli, and is rectangular. Epicranial and postoccipital sutures were visible on the dorsal surface. Head width was 732.14 ± 41.23 μm ($n = 8$), and head length was 683.03 ± 71.42 μm ($n = 8$). Antennae are filiform and 26 segmented with dense setae on segments 5 through 26 (Fig. 2). The numerous antennal setae are probably important in prey location, in orientation through the soil cavities, and in mating. Trichobothria (sensory setae) were visible on segments 4 and 5 (Fig. 2a). These structures originate from deeper pits than adjacent setae; only a single trichobothrium was located on each segment. Trichobothria in *Catajapyx aquilonaris* (Silvestri) occur on segments 4–6 and may function in orientation and reception of air currents (Nosek et al. 1974).

Mouth Parts.—Mouth parts are entognathous and reduced. The labium is subdivided into a pre- and postmentum, with postmentum clearly divided into a distal mentum and proximal submentum (Figs. 1b, 3, and 4). Labial palpi are 1-segmented, 3 times as long as wide, and have 10–11 setae (Fig. 3a). Admental plates (Silvestri 1933) are lateral to the prementum (Figs. 1b–b and 3b).

The maxillae have 3-segmented palps with approximately 16 setae/palp (Fig. 4a), flap-like, unsclerotized galeae (Figs. 4b and 5b), and highly modified laciniae (Figs. 4c, 5c, and 8). Mandibles are elongate and monocondylic (Figs. 6 and 7). Right mandible length was 609.27 ± 48.45 μm ($n = 2$); left mandible length was 625.77 ± 34.02 μm ($n = 2$). Twenty minutes of laboratory observations of *Metajapyx* specimens revealed that the mandibles can extend forward in front of the maxillae during feeding. The inner mandibular surface is concave (Fig. 6) and has a prominent dorsal tooth, while five apical teeth are apparent on the outer mandibular surface (Fig. 7). Careful dissection of the area around the mandibles revealed that they are retracted into the head dorsad to the maxillae. The laciniae are highly modified and

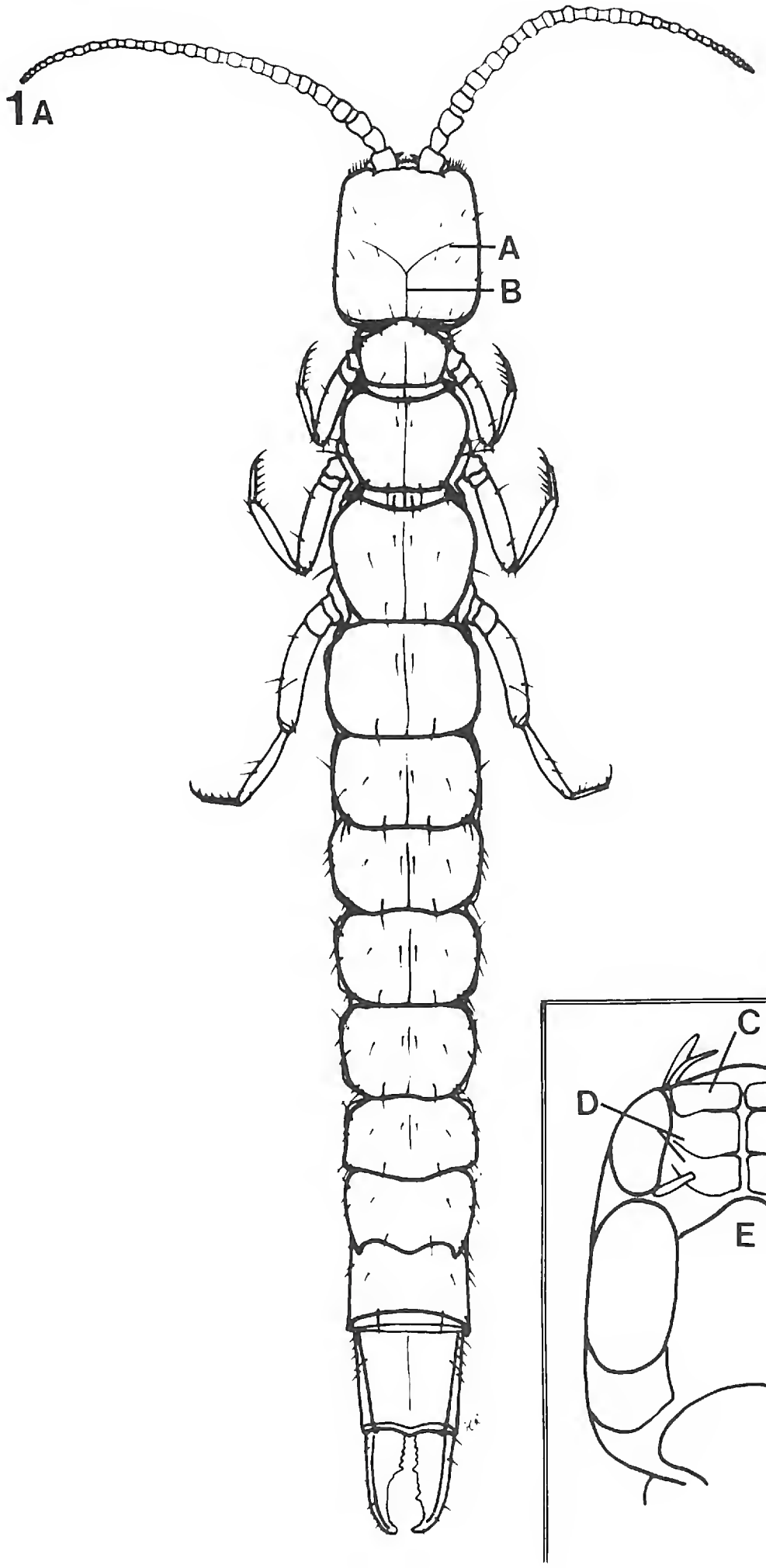
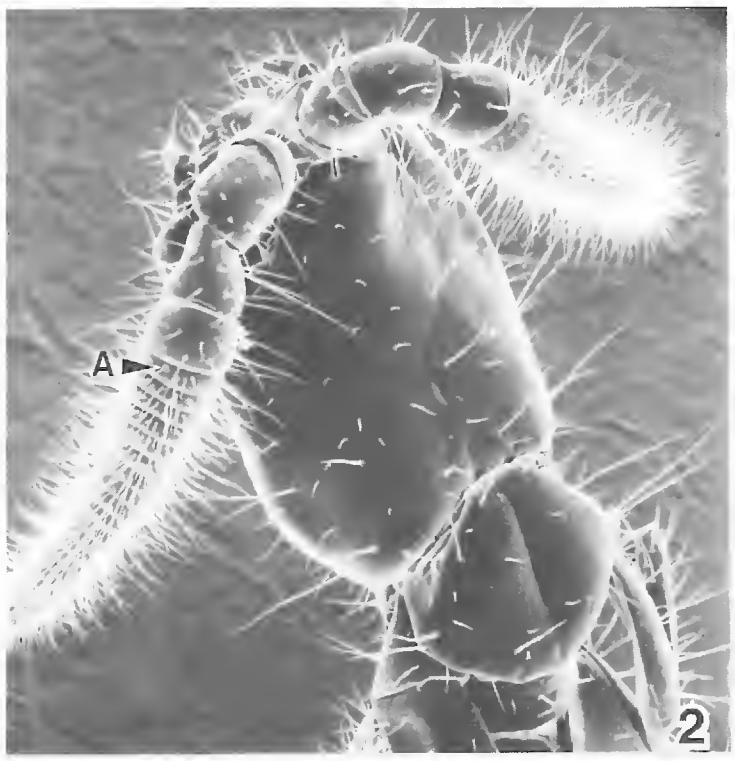
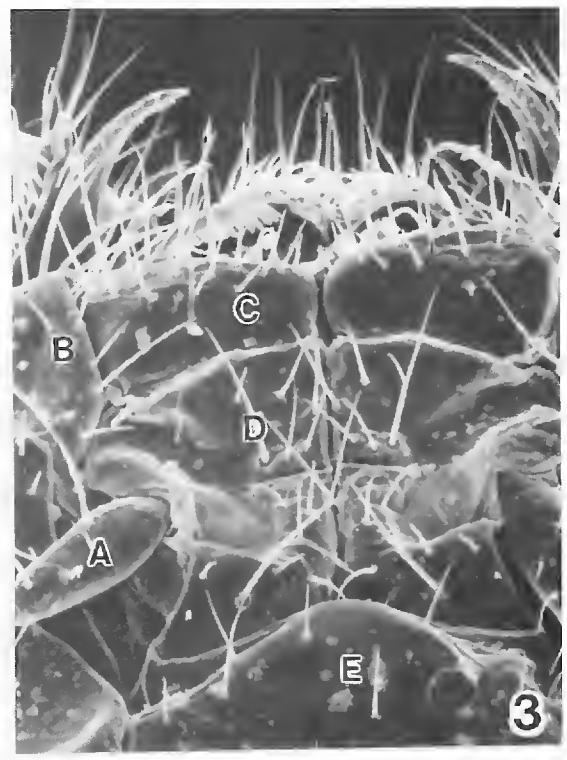
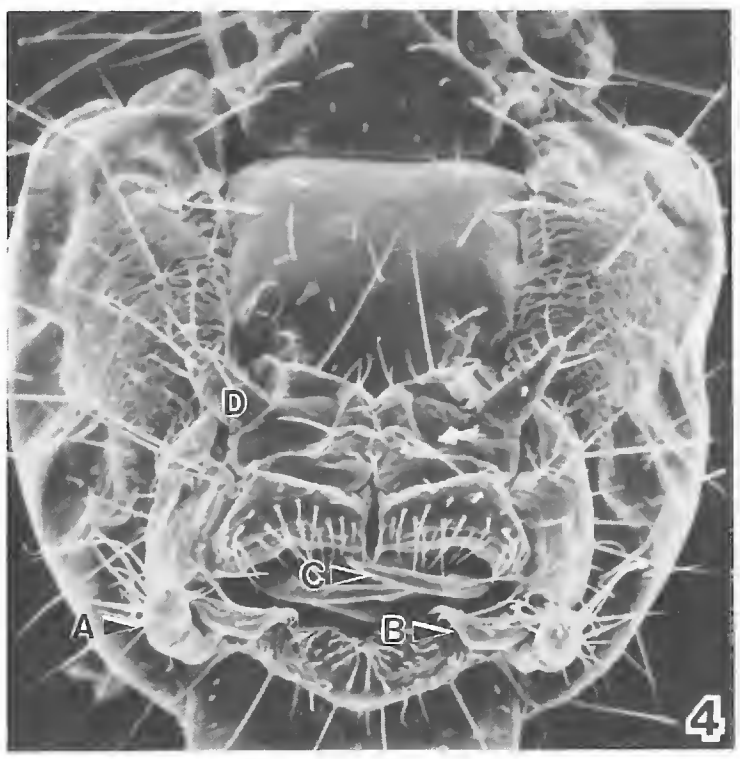


Figure 1a. Dorsal view of a *Metajapyx* specimen from Washington State. Head width was measured from the base of the diverging frontal sutures (A), head length from between the antennal scapes to the base of the coronal suture (B). Cerci were measured on the dorsal surface from the most distal point to the point of articulation with abdominal tergum 10. Figure 1b. Line drawing of the ventral surface of the head of a *Metajapyx* specimen. A = labial palp; B = admental plate; C = prementum; D = postmentum; E = submentum.







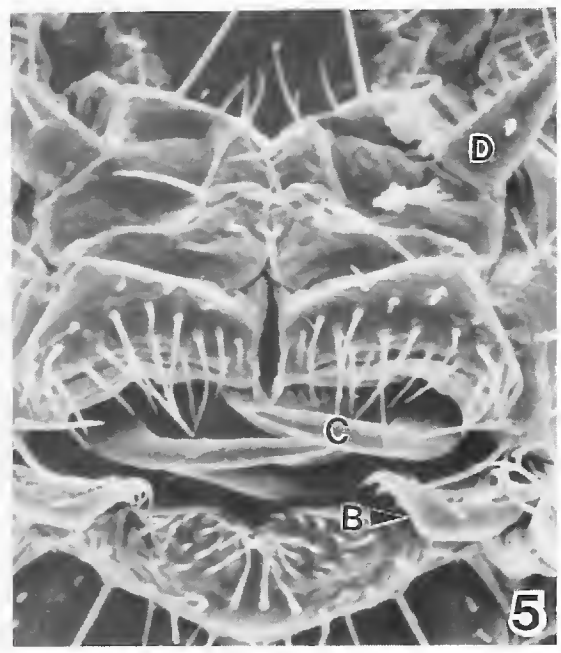
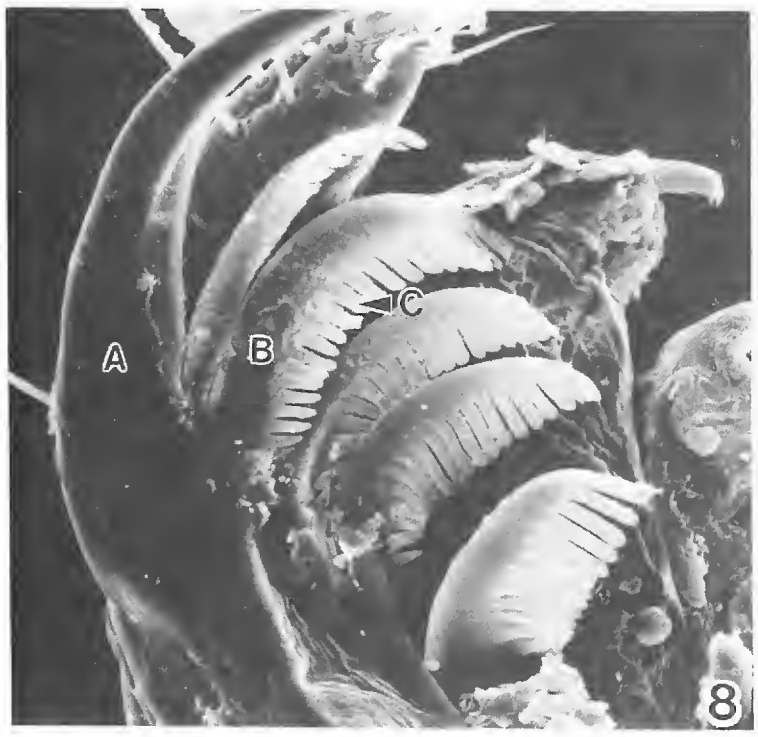


Figure 2. Rectangular-shaped head of a *Metajapyx* specimen without compound eyes or ocelli. Antennae are 26 segmented with trichobothria (A) on the 4th and 5th antennal segments. × 63. Figure 3. Ventral surface of a *Metajapyx* specimen head. Visible structures are labial palp (A), admental plate (B), prementum (C), postmentum (D) and submentum (E). × 208. Figure 4. Entognathous mouth parts of a *Metajapyx* specimen, ventral view. A = maxillary palp; B = galea; C = outer lamina of lacina; D = labial palp. × 167. Figure 5. Enlargement of mouth parts shown in Figure 3. × 280.

consist of an outer knife-like structure that is long, curved and heavily sclerotized (Fig. 8a) and an inner section subdivided into 5 pectins; the dorsal pectin with 5 distal teeth, the ventral pectins each with 20 teeth extending proximad to the base (Fig. 8c).

The order Diplura contains a few taxa which are thought to be carnivorous. For example, in central Europe japygids feed on collembola (Onychiuridae) and campodeids (Manton 1972). Two hours of observations of 20 *Metajapyx* specimens in the laboratory were made to record prey capturing behavior. These observations



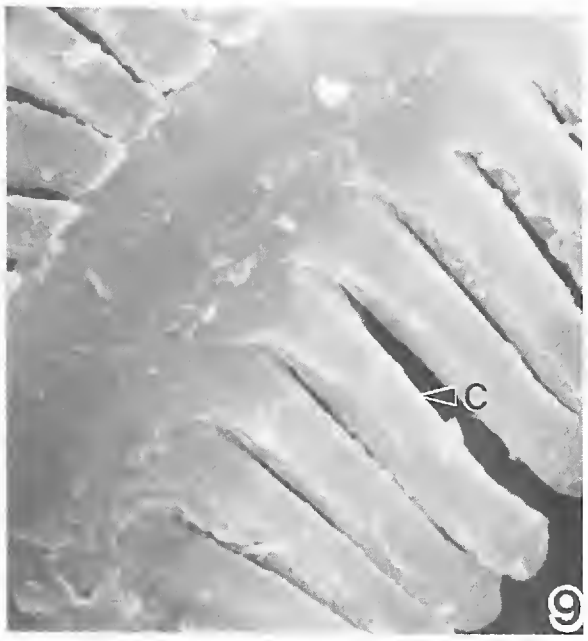


Figure 6. Inner surface of right mandible of a *Metajapyx* specimen showing 4 well-developed teeth. × 875. Figure 7. Outer surface of left mandible of a *Metajapyx* specimen with 5 teeth visible. × 1166. Figure 8. Left lacinia of maxilla of a *Metajapyx* specimen with 5 pectinate laminae visible on the mesal surface. A = outer lamina of lacinia; B = inner lamina of lacinia; C = pectin of inner lamina. × 470. Figure 9. Enlargement of pectinate laminae of Figure 7. × 2560.

failed to reveal a single individual capturing prey, even though collembola (Onychiuridae) were abundant. One individual was observed for 10 minutes scraping soil particles with extended mandibles. *Metajapyx* is probably a scavenger on dead arthropods, fungal mycelia, and organic debris. The highly modified maxillae indicate that *Metajapyx* may feed by filtering micro-flora and fauna through the pectinate laminae of the lacinae (Fig. 9c). Detailed examination of the mouth parts with SEM combined with laboratory observations support this hypothesis.

Conclusive determination of feeding habits of *Metajapyx* requires an analysis of gut contents. Individuals kept in a laboratory culture had brown digestive tracts, suggesting that soil was being filtered through the alimentary canal. Denis (1949) reviewed the feeding behavior of diplurans, especially the campodeids. Marten (1939) and Wygodzinsky (1941) noted animal fragments in the gut of *Campodea lankesteri* Silvestri, and they observed *C. lankesteri* attacking and feeding on sciarid larvae 5–7 mm long.

Valentine and Glorioso (1978) studied grooming behavior in *Metajapyx*. Their conclusions were that the complex lacinia with 5 pectinate laminae may function in antennal cleaning. Laboratory observations of the Washington *Metajapyx* specimens revealed frequent passage of the antennae through the mouth parts, as often as 10 times/min. Mouth parts were also used in grooming the body. Two individuals were observed using their mouth parts to clean body surfaces from the thorax to the cerci.

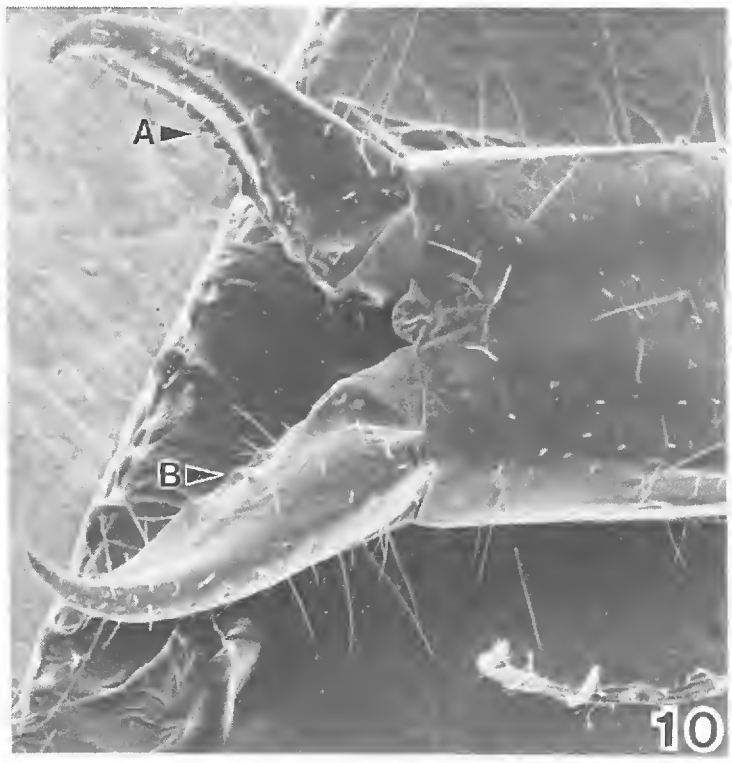
Cerci.—The family Japygidae is characterized by unisegmented, compact cerci which are strongly sclerotized and forcep-like. In *Metajapyx,* cerci, appendages of the 11th segment, are asymmetrical and armed with numerous sharp projections on the inner surface (Fig. 1a). Viewed dorsally, 2 rows of teeth are visible on the left arm (Fig. 10a). One row of teeth is visible on the right arm (Fig. 10b). Length [right cercus: 637.50 ± 32.89 μm ($n = 8$) and left cercus: 651.02 ± 28.84 μm ($n = 7$)] and shape were approximately equal on all examined specimens. Setae are present on both dorsal and ventral surfaces of the cerci, suggesting the forceps may be used in food and/or mate recognition.

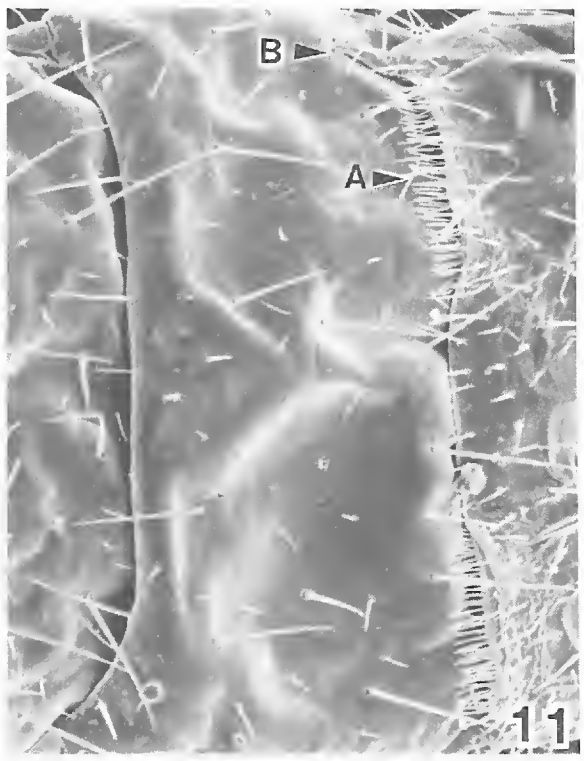
Kosaroff (1935) reported that cerci hold prey that are then attacked by using the mouth parts. In *C. aquilonaris* cerci are adapted for grasping prey. SEM of the cerci of *C. aquilonaris* showed numerous small pits and scale-like bristles which may serve as mechanoreceptors (Nosek et al. 1974).

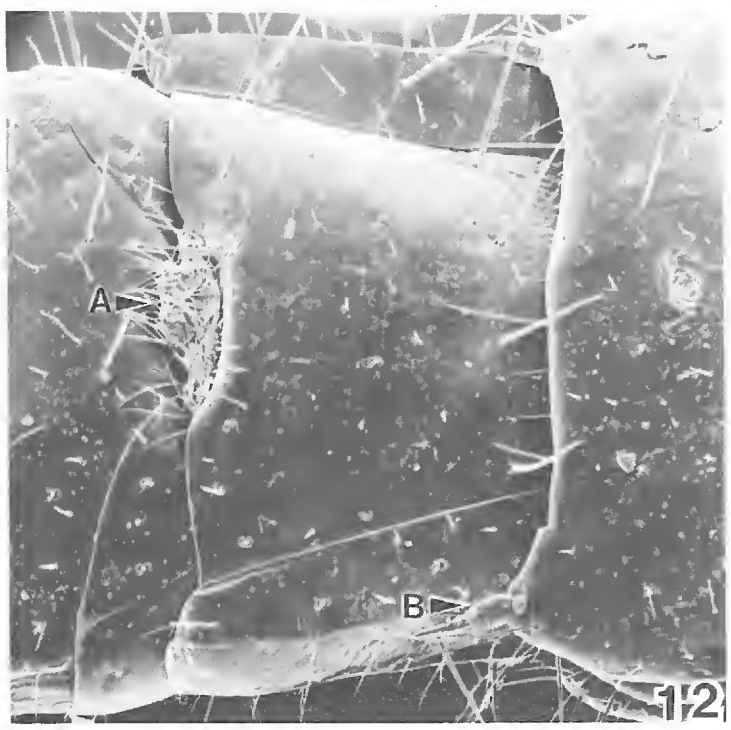
Abdominal Appendages.—Lateral styliform appendages were present on the sterna of segments 1 through 7 (Figs. 11b and 12b). Just medial to the styliform appendages of abdominal segment 1 were a pair of setose subcoxal organs occupying approximately 2/3 the distance between the styli (Fig. 11a). Setae of the subcoxal organs (approximately 50/side) were arranged in a single row and were approximately 1/3 the length of the abdominal styli. The function of the setose subcoxal organs is unknown. A median glandular structure sometimes protrudes between these structures (Smith and Bolton 1964), occupying 1/10 the distance between the styli. In the 10 specimens examined from Washington this gland was never visible.

Paired eversible vesicles resembling those of Thysanura are found on abdominal segments 2–7 of Campodeidae and Anajapygidae, on sterna 2 and 3 of the Parajapygidae, and on sterna 1–7 in the Japygidae (Richards and Davis 1977). In *Campodea* the vesicles may function in water uptake (Drummond 1953). In *Metajapyx* sp. paired eversible vesicles were not seen.

Very setaceous papillae associated with the gonopore of a male *Metajapyx* were present between the 8th and 9th abdominal sterna (Figs. 12a and 13). Von Orelli (1956) demonstrated that male campodeids deposit spermatophores at random. The female locates the spermatophore and positions it within her gonopore. Sperm transfer has not been observed in the Japygidae; however, the structure of the papillae indicates that spermatophore deposition may not be a random process. The male may use sensory setae on the papillae to position the spermatophore either in the soil substrate or within the female gonopore.







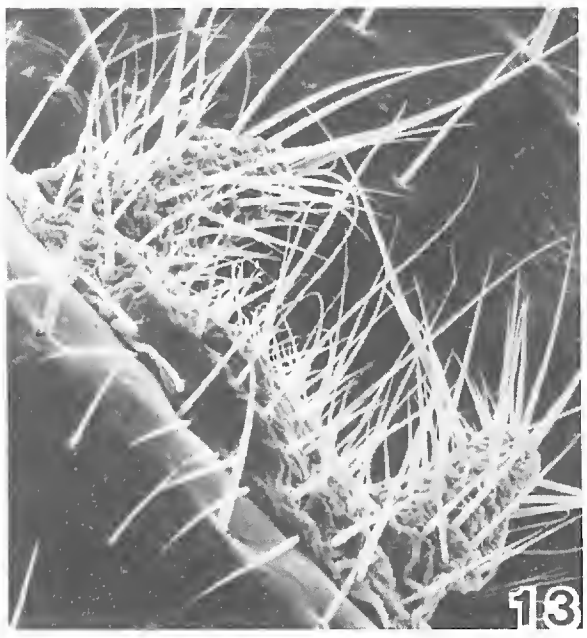


Figure 10. Forcep-like cerci of a *Metajapyx* specimen, dorsal view. A = denticles of left forcep; B = denticles of right forcep. × 62. Figure 11. Setose subcoxal organ (A) of a *Metajapyx* specimen between abdominal sterna 1 and 2. B = lateral styliform appendage. × 118. Figure 12. Reduced 9th abdominal sternum and setose genital papillae (A) of male *Metajapyx* specimen. Lateral styliform appendages (B) are visible on abdominal sternum 6. × 90. Figure 13. Enlargement of genital papillae of Figure 12. × 336.

Acknowledgments

We thank C. M. Davitt, J. T. Beneski, and J. L. Sutphin Davis for EM assistance, J. C. Rodriguez for the line drawings and R. S. Zack for assistance in obtaining and identifying specimens for the study. R. S. Zack and D. A. Suomi are thanked for critical review of the manuscript.

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PAN-PACIFIC ENTOMOLOGIST
64(2), 1988, pp. 193–198

Proceedings of the Pacific Coast Entomological Society, 1987

FOUR HUNDRED AND FIFTIETH MEETING

The 450th meeting was held on Friday, 16 January 1987, at 8:20 p.m., in Morrison Auditorium, California Academy of Sciences, San Francisco, with President Dr. Stanley C. Williams presiding.

The minutes of the meeting held 12 December 1986 were read and accepted. Four persons were proposed by Mr. Daniel F. Gross and elected as new regular members: Mrs. Karen M. Downs, Mr. Ted C. MacRae, Mr. Demetrios G. Skedros, and Dr. Molly W. Stock.

Dr. Williams announced the new chairs of the program and refreshment committees: Dr. Thomas J. Zavortink and Mr. Warren E. Savary, respectively. Ms. Leslie S. Saul mentioned that the Insect Zoo of the San Francisco Zoological Society will be presenting monthly entomological lectures in 1987. Mr. Vincent F. Lee announced that the 18th International Congress of Entomology will be held in Vancouver in July 1988. Dr. Williams announced that the Association of Biologists for Computing will be hosting a series of seminars at California State University, Fullerton, 23–24 January 1987. He also announced that there will be an insect photo day with dinner in March 1987, to be coordinated by Dr. John E. Hafernik Jr. and Mr. Savary and that a workshop on arachnids is being planned by Dr. Thomas S. Briggs in the fall. Mr. Benjamin Keh announced with regret that Mr. Gail Grodhaus, a former colleague of his at the California Department of Health, Berkeley, had undergone major surgery in December, and encouraged the audience to sign a get-well card for him. Mr. Keh said that a group photo and summary of the Esperanto meeting held in the People's Republic of China last year will be shown at the social hour. Dr. Paul H. Arnaud Jr. announced with sad regret that Dr. Cornelius B. Philip, a member and former president of the Society, research associate in the Department of Entomology at the California Academy of Sciences, and world renowned tabanidologist, rickettsiales specialist, and medical entomologist, died unexpectedly on 11 January 1987. Dr. Arnaud showed slides of Dr. Philip from his youth through his professional entomological career. Mr. Savary showed a new newsletter *Backyard Bug Watch,* published by Sonoran Arthropod Studies, Inc., of Tucson, Arizona. Dr. Edward L. Smith showed a brochure on the Eagle Lake Field Station and mentioned its availability for visiting scientists.

Dr. Harvey I. Scudder showed slides of semi-social orb-weaving spiders taken near Kunming, People's Republic of China. Dr. Smith mentioned that the sawfly *Pontania pacifica* Marlatt (Hymenoptera: Tenthredinidae) were just beginning to emerge from its host, the arroyo willow (*Salix lasiolepsis* Benth. Var. *Bigelovii* (Torr.) Bebb), in the Bay Area.

The featured speaker, Mr. Joseph W. Fox, PhD candidate at the University of California, Berkeley, presented "Host and Conspecific Discrimination in Two *Ips* Bark Beetles." He showed slides of his experiences as a smoke jumper which led to his interest in the cause of tree kill by bark beetles. *Ips confusus* (LeConte) and *I. paraconfusus* Lanier were studied in the San Bernardino National Forest, infesting their primary hosts, *Pinus monophylla* Torr. & Frem. and *P. Coulteri* D. Don, respectively. He presented the life histories of the beetles, and the research he and his colleagues had done on premating isolating mechanisms. Interestingly, the pheromones are similar in the two beetles, and tests so far have not demonstrated absolute premating isolating mechanisms.

The social hour was held in the entomology conference room following adjournment of the meeting.

The following 36 persons were present. 26 members: P. H. Arnaud Jr., A. M. Balmy, L. G. Bezark, T. S. Briggs, P. Buickerood, R. Buickerood, J. S. Chinn, J. G. Edwards, S. V. Fend, L. D. French, D. F. Gross, J. E. Hafernik Jr., A. I. Kaplan, B. Keh, R. L. Langston, V. F. Lee, G. J. Mallick, N. D. Penny, L. S. Saul, W. E. Savary, H. I. Scudder, E. L. Smith, D. Ubick, G. W. Ulrich, S. C. Williams, T. J. Zavortink. 10 guests: M. Arnaud, R. Berlin, V. Blanchard, J. W. Fox, C. French, N. Gershenz, T. F. Hlavac, W. C. Rauscher, S. Renkes, S. S. Shanks.—V. F. Lee, Secretary.

FOUR HUNDRED AND FIFTY-FIRST MEETING

The 451st meeting was held on Friday, 20 February 1987, at 8:15 p.m., in Morrison Auditorium, California Academy of Sciences, San Francisco, with President Dr. Stanley C. Williams presiding.

The minutes of the meeting held 16 January 1987 were read and accepted. Five persons were proposed by Mr. Daniel F. Gross and elected as new members: Ms. Wendy D. Cole and Ms. Joan Leong as student members, and Mr. Bennett T. Berke, Ms. Colleen A. Dibble, and Ms. Sandra S. Shanks as regular members.

Several guests were introduced by Dr. Ronald E. Stecker and by Dr. Williams. Dr. John E. Hafernik Jr. and Mr. Warren E. Savary presented additional details of the Insect Photography Day that will be held 28 March 1987. Dr. Williams encouraged the members to contribute noteworthy information to the Society's newsletter, *Bits & PCES*. Mr. Vincent F. Lee announced that the second Insect Zoo Lecture will be held on 28 February 1987. Mr. Alan I. Kaplan gave more information about the 18th International Congress of Entomology and suggested that the Society serve as a co-sponsor. Mrs. Lenore M. Bravo mentioned that a hobby beekeepers class will be starting soon at the Josephine D. Randall Junior Museum and that the International Beekeepers Congress will be held in Warsaw, Poland, this year.

The featured speaker, Dr. Robert V. Dowell, Primary State Entomologist of the California Department of Food and Agriculture, Sacramento, presented "Invertebrate Pests Recently Introduced into California." His slide-illustrated talk focused on some of the insect and snail pests established in California within the last twenty years and attempts by the state to monitor, control, and/or eliminate them. He noted that the state averages about six new establishments per year since 1965. He discussed in detail some of these pests, including *Phoracantha semipunctata* (Fabricius), a beautiful but very destructive cerambycid of eucalyptus trees; the oriental fruit fly (*Dacus dorsalis* Hendel), a tephritid shown to be correlated with increased airline flights from Hawaii; the peach fruit fly (*D. zonatus* (Saunders)); the guava fly (*D. correctus* (Bezzi)); and the honey bee mite (*Acarapis woodi* (Rennie), Tarsonemidae), which infests the tracheae of honey bees. The Africanized honey bee, which was given much publicity, was first discovered in the Lost Hills area of Kern County in July 1985. The colonies there were subsequently destroyed, but reinvasion of the "killer bees" into California is expected. Dr. Dowell then discussed the life history of the gypsy moth (*Lymantria dispar* (Linnaeus)) and its spread into California, with details on how it was introduced and on the methods used in its elimination. However, this pest is also expected to be re-introduced. The costs of the monitoring, control, and elimination of all pests in California and the losses to agriculture were presented.

The social hour was held in the entomology conference room following adjournment of the meeting.

The following 48 persons were present. Thirty-four members: P. H. Arnaud Jr., B. T. Berke, L. G. Bezark, T. S. Briggs, H. E. Carr, J. S. Chinn, J. S. Cope, H. K. Court, C. A. Dibble, R. V. Dowell, J. G. Edwards, S. S. Ferguson, W. E. Ferguson, P. V. Gambino, D. F. Gross, J. E. Hafernik Jr., A. I. Kaplan, B. Keh, M. P. Kennedy, V. F. Lee, J. Leong, P. A. Luft, W. A. Maffei, G. J. Mallick, W. W. Pitcher, W. E. Savary, S. S. Shanks, R. E. Stecker, C. Y. Takahashi, J. E. Tobler I, M. L. Utheim, D. A. Wagner, S. C. Williams, T. J. Zavortink. Fourteen guests: R. Bandar, L. Bettini, L. M. Bravo, J. E. Court, K. Dabney, L. V. Dubay, J. Lammis, T. Ohsumi, P. Pitcher, D. Pline, W. C. Rauscher, D. Solari, M. S. Wertz, A. Wilsdon.—V. F. Lee, Secretary.

FOUR HUNDRED AND FIFTY-SECOND MEETING

The 452nd meeting was held on Friday, 10 April 1987, at 8:10 p.m., in the Goethe Room, California Academy of Sciences, San Francisco, with President-elect Mr. Alan I. Kaplan presiding.

The minutes of the meeting held 20 February 1987 were read and accepted. Seventeen persons were proposed by Mr. Daniel F. Gross and elected as new members: Mr. Mark S. Burnell, Mr. Benny Fouche, Ms. Nancy Martin-MacKinnon, Ms. Patricia Reitman, and Ms. Marilyn M. Tierney as student members, and Dr. Robert L. Bugg, Ms. Rebecca Fall, Mr. Frank W. Furry, Mr. Norman E. Gershenz, Ms. Sandy E. Jordan, Ms. L. Patricia Kite, Mr. Michael J. Murphy, Ms. Hannah Nadel, Dr. Kevin M. O'Neill, Mr. Jeffrey D. Prill, Ms. Saray Puyans, and Mr. Richard T. Wion as regular members.

Mr. Warren E. Savary summarized the very successful Insect Photography Day that the Society hosted on 28 March 1987 at San Francisco State University. Dr. Robert S. Lane introduced two guests, Mrs. Mabel McKenney and Dr. William R. Lower. Mr. Vincent F. Lee announced that schmitt boxes and insect cabinets were for sale and that the California Academy of Sciences is offering a post-doctoral Tilton Fellowship. Dr. Lane announced that a symposium on arborviruses will be held on 11 April 1987 at the University of California at Berkeley, in honor of the retirement of Dr. William C. Reeves.

Mr. Lee presented a note on the discovery of a hitherto unreported find of a "living fossil" of a psocid (family Sphaeropsocidae), a *Sphaeropsocus* specimen collected from *Quercus agrifolia* Nee Leaf litter in Sonoma County, California. The only other published record of a member of the genus is from the Baltic amber.

The featured speaker, Dr. Robert S. Lane, Associate Professor at the University of California, Berkeley, presented "Lyme Disease and Other Tickborne Borrelioses in California." His slide-illustrated talk gave a general account of the importance of ticks in the transmission of diseases in the United States and specifically on the role they play as vectors of spirochetes causing relapsing fever and Lyme disease in

California. Relapsing fever is transmitted by *Ornithodoros* soft-bodied ticks (Argasidae) above 5,000 feet elevation in California, with chipmunks *(Eutamais)* serving as amplifying hosts. This disease is primarily associated with summer cabins that have chipmunks nesting in them. Lyme disease (*Borrelia burgdorferi* Johnson et al.) in the United States and specifically California was discussed in detail. Its increased incidence seems to be correlated with increased recreational use of federal and state park lands. The symptoms, treatment, and prevention of the disease; the life history of the only known vector in California, the western black-legged tick (*Ixodes pacificus* Cooley and Kohls); and research on the possible mammalian hosts, other possible tick vectors, and seasonal incidence of the disease were discussed.

The social hour was held in the entomology conference room following adjournment of the meeting.

The following 29 persons were present. Twenty members: J. R. Anderson, P. H. Arnaud Jr., R. L. Brett, T. S. Briggs, J. S. Chinn, H. K. Court, J. T. Doyen, D. F. Gross, L. Haimowitz, W. G. Iltis, A. I. Kaplan, B. Keh, R. S. Lane, V. F. Lee, G. J. Mallick, L. S. Saul, W. E. Savary, S. S. Shanks, M. M. Tierney, T. J. Zavortink. Nine guests: M. M. Arnaud, B. Atkinson, J. E. Court, T. F. Hlavac, W. R. Lower, M. MacKenney, W. C. Rauscher, M. Snively, B. A. Wilson.—V. F. Lee, Secretary.

FOUR HUNDRED AND FIFTY-THIRD MEETING

The 453rd meeting was held on Friday, 15 May 1987, at 8:15 p.m., in Morrison Auditorium, California Academy of Sciences, San Francisco, with President Dr. Stanley C. Williams presiding.

The minutes of the meeting held 10 April 1987 were read and accepted. Three persons were proposed by Mr. Daniel F. Gross and elected as new student members: Mr. Keith Dabney, Mr. Jeffrey Honda, and Mr. David P. Pline.

Several new guests were introduced. Ms. Leslie S. Saul announced the May and June lectures of the San Francisco Insect Zoo lecture series and the new insect sculptures on display there. Mr. Warren E. Savary gave further details about the arachnid special interest group and the arachnid workshop scheduled for September. Dr. Williams announced several job openings for entomologists.

Mr. Savary presented a note on a first record of a walking stick *Parabacillus hesperus* Hebard, taken at Zzyzyx Springs, San Bernardino County, California, being parasitized by an assamyiine tachnid. Ms. Karen Clayton showed scanning electron micrographs of the spiracles of the scorpions *Hadrurus arizonensis* Stahnke and *Uroctonus mordax* Thorell. Dr. Kirby W. Brown showed coins with beehives as subject. Mr. Curtis Y. Takahashi noted that the spotted asparagus beetle stridulates. Mr. Alan I. Kaplan gave further details about the AAAS-Pacific Division and International Congress of Entomology meetings. Dr. Williams presented a Certificate of Achievement from the Society to Dr. Edward S. Ross for his contributions to entomology as a world-renowned photographer, teacher, and entomologist.

The featured speaker, Dr. Edward S. Ross, Curator Emeritus in the Department of Entomology of the California Academy of Sciences, presented "Recent Field Work in Panama and Venezuela." His slide-illustrated talk gave an account of a 44-day trip to these countries in search of embiids, with suggestions for logistics to get into the remote areas.

The social hour was held in the entomology conference room following adjournment of the meeting.

The following 52 persons were present. Thirty-one members: P. H. Arnaud Jr., F. L. Blanc, T. S. Briggs, K. W. Brown, H. E. Carr, J. S. Chinn, W. D. Cole, K. Dabney, J. G. Edwards, B. Ehreth, S. V. Fend, M. Garcia-Vidal, D. F. Gross, J. Honda, A. I. Kaplan, R. L. Langston, V. F. Lee, P. A. Luft, L. B. Mak, G. J. Mallick, N. D. Penny, D. P. Pline, E. S. Ross, L. S. Saul, W. E. Savary, R. E. Stecker, C. Y. Takahashi, M. L. Utheim, J. S. Wasbauer, M. S. Wasbauer, S. C. Williams. Nineteen guests: M. M. Arnaud, R. Bandar, K. Clayton, P. R. Craig, W. Harrington, K. S. Hom, J. Johnston, A. Jung, G. Y. Leung, J. C. Leung, S. Leung, T. K. Ohsumi, A. M. Penny, R. Penny, W. C. Rauscher, S. Renkes, P. Stecker, B. A. Wilson, G. Wong. 2 unsigned.—V. F. Lee, Secretary.

FOUR HUNDRED AND FIFTY-FOURTH MEETING

The 454th meeting was held as a joint meeting with the San Francisco Microscopical Society on Friday, 18 September 1987, at 8:10 p.m. in Morrison Auditorium, California Academy of Sciences, San Francisco, with President Dr. Stanley C. Williams presiding.

Six persons were proposed by Mr. Daniel F. Gross and elected as new members: Mr. Folke K. Larsson as student member; and Mr. Charles R. Ash, Mrs. Debbie S. Brennan, Mr. Anthony H. Cobb, Mr. Frank T. Hovore IV, and Mr. Lawrence J. Pinter as regular members.

Dr. Williams introduced Dr. Gregory A. Antipa, President of the San Francisco Microscopical Society. Ms. Leslie S. Saul invited members of the Society and their guests to a special tour of the Insect Zoo on Saturday 19 September and announced some of the forthcoming fall lectures in the Insect Zoo Lecture

series. Dr. Williams announced that the Western Apiculture Society will be hosting a meeting at San Francisco State University in August 1989. Mr. Larry G. Bezark announced two job openings with the California Department of Food and Agriculture and an insect swap at the November meeting. Dr. Ronald E. Stecker added that he will organize a literature swap at the same meeting. Mr. Darrell Ubick announced that an arachnid workshop is scheduled for 22 November.

Mr. Ubick presented photographic slides showing the larval, pupal, and adult stages of *Dermatobia hominis* (Linnaeus) (Diptera: Cuterebridae), which he incubated in himself after contracting a larva on a collecting trip to Costa Rica in March. Mr. Warren E. Savary showed slides of several species of solpugids, including first instar larvae hatched from eggs.

Dr. Antipa introduced the featured speaker, Dr. Thomas K. Golder, research scientist at the International Centre of Insect Physiology and Ecology, Nairobi, Kenya, who presented "The Tsetse Fly *(Glossina)*—Field/Microscopical Studies in Kenya." He gave an account of the importance of the fly as a vector of trypanosomes and how trypanosomiasis significantly affects the economy and health of the peoples and animals of Africa. The vectors and mammalian hosts, life histories of the vector, methods of control, antigenic variation in the trypanosomes, and the results of the research by his team in Nkurumar, Kenya, were discussed. Dr. John Thayer then discussed the medical symptoms and methods of treatment of the sleeping sickness disease in humans and showed microscope slides of the trypanosomes during the social hour.

The social hour was held in the entomology conference room following adjournment of the meeting.

The following 55 persons were present. Thirty-four members: P. H. Arnaud Jr., L. G. Bezark, F. L. Blanc, T. S. Briggs, D. J. Burdick, H. E. Carr, J. S. Chinn, W. D. Cole, J. S. Cope, K. Dabney, L. Dong, J. G. Edwards, F. Ennik, S. V. Fend, S. S. Ferguson, W. E. Ferguson, N. E. Gershenz, D. F. Gross, J. E. Hafernik Jr., B. Keh, R. L. Langston, V. F. Lee, J. Leong, L. B. Mak, G. J. Mallick, N. D. Penny, D. P. Pline, L. S. Saul, W. E. Savary, R. E. Stecker, C. Y. Takahashi, M. M. Tierney, D. Ubick, S. C. Williams. Twenty-one guests: G. A. Antipa, M. M. Arnaud, T. D. Cuneo, L. J. Diggs, T. K. Golder, C. F. Hagar, D. Hayward, T. Henry, J. Koh, J. Langridge, K. Letsch, D. Longanecker, D. A. Moon, E. Page, W. C. Rauscher, S. Renkes, P. Rice, J. Runner, H. Schott, J. Thayer, A. Wilson.—V. F. Lee, Secretary.

FOUR HUNDRED AND FIFTY-FIFTH MEETING

The 455th meeting was held on Friday, 16 October 1987, at 8:10 p.m., in Morrison Auditorium, California Academy of Sciences, San Francisco, with President Dr. Stanley C. Williams presiding.

The minutes of the 18 September meeting were read, emended, and accepted. Three persons were proposed by Mr. Daniel F. Gross and elected as new student members: Mr. John F. Barthell, Ms. Terry D. Cuneo, and Mr. Alan R. Robinson.

Several guests were introduced. Mr. Darrell Ubick announced the arachnid workshop scheduled for 22 November. Dr. David L. Wagner announced that Dr. Ernst Mayr will be lecturing at the University of California at Berkeley and at Davis within the next two weeks. Dr. Paul H. Arnaud Jr. mentioned that the Executive Board approved an annual $50.00 organizational membership in the American Association for Zoological Nomenclature and also the purchase of archival boxes and file folders for the Society's historical materials. Mr. Vincent F. Lee announced that an Italian entomologist is willing to exchange insect specimens with interested individuals and that the University of California Press is having a special discount sale on some of their books. Dr. Williams reminded that the November meeting will feature an insect and literature swap.

Dr. Harvey I. Scudder showed a slide of a beautifully preserved tipulid from the paper shales of Stewart Valley, Nevada. Mr. Warren E. Savary showed slides of predation by the black widow spider *Lactrodectus hesperus* Chamberlin and Ivie (Araneae: Theridiidae) on the scorpion *Serradigitus gertschi striatus* Hjelle (Scorpiones: Vaejovidae). Mr. Keith Dabney displayed a box of insects, mostly of Missouran membracids, that he had received from a member of the Young Entomologists Society. Dr. Williams elicited comments regarding the new printer of our journal, A-R Editions. He also appointed Dr. Arnaud as chair of the nominating committee, with Dr. John T. Doyen and Dr. Ronald E. Somerby as members. He mentioned that the Executive Board will experiment with splitting the secretary's position into a recording secretary and a managing secretary for one year. He solicited volunteers to edit the newsletter *Bits & PCES*. He also sppointed Mr. H. Vannoy Davis as chair of the auditing committee, with Dr. Arnaud and Mrs. Helen K. Court as members.

Dr. Williams then introduced the featured speaker Mr. Benjamin Keh, retired medical entomologist with the California Department of Health Services, who presented "Selected Topics in Forensic Entomology." He discussed how forensic entomology is part of the larger field, forensic biology. He mentioned

several cases in which entomological evidence was used in solving both criminal and non-criminal cases. Trace evidence was shown to be very important but entomological clues among them are sometimes overlooked, ignored, or rejected by forensic specialists. The identification of insects in determining origins of plant material (e.g., marijuana) has shown to be a valuable tool in non-homicidal crimes. He concluded with comments on the need to expand training of specialists in forensic entomology.

The social hour was held in the entomology conference room following adjournment of the meeting.

The following 43 persons were present. 32 members: P. H. Arnaud Jr., J. S. Chinn, H. K. Court, T. D. Cuneo, K. Dabney, L. Dong, W. A. Doolin, J. G. Edwards, F. Ennik, S. V. Fend, B. Fouche, M. Garcia-Vidal, D. F. Gross, J. E. Hafernik Jr., A. I. Kaplan, B. Keh, R. L. Langston, V. F. Lee, G. J. Mallick, D. P. Pline, L. S. Saul, W. E. Savary, H. I. Scudder, S. S. Shanks, E. L. Smith, C. Y. Takahashi, D. Ubick, G. W. Ulrich, M. L. Utheim, D. L. Wagner, S. C. Williams, T. J. Zavortink. 11 guests: C. Buskirk, J. E. Court, P. R. Craig, T. F. Davis IV, D. Giuliani, K. Griffin, D. Hayward, R. Heglar, A. Hom, S. Renkes, B. A. Wilson.—V. F. Lee, Secretary.

FOUR HUNDRED AND FIFTY-SIXTH MEETING

The 456th meeting was held on Friday, 20 November 1987, at 8:10 p.m., in Morrison Auditorium, California Academy of Sciences, San Francisco, with President Dr. Stanley C. Williams presiding.

The minutes of the 16 October meeting were read on behalf of Mr. Vincent F. Lee by Mr. Warren E. Savary and were accepted as read. Mr. Daniel F. Gross reported that there were no new nominations for membership.

Mr. Larry G. Bezark announced that an insect swap would take place during the social hour following the meeting. Dr. Ronald E. Stecker announced that a literature swap would also take place following the meeting and that he had brought along for free distribution or trade a wealth of California Academy of Sciences publications which had resided at San Jose State University for the past 15 years. Dr. Paul H. Arnaud Jr. noted that the publications had been given to San Jose State University when the CAS Department of Entomology first moved to its present quarters on the second floor of Wattis Hall. Mr. Darrell Ubick announced that the arachnid workshop had elicited an overwhelming response and noted that individuals who had not pre-registered were still welcome to attend the lectures, but could not be accommodated in the identification labs. Dr. William E. Ferguson noted that a program which recently aired on PBS television mentioned the use of dried scorpions and centipedes in Chinese medicine. Dr. Williams commented that dried centipedes are also utilized in Viet Nam, and Dr. Edward L. Smith recalled the use of scorpions in olive oil by the Greeks.

Mr. Bezark showed slides of the displays at the Entomology Museum of Osaka Prefecture in Min-o Park, Osaka, which he visited during a recent trip to Japan. During the social hour, he displayed an assortment of Japanese insects, including syrphid flies and cetoniine scarab beetles, and several nice entomological publications which he acquired during his travels.

Dr. Williams then yielded the podium to Dr. Edward S. Ross, who introduced the featured speaker of the evening, Mr. Jae C. Choe, a PhD candidate from Harvard University, who presented an illustrated lecture entitled "Sexual Selection and Social Evolution in Zoraptera." Mr. Choe noted that this little-known order of insect, which contains a single family (Zorotypidae), a single genus *(Zorotypus),* and 27 known species, may provide clues useful in understanding the development of sociality in termites, to which they may be related. He detailed the courtship strategies of two species (*Z. barberi* Gurney and an undescribed *Zorotypus* which Mr. Choe will describe) which he collected from under the bark of fallen trees on Barro Colorado Island, Panama. He noted that the courtship of *Z. barberi,* a polygynandrous and promiscuous species, involves female choice as a selective force, with the male producing "nuptial gifts" in the form of an exudate from a specialized cephalic gland which is contacted by the female prior to mating. He contrasted this with the comparative lack of courtship in the polygynous new species in which the males may be divided into a dominance hierarchy, with the top male defending a harem of females. In the new species, the cephalic gland is lacking, and males present no "nuptial gift," suggesting that male-male competition becomes a dominant selective force. Mr. Choe concluded his presentation by answering the many questions of those in attendance.

The social hour was held in the entomology conference room following adjournment of the meeting. Mr. Jett S. Chinn provided the refreshments.

The following 39 persons were present. 25 members: P. H. Arnaud Jr., L. G. Bezark, T. S. Briggs, H. E. Carr, J. S. Chinn, J. S. Cope, K. Dabney, W. A. Doolin, S. S. Ferguson, W. E. Ferguson, D. F. Gross, J. E. Hafernik Jr., J. Honda, R. L. Langston, P. A. Luft, G. J. Mallick, N. D. Penny, W. J. Pulawski, E. S. Ross, W. E. Savary, H. I. Scudder, E. L. Smith, R. E. Stecker, D. Ubick, S. C. Williams. 14 guests: M. M. Arnaud, A. Cheng, H. Cheng, H.-K. Choe, J. C. Choe, B. Chu, S. Chu, C. Dingman, N.

Doolin, D. M. Horowitz, E. Johnson, N. Johnson, W. C. Rauscher, 1 illegible signature.—W. E. Savary, Acting Secretary.

FOUR HUNDRED AND FIFTY-SEVENTH MEETING

The 457th meeting was held on Friday, 11 December 1987, at 8:15 p.m., in Morrison Auditorium, California Academy of Sciences, San Francisco, with President Dr. Stanley C. Williams presiding.

The minutes of the 20 November meeting were read, emended, and accepted. Mr. Daniel F. Gross proposed one nominee for membership in 1987 and seven for 1988, and the members present approved. These new members included Ms. Dyvon M. Havens, Mr. Akira Nishiyama, Mr. Felipe Noguera, Mr. Charles L. Staines Jr. (for 1987), and Dr. Michael J. Weissmann as regular members, and Ms. Marie Demers, Ms. Elizabeth Jakob, and Ms. Susan W. Miller as student members. Several guests were introduced.

Mr. Darrell Ubick announced that an arachnid identification workshop was tentatively planned for 22 January 1988. Ms. Sharon S. Mead announced a full-time position available with the Alameda County Mosquito Abatement District.

Mr. Wesley A. Maffei presented a series of slides showing the ultrastructure of scales of several species of *Morpho* butterflies and an interesting error in the identification of a chrysopid as a dragonfly in the San Jose Mercury News. Mr. Alan I. Kaplan showed a portrait and gave a biography of Thomas Say, the father of American entomology, on the occasion of the bicentennial of Say's birthday. Mr. Vincent F. Lee announced that Fiji issued a first day cover with five different stamps depicting Fijian beetles in September 1987 and displayed a cover at the social hour.

Dr. Williams presented Distinguished Service Awards to Dr. John E. Hafernik Jr. for his participation in the Insect Photography Day, Mr. Darrell Ubick for his supervision of the Arachnid Workshop Day, Mr. Vincent F. Lee for his service as secretary from 1982 through 1987, Dr. John A. Chemsak for being editor of *The Pan-Pacific Entomologist,* and Mr. Warren E. Savary for working behind the scenes for the two workshops and helping with the refreshments.

Dr. Williams then asked for committee reports. Mr. Gross, chair of the Membership Committee, reported that the 1987 membership roll consists of 471 members, which included 52 new members added in 1987 (33 regular and 19 student members), of which 11 were a result of the two workshops. The breakdown of the membership is: 349 regular, 77 student, and 45 sponsoring and sponsoring family members. Dr. Paul H. Arnaud Jr. read a report from the Treasurer, Dr. Wojciech J. Pulawski, who was not able to attend. Mrs. Helen K. Court read a statement by the auditor, Mr. H. Vannoy Davis, whose audit showed that the financial status of the Society is favorable. Dr. Edward L. Smith asked that the Society acknowledge Mr. Davis's service through several years of auditing the Society's records without compensation. Dr. Arnaud, chair of the Historical Committee, reported that the committee transferred correspondence and other materials into Hollinger Archival File Folders and Document Boxes. These included 19 boxes of material from Frank E. Blaisdell Sr., 9 from Owen Bryant, 1 from Laurence I. Hewes, 7 from Ralph Hopping, 7 from Mary I. McMcracken, 5 from Frank W. Nunenmacher, 9 from Paul A. Opler, and 1 from Edwin C. Van Dyke. This material was then transferred to the Archives of the California Academy of Sciences. Dr. Arnaud, chair of the Nominating Committee, proposed these nominees for the offices of the Society for 1988: Mr. Alan I. Kaplan as President, Dr. Thomas J. Zavortink as President-elect, Dr. Wojciech J. Pulawski as Treasurer, Ms. Leslie S. Saul as Recording Secretary, and Mr. Vincent F. Lee as Managing Secretary. The members in attendance unanimously elected these nominees as the new officers. Dr. Williams then handed the gavel over to the new president, Mr. Kaplan.

Mr. Kaplan introduced Dr. Williams, who presented the presidential address, "The Biology of Scorpions." He gave a description of scorpion morphology, their geological history, life history, neurobiology, and excretory biology. Dr. Williams proposed some interesting speculations on why scorpions fluoresce, why there are only a few families extant today as contrasted to the greater numbers of families before the Permian, and on the use of venom as an exocrine secretion for mating purposes.

The social hour was held in the entomology conference room following adjournment of the meeting.

The following 46 persons were present. 35 members: P. H. Arnaud Jr., B. T. Berke, L. G. Bezark, T. S. Briggs, J. S. Chinn, W. D. Cole, H. K. Court, K. Dabney, J. G. Edwards, S. V. Fend, E. M. Fisher, D. F. Gross, J. E. Hafernik Jr., A. I. Kaplan, B. Keh, C. Y. Kitayama, R. L. Langston, V. F. Lee, J. Leong, P. A. Luft, W. A. Maffei, G. J. Mallick, S. S. Mead, L. S. Saul, W. E. Savary, H. I. Scudder, S. S. Shanks, E. L. Smith, R. E. Somerby, R. E. Stecker, C. Y. Takahashi, D. Ubick, D. L. Wagner, S. C. Williams, T. J. Zavortink. 11 guests: M. M. Arnaud, L. M. Bravo, B. Chinn, J. E. Court, P. R. Craig, L. V. Dubay, R. Kitayama, G. Kurtovich, W. C. Rauscher, S. Renkes, D. Solari.—V. F. Lee, Secretary.

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64(2), 1988, pp. 199–200

PACIFIC COAST ENTOMOLOGICAL SOCIETY
STATEMENT OF INCOME, EXPENDITURES AND CHANGES IN FUND BALANCES

Year Ended September 30, 1987 and 1986

	1987	1986
Income		
Dues and subscriptions	$12,030	$11,450
Reprints and miscellaneous	16,202	12,179
Sales of Memoirs	67	74
Interest	4,133	5,013
Dividends	513	485
Increase in value of capital stock: American Telephone & Telegraph Company and Pacific Telesis Group	1,793	2,477
	$31,152	$31,678
Expenditures		
Publication costs—Pan-Pacific Entomologist	$28,234	$18,343
Reprints, postage and miscellaneous	1,840	1,087
	$30,074	$19,430
Increase (Decrease) in fund balances	$ 1,078	$12,248
Fund balances October 1, 1986 and 1985	99,478	87,230
Fund balances September 30, 1987 and 1986	$100,556	$99,478

STATEMENT OF ASSETS

September 30, 1987 and 1986

	1987	1986
Cash in bank		
Commercial account	$ 8,631	$ 9,258
Savings accounts & Certificates of Deposit		
General Fund	19,745	18,863
Charles P. Alexander Fund	37,649	36,264
Fall Memoir Fund	27,591	26,359
Total cash in bank	$93,616	$90,744
Investment in 80 shares of American Telephone & Telegraph Co. common stock and 132 shares of Pacific Telesis Group at market value.	$ 6,940	$ 8,734
	$100,556	$99,478

See accompanying notes to the financial statements.

PACIFIC COAST ENTOMOLOGICAL SOCIETY
NOTES TO THE FINANCIAL STATEMENTS

Year Ended September 30, 1987

Summary of Significant Accounting Policies

Accounting Method: Income and expenses are recorded by using the cash basis of accounting. *Capital Expenditures:* Annual capital expenditures of $5,000 or less are charged to expense. *Marketable Securities:* American Telephone & Telegraph Co. and Pacific Telesis Group common stock are carried at market value. Increases and decreases in value are reflected in income. *Income Tax:* The Society is exempt from Federal income and California franchise tax. *Undeposited Receipts*—$0. *Accounts Receivable*—$1,963. *Accounts Payable*—$0.

As Chairman of the Auditing Committee, and in accordance with its bylaws, I have reviewed the financial records of the Society.

During the course of this review nothing was noted which indicated any material inaccuracy in the foregoing statements.

H. Vannoy Davis
Chairman of the Auditing Committee

THE PAN-PACIFIC ENTOMOLOGIST
Information for Contributors

Members are invited to submit manuscripts on the systematic and biological phases of entomology, including short notes or articles on insect taxonomy, morphology, ecology, behavior, life history, and distribution. Non-members may submit manuscripts for publication, but they should read the information below regarding editing and administrative charges. Manuscripts of less than a printed page will be published as space is available, in Scientific Notes. All manuscripts will be reviewed before acceptance. Manuscripts for publication, proofs, and all editorial matters should be addressed to the editor.

General.—The metric system is to be used exclusively in manuscripts, except when citing label data on type material, or in direct quotations when cited as such. Equivalents in other systems may be placed in parentheses following the metric, *i.e.* "1370 m (4500 ft.) elevation."

Typing.—Two copies of each manuscript must be submitted (original and one xerox copy or two xerox copies are suitable). All manuscripts must be **typewritten, double-spaced** throughout, with ample margins, and be on bond paper or an equivalent weight. **Carbon copies** or copies on paper larger than $8\frac{1}{2} \times 11$ inches are not acceptable.

Underscore only where *italics* are intended in the body of the text. **Number all pages** consecutively and put authors name on each sheet. References to **footnotes** in text should be numbered consecutively. Footnotes **must** be typed on a separate sheet.

Manuscripts with extensive corrections or revisions will be returned to the author for retyping.

First Page.—The page preceding the text of the manuscript must include (1) the complete title, (2) the order and family in parentheses, (3) the author's name or names, (4) the institution with city and state or the author's home city and state if not affiliated (5) the complete name and address to which proof is to be sent.

Names and descriptions of organisms.—The first mention of a plant or animal should include the full scientific name with the author of a zoological name *not* abbreviated. Do not abbreviate generic names. Descriptions of taxa should be in telegraphic style. The International Code of Zoological Nomenclature must be followed.

Tables.—Tables are expensive and should be kept to a minimum. Each table should be prepared as a line drawing *or* typed on a separate page with heading at top and footnotes below. Number tables with Arabic numerals. Number footnotes consecutively for each table. Use only horizontal rules. Extensive use of tabular material requiring typesetting may result in increased charges to the author.

Illustrations.—No extra charge is made for line drawings or halftones. Submit only photographs on glossy paper and original drawings. Authors *must* plan their illustrations for reduction to the dimension of the printed page (117×181 mm; $4\frac{5}{8} \times 7\frac{1}{8}$ inches). If possible, allowance should be made for the legend to be placed beneath the illustration. Photographs should not be less than the width of the printed page. Photographs should be mounted on stiff card stock, and bear the illustration number on the face.

Loose photographs or drawings which need mounting and/or numbering are not acceptable. Photographs to be placed together should be trimmed and abut when mounted. Drawings should be in India Ink, or equivalent, and at least twice as large as the printed illustration. Excessively large illustrations are awkward to handle and may be damaged in transit. It is recommended that a metric scale be placed on the drawing or the magnification of the *printed* illustration be stated in the legend where applicable. Arrange figures to use space efficiently. Lettering should reduce to no less than 1 mm. *On the back of each illustration* should be stated (1) the title of the paper, (2) the author's complete name and address, and (3) whether he wishes the illustration returned to him. Illustrations not specifically requested will be destroyed. **Improperly prepared illustrations will be returned to the author for correction prior to acceptance of the manuscript.**

Figure legends.—Legends should be typewritten double-spaced on separate pages headed EXPLANATION OF FIGURES and placed following LITERATURE CITED. Do not attach legends to illustrations.

References.—All citations in text, e.g., Essig (1926) or (Essig 1958), must be listed alphabetically under LITERATURE CITED in the following format:

Essig, E. O. 1926. A butterfly migration. Pan-Pac. Entomol., 2:211–212.

Essig, E. O. 1958. Insects and mites of western North America. Rev. ed. The Macmillan Co., New York, 1050 pp.

Abbreviations for titles of journals should follow a recent volume of *Serial Sources for the Biosis Data Base,* BioSciences Information Service. For **Scientific Notes** the citations to articles will appear within the text, i.e. . . ."Essig (1926, Pan-Pac. Entomol., 2:211–212) noted. . . ."

Proofs, reprints, and abstracts.—Proofs and forms for the abstract and reprint order will be sent to authors. Changes in proof will be charged to the author.

Editing and administrative charges.—Papers by members of the Pacific Coast Entomological Society are charged at the rate of $30.00 per page. Members without institutional or grant funds may apply for a society grant to cover a maximum of one-half of these charges. Non-members will be charged at the rate of $60.00 per page. Editing and administrative charges are in addition to the charge for reprints and do not include the possible charges for author's changes after the manuscript has been sent to the printer.

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*(Add 6% sales tax on all California orders (residents of Alameda, Contra Costa, and San Francisco counties add 6½%). Members of the Society will receive a 20% discount on the price of the memoirs, except vol. 4.)

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U.S.A.

Vol. 64 July 1988 No. 3

THE PAN-PACIFIC ENTOMOLOGIST

SAN FRANCISCO, CALIFORNIA • 1988

Published by the **PACIFIC COAST ENTOMOLOGICAL SOCIETY**
in cooperation with **THE CALIFORNIA ACADEMY OF SCIENCES**

The Pan-Pacific Entomologist

Published quarterly in January, April, July, and October with Society Proceedings appearing in the October number. All communications regarding nonreceipt of numbers, requests for sample copies, and financial communications should be addressed to the Treasurer, Dr. Wojciech J. Pulawski, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Application for membership in the Society and changes of address should be addressed to the Secretary, Mr. Vincent F. Lee, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Manuscripts, proofs, and all correspondence concerning editorial matters should be addressed to Editor, Pacific Coast Entomological Society, 201 Wellman Hall, University of California, Berkeley, CA 94720. See back cover for instructions.

The annual dues, paid in advance, are $15.00 for regular members of the Society, $7.50 for student members, $30.00 or more for sponsoring members, or $20.00 for subscription only. Members of the Society receive *The Pan-Pacific Entomologist.* Single copies of recent numbers are $5.00 each or $20.00 a volume. See back cover for prices of earlier back numbers. Make checks payable to the *Pacific Coast Entomological Society*.

Statement of Ownership

Title of Publication: The Pan-Pacific Entomologist.

Location of Office of Publication, Business Office of Publisher and Owner: Pacific Coast Entomological Society, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118-4599.

Editor: J. A. Chemsak, 201 Wellman Hall, University of California, Berkeley, California 94720.

Managing Editor and Known Bondholders or other Security Holders: None.

This issue mailed December 12, 1988

The Pan-Pacific Entomologist (ISSN 0031-0603)
PRODUCED BY A-R EDITIONS, INC., MADISON, WI 53703, U.S.A.

PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 201–227

A Revision of the *Nomada* Subgenus *Pachynomada* (Hymenoptera: Anthophoridae)

DEREK K. BROEMELING[1] AND ALI S. MOALIF[2]

USDA-Agricultural Research Service, Bee Biology & Systematics Laboratory, Utah State University, Logan, Utah 84322-5310.

Abstract.—The *Nomada* subgenus *Pachynomada* is revised. Fourteen species and subspecies are recognized, five of which are new to science. New species described *are Nomada bohartorum* Moalif n. sp., *N. dreisbachorum* Moalif n. sp., *N. tepoztlan* Moalif n. sp., *N. utahensis* Moalif n. sp., and *N. saltillo* Broemeling n. sp., *Nomada vincta heterochroa* Cockerell is placed in synonymy with *N. vincta* Say. *Pachynomada* is kleptoparasitic upon the *Andrena* subgenus *Callandrena.*

The kleptoparasitic bee genus *Nomada* is found on nearly every continent. *Pachynomada* is a new world subgenus of late summer to fall bees, ranging from southern Canada to the mountains of southern Mexico. They are most frequently collected on or around large flowered composites, especially species of *Helianthus.* Males are often found in the afternoon, flying amongst the stems of *Helianthus,* possibly in search of females (pers. obs.). *Nomada (Pachynomada) utahensis* n. sp. has been reared from the nests of *Andrena (Callandrena) helianthi* Robertson (Parker and Bohart, 1982). This same *Nomada* species has been observed leaving an unplugged burrow of *Andrena (Callandrena) haynesi* Viereck and Cockerell in southeastern Utah (Parker and Griswold, 1983).

Rodeck (1945) described *Pachynomada* as a segregate of the subgenus *Holonomada,* with *Nomada vincta* Say as the type species. *Pachynomada* was defined as having "the dorsum of the pronotum rounded-carinate, slightly depressed medially, the scape of the male antenna globular and swollen, the apex of the hind tibiae with 4–6 widely spaced short acute spines." Moalif (1979) revised the subgenus *Pachynomada* and his redefinition of the subgenus was based upon unique genitalic characters and the form of the hind basitarsus.

The morphological terminology used in this study generally follows that of Michener (1944) and Stephen, et al., (1969). The following is a list of abbreviations and new or uncommon morphological terminology used:

—acetabular carina (see Fig. 13); a lamellate projection at the upper base of the mandible, especially prominent in male *Nomada.*

—prelobar carina (see Fig. 18); connects posterior margin of pronotal ridge with anterior margin of pronotal lobe.

—paraocular carina; raised area running along interior margin of compound eye and crossing from base of eye to anterior mandibular articulation.

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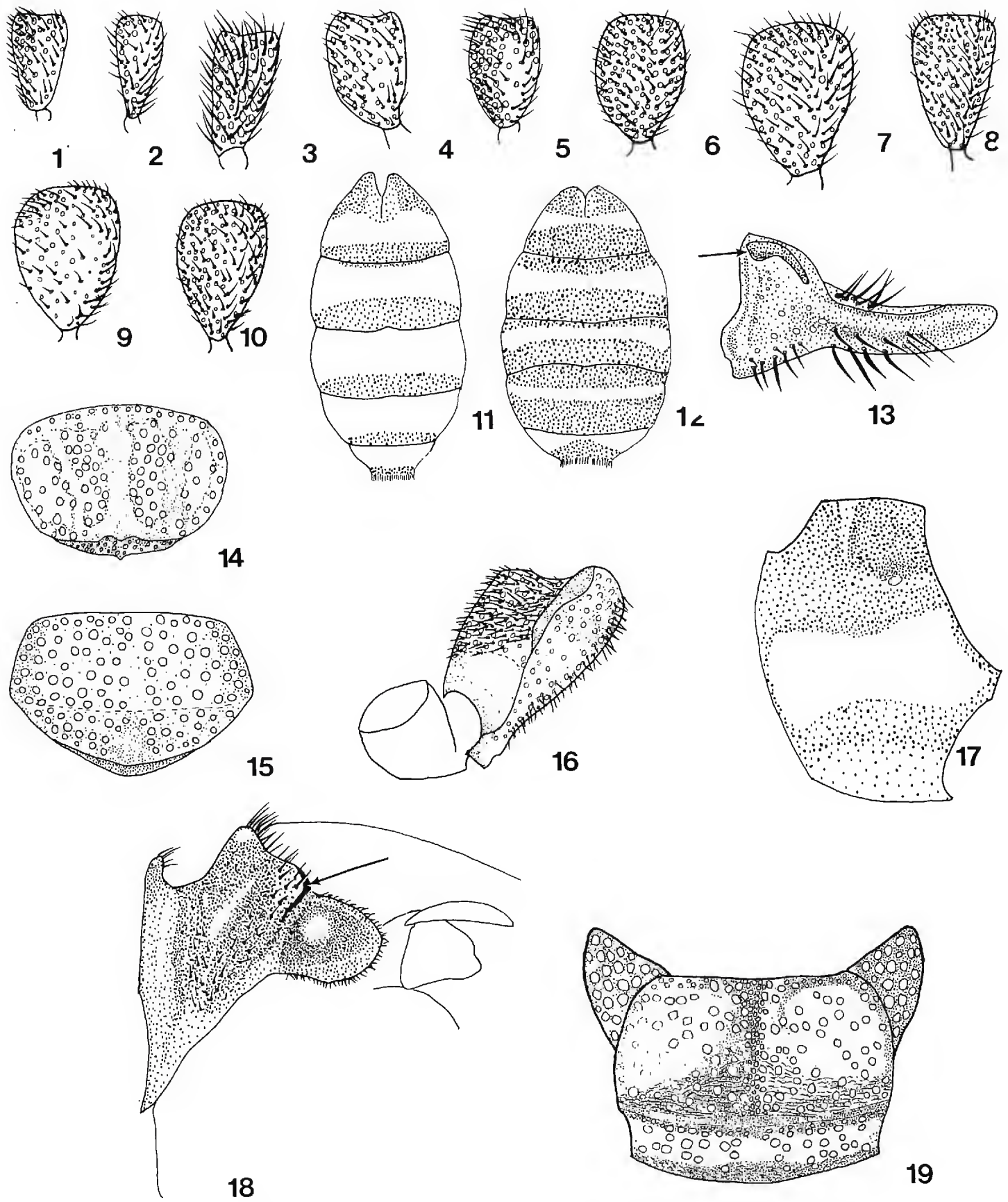


Figures 1–19. Figures 1–10. Male antennal scape. Figure 1. *Bohartorum.* Figure 2. *Tepoztlan.* Figure 3. *Dreisbachorum.* Figure 4. *Besseyi.* Figure 5. *Victrix.* Figure 6. *Asteris.* Figure 7. *Aztecorum.* Figure 8. *Utahensis.* Figure 9. *Zebrata.* Figure 10. *Vincta.* Figure 11. *Utahensis,* abdomen of female. Figure 12. *Vincta*, abdomen of female. Figure 13. *Nomada (Pachynomada)* sp., mandible, with acetabular carina. Figure 14. *Aztecorum,* labrum. Figure 15. *Suffossa,* labrum. Figure 16. *Victrix,* hind coxa. Figure 17. *Zebrata,* mesopleuron. Figure 18. *Nomada (Pachynomada),* pronotum with prelobar carina. Figure 19. *Aztecorum,* scutellum and metanotum.

—hypoepimeral area; dorsal posterior quarter of mesopleuron. (see Michener, 1944, p. 305)
—IOD = interocellar distance;
—OOD = ocellocular distance;
—MLOD = mid-lateral ocellar distance;
—MOD = mid-ocellar diameter;
—MOOM = mid-ocellar occipital margin distance;
—IPS = interpunctural surface.

In the species descriptions the rims of the scutal punctures are referred to as "rounded" or "angulate." An angulate puncture rim is one in which the scutal surface appears to have been shaved off, leaving the punctures incomplete. Tergum and sternum refer to the metasomal sclerites only. Thoracic sterna will be referred to as mesosternum or metasternum.

Subgenus Pachynomada *Rodeck*

Pachynomada Rodeck, 1945, Entomol. News 56:180.
Type species: *Nomada vincta* Say, original designation

Diagnosis.—Penis valve with conspicuous ventral subapical hook, eighth sternum elongated apically; occipital margin gently rounded, posterior basitarsus expanded medially (Fig. 44); posterior tibia with 4–8 apical bristles; minimum length of first flagellar segment longer than maximum length of second; propodeum lacking dorso-lateral angle behind spiracles; supraclypeal area distinctly protuberant; mandibles simple; female with paraocular carina.

Description.—Length 7.4–13.3 mm, forewing length 5.3–10.4 mm, hindwing length 4.1–8.1 mm; minimum length of first flagellar segment greater than maximum length of second; antennal scape in males often inflated to globose; pre-occipital ridge rounded, not reflexed or strongly angulate; supraclypeal area distinctly protruberant between antennal insertions, with a flattened median carina; margin of labrum sharply angulate; females with well developed paraocular carina; mandibular acetabular carina lamellate in males; mandibles lacking subapical tooth; head densely punctate with smooth shiny IPS (exceptions noted in species descriptions); Thorax: prelobar carina short, prominent; apex of pronotal ridge usually rounded, broadly depressed medially; scutum deeply, contiguously punctured, occasionally reticulate; rim of punctures frequently angulate, giving them a "shaved" appearance, IPS smooth and shiny; tegulae shallowly punctured with glassy surface; scutellum weakly to strongly bilobate, postero-medial region with distinctly microrugose IPS; propodeal disk rugose medio-apically and latero-apically, shagreened ventrally; sides of propodeum somewhat swollen posterior to spiracle (but not angulate), supraspiracular ridge undeveloped; mesopleuron densely, circularly punctured (sometimes reticulate), IPS glassy ventrally roughened dorsally, hypoepimeral area often distinctly protruding; procoxa often bearing a rudimentary posterior spine, usually showing as a sharp bump or angulation; hind tibial apex with a row of 4 to 8 thickened bristles; hind basitarsi distinctly widened medially, with curved anterior and posterior margins; forewing with 2 or 3 submarginal cells; sternum 8 of males with narrow, elongated distal process; penis valves with distinct ventral subapical projection; body sparsely clothed with moderately long pubescence; COLOR: Various combinations of black, yellow,

ferruginous, and rufo-ferruginous. Female differs from male as follows: Scape cylindrical; short, wide pseudopygidium present, anterior tarsal brushes absent; apex of sternum 8 with conspicuous lateral tufts of long inward curving hairs.

Most *Pachynomada* species fall within 3 distinct species groups, the members of which are quite similar morphologically, although they may differ greatly in coloration. Most of the species are related closely to *vincta.* Three species are assigned to monotypic species groups.

Vincta Group:

vincta Say, 1837;
aztecorum aztecorum Cockerell, 1903;
aztecorum pratensis Cockerell, 1919;
saltillo n. sp.;
suffossa Cockerell, 1922;
utahensis n. sp.;
zebrata Cresson, 1878;

Bohartorum Group:

bohartorum n. sp.;
tepoztlan n. sp.;

Vitticollis Group:

dreisbachorum n. sp.;
vitticollis Cresson, 1878;

Asteris Group:

asteris Swenk, 1913;

Besseyi Group:

besseyi Swenk, 1913;

Victrix Group:

victrix Cockerell, 1911;

Key to the Species of *Pachynomada*

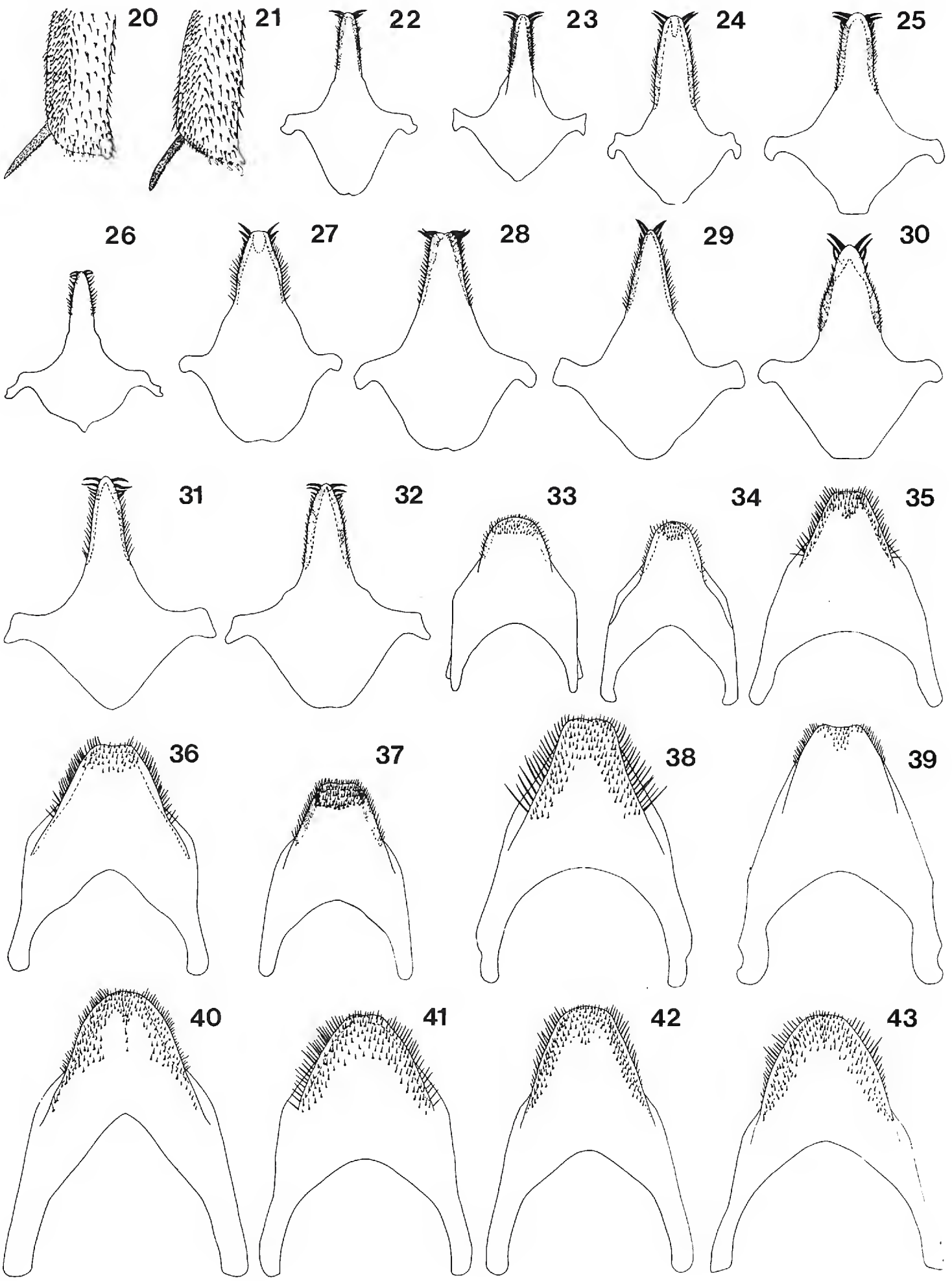
Males:

1. 2 submarginal cells in forewing 2
— 3 submarginal cells in forewing 3
2. hind coxa with a dorsal posterior carina extending almost 1/2 the length of the coxa (Fig. 16) ..... *victrix* Cockerell
— hind coxa not as above, antennal scape with hairs longer than 2/3 length of scape *dreisbachorum* n. sp.
3. propodeum appearing naked, pubescence little longer than the diameter of a puncture ..... *besseyi* Swenk
— propodeum with long lateral pubescence 4
4. propodeum with extensive yellow or ferruginous lateral marks, covering most of propodeal sides 5
— sides of propodeum black, rarely with a small yellow posterior lateral mark, not much larger than spiracle 8
5. small bee (7.5 mm), entire body a uniform light brown color with greatly reduced ornamentation ..... *tepoztlan* n. sp.
— larger bees (9.0 mm), or with bodies not a uniform light brown color and having extensive yellow maculations on thorax, head and abdomen 6
6. antennal scape globose or ovate (Fig. 9, 10) 7
— antennal scape not globose, somewhat swollen apically (Fig. 8) *utahensis* n. sp.

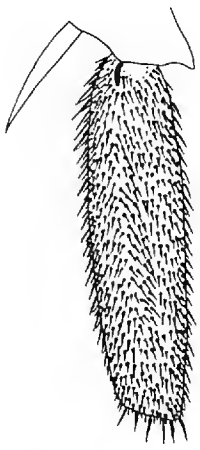
7. mesopleuron with a longitudinal yellow band extending from anterior margin to posterior margin, narrowed medially (Fig. 17) ..... *zebrata* Cresson
— mesopleuron without a complete longitudinal yellow band, usually only an anterior triangular patch ..... *vincta* Say
8. antennal scape globose 9
— antennal scape narrow apically ..... *bohartorum* n. sp.
9. antennal scape uniformly ferruginous, scutellum cream colored, without median black area ..... *asteris* Swenk
— antennal scape black, or if ferruginous, with dark posterior markings, scutellum with median black area 10
10. labrum with broad impunctate median welt and basal lateral welts, curving downward from center to apex (Fig. 14) 11
— labrum without impunctate lateral welts, entire apex strongly upturned (Fig. 15) ..... *suffossa* Cockerell
11. yellow bands on abdominal terga narrow, at midpoint less than 1/3 total length of tergum, legs usually black or with extensive dark areas .. *aztecorum aztecorum* Cockerell
— yellow bands on abdominal terga wide, at midpoint more than 1/2 total length of tergum, legs completely ferruginous ..... *aztecorum pratensis* Cockerell

Females:

1. hind coxa with a dorsal, posterior carina extending almost 1/2 length of coxa (Fig. 16), 2 submarginal cells in forewing ..... *victrix* Cockerell
— hind coxa not as above, 3 submarginal cells in forewing 2
2. abdominal terga with several complete transverse yellow or cream-colored bands 3
— abdominal terga never with complete transverse yellow bands, body ferruginous ..... *asteris* Swenk
3. propodeum appearing naked, pubescence not longer than the diameter of a puncture ..... *besseyi* Swenk
— propodeum with long lateral pubescence 4
4. propodeum with extensive yellow or ferruginous lateral markings 8
— propodeum black, or with small yellow mark, not much larger than spiracular area 5
5. scutellum with yellow markings widely separated by dark areas, at least posteriorly, hind tibial bristles not flattened or curved apically (Fig. 19, 20) .. 6
— scutellum with yellow markings not separated, hind tibia with 4 or 5 apical bristles, flattened, strongly curved (Fig. 21) ..... *bohartorum* n. sp.
6. labrum with broad impunctate median and lateral welts, curving downwards at sides (Fig. 14) 7
— labrum evenly punctate, may have impunctate median line, but not raised, apical margin with a strongly upcurved lip (Fig. 15) ..... *suffossa* Cockerell
7. yellow bands on abdominal terga narrow, at midpoint less than 1/3 length of tergum, legs usually black or with extensive dark areas .. *aztecorum aztecorum* Cockerell
— yellow bands on abdominal terga wide, at midpoint more than 1/2 length of tergum, legs completely ferruginous ..... *aztecorum pratensis* Cockerell



Figures 20–43. Figure 20. *Vincta,* posterior tibial apex. Figure 21. *Bohartorum,* posterior tibial apex. Figures 22–32, sternum VIII of Male. Figure 22. *Bohartorum.* Figure 23. *Tepoztlan.* Figure 24. *Asteris.* Figure 25. *Besseyi.* Figure 26. *Victrix.* Figure 27. *Dreisbachorum.* Figure 28. *Aztecorum.* Figure 29. *Suffossa.* Figure 30. *zebrata.* Figure 31. *Utahensis.* Figure 32. *Vincta.* Figures 33–43, Sternum VII of Male. Figure 33. *Bohartorum.* Figure 34. *Tepoztlan.* Figure 35. *Asteris.* Figure 36. *Besseyi.* Figure 37. *Victrix.* Figure 38. *Dreisbachorum* Figure 39. *Aztecorum.* Figure 40. *Suffossa.* Figure 41. *Utahensis.* Figure 42. *Zebrata.* Figure 43. *Vincta.*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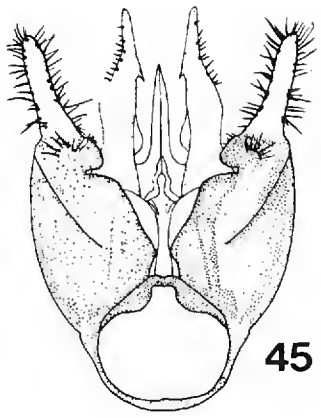
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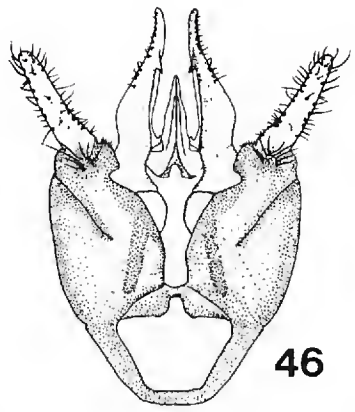
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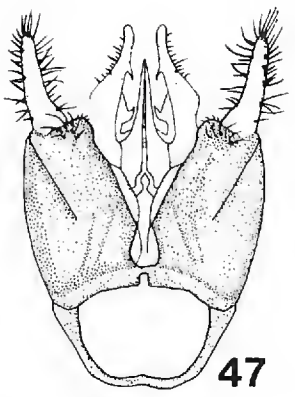
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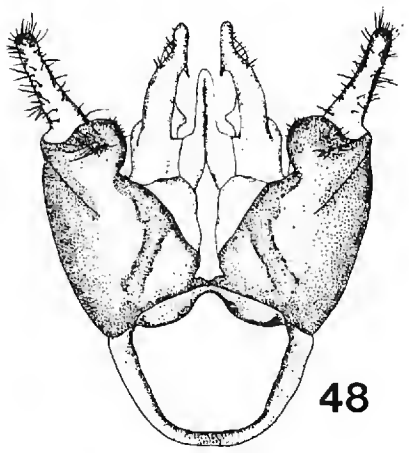
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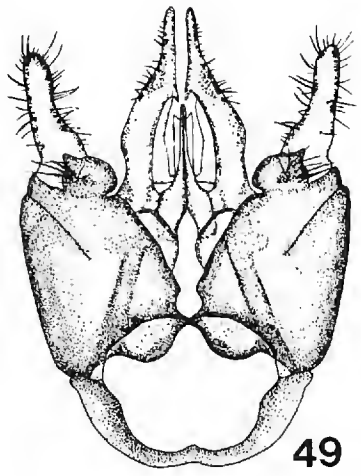
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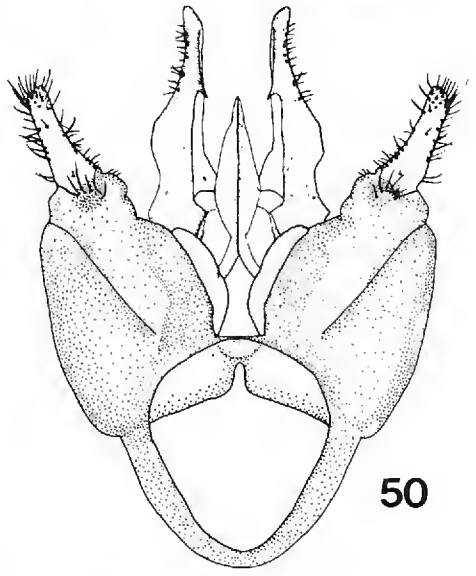
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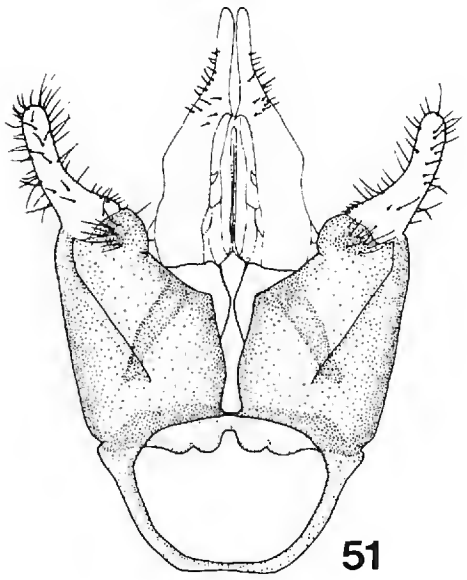
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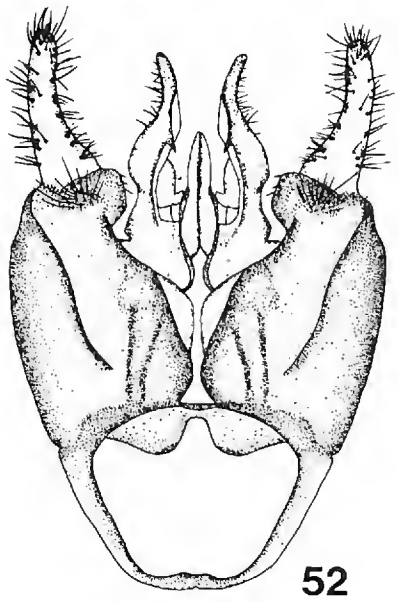
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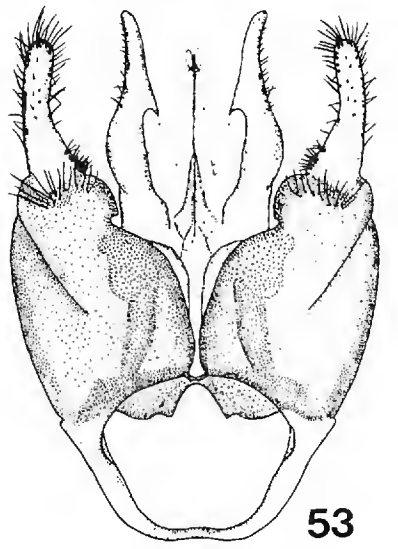
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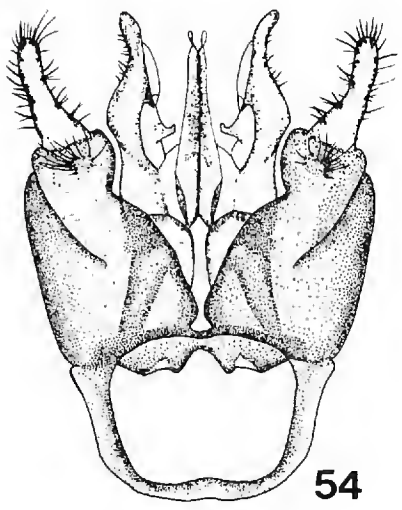
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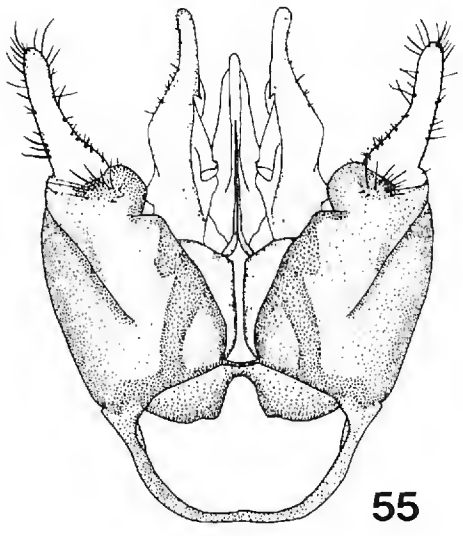
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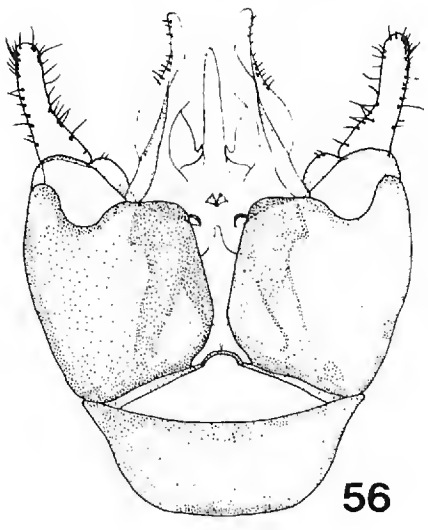
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Figures 44–56. Figure 44. *Vincta,* hind basitarsus. Figures 45–55. Male genital capsule (ventral view). Figure 45. *Bohartorum.* Figure 46. *Tepoztlan.* Figure 47. *Victrix.* Figure 48. *Asteris.* Figure 49. *besseyi.* Figure 50. *dreisbachorum.* Figure 51. *Aztecorum.* Figure 52. *Suffossa.* Figure 53. *Utahensis.* Figure 54. *Zebrata.* Figure 55. *Vincta.* Figure 56. *Vincta,* genital capsule (dorsal view).

8. pronotum, mesopleuron, metapleuron, and propodeum almost entirely yellow *vitticollis* Cresson
— thorax with extensive ferruginous or black areas 9
9. mesopleuron with a longitudinal yellow band from anterior to posterior border, narrowed medially, (Fig. 17) ..... *zebrata* Cresson
— mesopleuron with at most a small anterior yellow patch 10
10. sides of propodeum ferruginous, with a basal posterior yellow spot, not much larger than spiracular area, maculations cream-colored ..... *saltillo* n. sp.
— sides of propodeum with extensive yellow markings, maculations yellow ... 11
11. tergum II with narrow median transverse band, extensive dark areas anteriorly and posteriorly (Fig. 12) ..... *vincta* Say
— tergum II with broad median transverse yellow band, almost no dark area anteriorly (Fig. 11) ..... *utahensis* n. sp.

Descriptions of the Species

Vincta Group:

Nomada vincta Say, 1837. Boston Jour. Nat. Hist. 1:401.
Nomada vincta heterochroa Cockerell, 1921. Amer. Mus. Novit. 24:1. NEW SYNONYMY

Type.—Apparently lost.

Diagnosis.—3 submarginal cells, complete transverse median bands on terga, sides of propodeum yellow with long pubescence, antennal scape obovate, mesopleuron lacking longitudinal yellow band (if present, greatly expanded anteriorly, reaching to pronotal lobe), punctation below mesopleural scrobe with interpunctural spaces up to half a puncture diameter.

Male.—Length 9.6–12.4 mm, forewing length 7.4–9.3 mm, hindwing length 5.8–6.8 mm; antennal scape globose, densely punctate, IPS shiny, slightly roughened; IOD = OOD = MOOM, MLOD = MOD; labrum densely punctate, with impunctate medio-apical strip produced into a weak beak; prelobar carina thickened, pronotal ridge rounded anteriorly; scutum deeply, contiguously punctured with puncture rims angulate, IPS shiny; scutellum depressed medially; metanotum with shiny roughened IPS; propodeal disk moderately rugose dorso-medially, remainder shagreened; propodeum clothed with long hairs (0.3 mm); tegulae densely, shallowly punctate, glassy IPS; metapleuron with lower half smooth, moderately punctate; procoxal spine rudiment reduced to slight bump; hind tibial apex with 5 evenly spaced ferruginous bristles; forewing with 3 submarginal cells; COLOR: antennal scape ferruginous, blending to light yellow, flagellum light ferruginous, darker apically; supraclypeal area, clypeus, sides of face extending to apex of compound eyes, basal two-thirds of mandibles, malar space, gena, ring behind compound eyes, pronotal ridge and lobes, tegulae, axillary sclerites (in part), scutellum, metanotum, sides of propodeum, triangular anterior mesopleural patch, apex of fore- and mid-coxae, hind coxae, remainder of legs, median transverse band on abdominal terga, spot on first sternum, large transverse bands on remaining sterna, light yellow; remainder of body fuscous to black.

Females.—Length 8.1–11.5 mm, forewing length 6.5–9.3 mm, hindwing length 5.2–7.3 mm; similar to males except: antennal scape not inflated, sparsely punctate, with shiny, shagreened IPS; markings on face usually ferruginous, transverse median yellow bands on abdominal terga narrower.

Discussion.—Nomada vincta is the most common and widespread *Pachynomada* species. *Nomada vincta heterochroa* is based upon some unusually colored specimens with the normally black markings being ferruginous. It occurs at the same locality as normal *vincta* which rules it out as a valid subspecies, it is therefore relegated to synonymy. The type series of *Nomada vincta* appears to be lost. However, the type locality of Indiana has only two possible species of *Pachynomada,* and *N. besseyi* is not likely to have been confused with *N. vincta.* Since there seem to be no doubts about the identity *Nomada vincta,* the requirements of the International Code of Zoological Nomenclature for the designation of a neotype (Article 75) are not met.

Specimens examined.—CANADA: ALBERTA: 4.8 km (3mi) SE Picture Butte, 1 ♂, 6–VIII–1978 *Helianthus petiolaris* (C. D. Michener) SMEK; Medicine Hat, 1 ♀, (J. R. Malloch), 1 ♀, 13–VIII–1939 (E. H. Strickland), 1 ♂, 1 ♀, 16–VIII–1924 (F. S. Carr), 4 ♂♂, 8 ♀♀, 23–VIII–1919 (Sladen), 1 ♀, 7–IX–1925 (F. S. Carr), 1 ♀, 7–VIII-1938 (E. H. Strickland), 1 ♀, 9–IX–1939, (J. L. Carr); MANITOBA: Aweme, 1 ♀, 14–IX–1924 (N. Criddle); U.S.A.: COLORADO: 1 ♀, (Snow) ANSP; 14.5 km (9 mi) S Wray, 1 ♀, 2–IX–1951 (Paul P. ?) USNM; Fort Collins, 1 ♂, 1 ♀, 12–IX–03 BBSL; Wray 40 0′N 102 10′W, 1130 m (3700′), 1 ♂, 17–19/VIII/1919 CAS, 2 ♀♀, 17–19/VIII/1919, 1 ♀, 17–19/VIII/1919 Boul, 1 ♀, 17–19/VIII/1919 BBSL, 1 ♂, 1 ♀, 17–19/VIII/1919 USNM; ILLINOIS: Algonquin, 1 ♀, 13–IX–1894; Chicago 1 ♀, (A. L. Melander); Macoupin Co., Carlinville, (Charles Robertson), 1 ♀, 2–IX–1895 *Helianthus grosseseratus, 5* ♀♀, 21–IX–1895 *Aster ericoides villosus,* 1 ♀, 5–IX–1895 *Helianthus grosseseratus, 1* ♀, 9–IX–1895 *Helianthus grosseseratus,* 1 ♂; INDIANA: Lafayette, 1 ♂, 1 ♀, (Geo. G. Ainslie); Plymouth, 1 ♀, 4–IX–1917 (M. R. Smith); IOWA: Clarence, 1 ♀, 3–IX–1953 *Helianthus* (N. F. Stage); Sioux City, 1 ♂, 1–IX–1922 *Solidago* (C. N. Ainslie), 1 ♂, 5–IX–1927 (C. N. Ainslie), 1 ♂, 3 ♀♀, 8–IX–1920 (C. N. Ainslie); KANSAS: 2 ♂♂, 2589.5, 2589.4; Manhattan, (O. A. Stevens), 1 ♀, 24–VIII–1908 *Helianthus tuberosus,* 2 ♂♂, 25–VIII–1908 *Helianthus tuberosus;* Marysville, 1 ♀, 12–IX–1920 *Heliopsis scabra* (Edna M. Stevens); Topeka, 1 ♀, –IX– (J. E. Taylor); Clay Co., 1 ♂; Douglas Co., 2 ♂♂, 1 ♀, 25–VIII–1949 *Silphium perfoliatum,* (Michener, Beamer); MINNESOTA: Detroit, 1 ♀, 25–VIII–1913 *Aster sagittifolius* (O. A. Stevens); Hastings, 1 ♂, 26–VIII–1928, 3 ♂♂, 28–VIII–1928, 1 ♀, 30–VIII–1928 (H. A. Scullen); Lake Park, 1 ♀, 22–VIII–1911 *Rudbeckia laciniata* (C. H. Waldron); Miesville, 1 ♀, 4–IX–1951 *Helianthus maximiliani* (Roland Fischer); Stanton, 1♀, 28–IX–1957 *Helianthus maximiliani* (Roland L. Fischer) Mich; U. Farm, 1 ♀, 2–IX–1951 *Grindelia squarrosa* (Roland L. Fischer) Mich; MONTANA: 2 ♂♂, 1 +, ANSP; Huntley, 1 ♂, 16–VIII–1916; NORTH CAROLINA: Black Mountains, 1 ♂, 1 ♀, 1911; NORTH DAKOTA: Bismarck, 1 ♀, 12–IX–1920 *Helianthus tuberosus* (O. A. Stevens) Boul, 1 ♀, 23–VIII–1946 (Richard L. Post); Fargo, (O. A. Stevens), 1 ♂, 10–VIII–1912 *Grindelia squarrosa* NEBR, 2 ♂♂, 12–VIII–1910 *Grindelia squarrosa,* 1 ♂, 13–VIII–1910 *Solidago serotina,* 1 ♀, 13–VIII–1911 *Helianthus* (cult.), 2 ♂♂, 17–VIII–1911 *Grindelia squarrosa,* 3 ♂♂, 17–VIII–1911 *Grindelia squarrosa,* 2 ♀♀, 18–IX–1915 *Helianthus tuberosus,* 1 ♂, 18–VIII–1912 *Helianthus maximiliani,* 1 ♂♂, 29–VIII–1917 *Helianthus maximiliani* Boul, 1 ♀, 4–VIII–1911 *Helianthus* (cult.), 2 ♀♀, 8–IX–1913 *Helianthus tuberosus,* 1 ♂, 8–VIII–1920 *Sonchus arvensis,* Boul; Mandan, 1 ♀, 11–IX–1920 *Helianthus tuberosus* (O. A. Stevens); Mott, 1 ♂, 20–VIII–1914 *Solidago rigida* (J. R. Campbell) NEBR; Schafer, 1 ♀, 5–IX–1914 *Grindelia squarrosa* (O. A. Stevens) NEBR; Sheldon, (0. A. Stevens) 1 ♂, 10–VIII–1969 *Helianthus petiolaris* AMNH, 1 ♀, 20–VIII–1949

Figure 57. Distribution of *Pachynomada* species of the vincta group.

Helianthus petiolaris; Williston, (O. A. Stevens), 1 ♂, 15–VIII–1915 *Grindelia squarrosa* Boul, 1 ♂, 15–VIII–1915 *Grindelia squarrosa* AMNH; Ransom Co., 11.3 km (7 mi) SE Sheldon, 1 ♂, 19–VIII–1980 (J. R. Powers); NEBRASKA: Lincoln, 1 ♂, NEBR, 1 ♀, –IX–, 1 ♀, 18–IX–1903 *Grindelia* (M. H. Swenk), 1 ♀, 29–VIII–1936 (R. E. Hill); Mitchell, 1 ♂, 12–VIII–1915 (E. M. Partridge) NEBR, 2 ♀♀, 12–VIII–1916 (C. E. Mickel), 1 ♀, 24–VIII–1916 (R. W. Dawson), 1 ♀, 25–VIII–1916 (R. W. Dawson), 1 ♀, 29–VII–1913 (L. M. Gates), 1 ♀, 5–IX–1916 (R. W. Dawson), 1 ♀, 8–VIII–1913 *Helianthus annuus* (L. M. Gates), 1 ♂, 9–VIII–1915 (E. M. Partridge) NEBR; Morrill, 1 ♂, 11–VIII–1930 (D. B. Whelan) Boul; Omaha, (L. T. Williams), 1 ♂, 13–VIII–19—, 1♂, 1 ♀, 16–VIII–1913, 1 ♀, 16–VIII–1913 *Helianthus,* 1 ♂, 17–VIII–1913, 1 ♀, 2–IX–1913, 1 ♂, 4 ♀♀, 22–VIII–1913 *Helianthus,* 1 ♀, 23–VIII–1913, 1 ♀, 29–VIII–1913; West Point, 2 ♂♂, 6 ♀♀, –VIII–1887, 1 ♂, 12–IX–1903 *Solidago* (J. C. Crawford), 1 ♀, 2–IX–1900 *Helianthus,* 1 ♂, 4–IX–1903 *Helianthus* (J. C. Crawford), 1 ♀, 27–VIII–1903 (J. C. Crawford); Sioux Co., Glen, 1 ♂, 12–VIII–1906 *Helianthus* (H. S. Smith), 1 ♀, 20–VIII–1906 *Cleome* (H. S. Smith); Holt Co., Atkinson, 1 ♂, 30–VIII–1954 *Helianthus petiolaris* (L. W. Quate); Lancaster Co., Lincoln, 1 ♂, 1 ♀, –VIII–, 1 ♀, 11–IX–1954 jap beetle trap, 1 ♀, 11–IX–1954, 1 ♀, 17–IX–1917 *Grindelia squarrosa* (L. Bruner), 1 ♀, 20–IX–1915 (C. E. Mickel), 1 ♂, 30–VIII–1964 *Helianthus* (D. W. Ribble), 1 ♀, 4–IX–1904 *Solidago,* 1 ♀, 6–IX–1964 *Helianthus* (D. W. Ribble), 3 ♀♀, 7–IX–1964 *Helianthus* (D. W. Ribble); NEW JERSEY: Ramsey, 2 ♂♂, 1 +, 23–VIII–1921, 1 ♀, 3–IX–1917, 1 ♀, 6–IX–1917; NEW YORK: Cooperstown, 1 ♀, 30–VII–1927 (L. Lacey); SOUTH DAKOTA: 4.8 km (3 mi) W. Dallas, 1 ♂, 15–VIII–1958 *Helianthus annuus* (W. E. LaBerge) NEBR; Brookings, (H. C. Severin), 1 ♂, 23–VIII–1933 LACM, 5 ♀♀, 25–VIII–1921 USNM; Dallas, 2 ♀♀, 15–VIII–1958 *Helianthus annuus* (W. E. LaBerge); Gettysburg, 1 ♂, 12–VIII–1924 USNM; Wobridge, 1 ♂, 15–VIII–1924 USNM; WISCONSIN: Buffalo Co., Fountain City, 1 ♂, 12–17/VIII/1910;

Nomada (Pachynomada) aztecorum aztecorum Cockerell

Nomada aztecorum Cockerell, 1903. Ann. Mag. Nat. Hist. 12:211. Lectotype, female: "Amecameca, Mex. IX, Type No. 10145." type Depository, Academy of Natural Sciences of Philadelphia.

Diagnosis.—3 submarginal cells, propodeum black (at most with a small posterior basal yellow spot) with long pubescence, terga with complete yellow transverse bands, antennal scape globose, mesopleural punctation separated by half a puncture diameter or more in posterior ventral area.

Males.—Length 8.7–13.3 mm, forewing length 7.0–10.1 mm, hindwing length 5.8–7.7 mm; antennal scape globose; acetabular carina strongly lamellate, otherwise similar to females.

Females.—Length 9.6–12.3 mm, forewing length 8.7–9.8 mm, hindwing length 6.4–7.8 mm; antennal scape sparsely punctate basally, dense apically, IPS roughened basally, smooth apically; face densely, deeply punctured, many deformed, IPS roughened, rather dull over most of head; IOD < OOD < MOOM, MLOD < MOD; labrum with strongly carinate margin, surface highly polished and deeply punctate laterally, impunctate welt basolaterally and medially, protruding into a beak; prelobar carina strong; pronotal ridge rounded anteriorly, broadly depressed medially, impunctate medially; scutum contiguously punctured with much

deformation; scutellum elevated, flattened dorsally, slightly depressed medially, postero-medial IPS coarsely roughened; propodeal sides deeply punctured, hairs 0.4 mm long; mesopleuron densely punctured (0.06 mm diameter), with dull, coarsely roughened IPS; metapleuron with ventral half shiny, rugose; procoxal spine rudiments short; hind tibial apex with 6 staggered bristles, pygidium with impunctate median welt; forewing with three submarginal cells: COLOR: scape, pedical, first flagellar segment ferruginous anteriorly, remainder of antennae brown; apical half of clypeus, sides of face to about top of scape, labrum, mandibles, malar space, pronotal ridge and lobes, two spots on scutellum, metanotum, anterior rectangle on mesopleuron, posterior lateral spot near propodeal spiracle, apex of fore- and mid coxae, hind coxae, attenuated transverse median band on tergum 1–5, spot on sternum 1, band of sternum 2, yellow; remainder of body fuscous to black.

Discussion.—Nomada aztecorum is a southern *Pachynomada,* to date found only in Mexico. The northern specimens from Chihuahua have more extensive ferruginous markings, the transverse yellow bands on the abdomen are much wider, and the body is more robust than the typical form. Moalif (1979) commented that this was a highly variable species and proposed synonomy of *aztecorum pratensis* and *suffossa* with *aztecorum. Nomada suffossa* is a distinct species, with a differently shaped labrum and denser mesopleural punctation. The elimination of specimens of *suffossa* which were confused with *aztecorum* leaves very little intergradation in coloration of *aztecorum aztecorum* and *aztecorum pratensis. Nomada aztecorum pratensis* is therefore retained as a distinct subspecies.

Specimens examined.—MEXICO: Atlacomulco, 2600 m (8550′), 1 ♂, 30–VIII–1963 (Scullen & Bolinger); HIDALGO: 38.0 km (23.6 mi) NW Zacatlan, 2030 m (6650′), (U. Kans. Mex. Exped.) SMEK, 2 ♂♂, 1 + 22–VIII–1962; Tepeapulco, 1 ♀, 18–IX–1974 (W. Hanson, G. Bohart) BBSL; MEXICO: 29.0 km (18 mi) S. of Mexico City, 2800 m (9200′), (H. A. Scullen), 2 ♂♂, 10–IX–1957 ORSU, 3 ♂♂, 10–IX–1957 ORSU, 3 ♂♂, 10–IX–1957, 1 ♂, 1 ♀, 2750 m (9000′), 14–IX–1957, 3 ♂♂, 14–IX–1957 ORSU; 64.4 km (40 mi) E. Mexico City, 3010 m (9900′), (H. A. Scullen), 1 ♂, 7–IX–1957 ORSU, 3 ♂♂, 7–IX–1957; 0.6 km W Bosencheve, 2514 m., (C. D. George, R. R. Snelling) LACM, 1 ♂, 14–IX–1976 *Simsia amplexicaulis,* 3 ♂♂, 2 ♀♀, 14–IX–1976; MORELOS: Tres Cumbres, 1 ♂, 20–IX–1938 (L. J. Lipovsky) SMEK; NAYARIT: Santa Teresa, 2073 m., 2 ♀♀, 22–25/X–1979 (D. E. & J. A. Breedlove); PUEBLA: 6.9 km (4.3) mi W. Huauchinango, 1720 m (5650′), 1 ♂, 21–VIII–1962 (U. Kans. Mex. Exped.); 64.4 km (40 mi) W of Puebla, 2800 m (9200′) (H. A. Scullen), 3 ♂♂, 1 + 7–IX–1957; 9.7 km (6 mi) NW Zacatlan, 2440 m (8000′), 1 ♂, 22–VIII–1962 *Heterotheca* (Ordway & Roberts);

Nomada (Pachynomada) aztecorum pratensis Cockerell

Nomada aztecorum pratensis Cockerell, 1919. Proc. U.S. Natl. Mus., 55:180

Holotype Female.—"Meadow Vy, Mex. Collector Townsend, Type No. 20213". Type Depository, United States National Museum.

Males.—Length 9.8–12.9 mm, forewing length 8.4–9.3 mm, hindwing length 6.4–7.6 mm; differs from nominate subspecies by much thicker yellow bands on abdominal terga, legs almost completely ferruginous, antennal scape more ferruginous, mesopleural mark ranging from a spot to a longitudinal band;

Figure 58. Distribution of *Pachynomada* species exclusive of the vincta group.

Females.—Length 11.0–11.9 mm, forewing length 8.6–9.8 mm, hindwing length 6.7–7.7 mm; differs from males by supraclypeal area ferruginous, mesopleural mark forming a longitudinal band, mesopleuron ferruginous in the type.

Specimens examined.—MEXICO: Meadow Vy., 3 ♂♂, (Townsend) USNM; CHIHUAHUA: 6.4 km (4 mi) S. Santo Tomas, 1 ♂, 22–VIII–1950 (Ray F. Smith); Creel, (Sears, Gardner, Glaser) 1 ♂, 1 ♀, 24–VIII–1969, 1 ♀, 8–IX–1969;

Nomada (Pachynomada) saltillo Broemeling New Species

Holotype Female.—"Mexico, Coah. Saltillo, 32 mi S., VIII–23–1957, D. Spencer, R., J. & A. Ryckman Collectors." Type Depository, Natural History Museum of Los Angeles County.

Diagnosis.—3 submarginal cells, abdomen with transverse medial bands, sides of propodeum ferruginous (with small cream-colored posterior basal spot) with long pubescence, lacking longitudinal mesopleural band.

Males.—Unknown

Females.—Length 10.8 mm, forewing length 9.9 mm, hindwing length 7.6 mm; antennal scape sparsely, shallowly punctate, shiny shagreened IPS; IOD = OOD = MOOM, MLOD < MOD; raised impunctate hump behind mid-ocellus; head densely punctate, polished IPS; sides of labrum slightly downturned, (not as sharply as *aztecorum*), broad, impunctate median welt, apex upturned, forming a wedge; prelobar carina thick, rounded; pronotal ridge rounded anteriorly, broadly shallowly depressed medially, impunctate at very middle; scutum densely, deeply punctured, interpunctural spaces reduced to knife-like ridge; tegulae densely, shallowly punctured, IPS glassy; scutellum moderately depressed medially; metanotum somewhat flattened medially; mesopleuron with interpunctural spaces reduced to thin sharpened ridges; metapleuron shiny, punctate ventrally; pro-coxal spine rudiment virtually absent; hind tibial apex with six ferruginous, evenly spaced, straight bristles; forewing with 3 submarginal cells, apex darkly infuscated: COLOR: lower sides of face, malar space, pronotal ridge and lobes, most of tegulae, lobes of scutellum, metanotum, small postero-baso-lateral propodeal spots, anterior spot on mesopleuron, apices of mid- and hind-coxae, broken transverse median band on tergum 1, complete but very narrow medially on tergum 2–4, extensive band on tergum 5, broken band on sternum 3, emarginate band on sternum 4, creamy white; head except vertex and area directly above antennal insertions, antennae, scutum (except posterior medial patch), mesopleuron and mesosternum, sides of propodeum, legs, terga and abdominal sterna, rufo-ferruginous; remainder fuscous to black.

Discussion.—Nomada saltillo is similar morphologically to *aztecorum* and *suffossa,* but body coloration and conformation of the labrum are different. Extensive collecting might show this species to be merely an aberrant specimen. *Nomada saltillo* is also similar to *zebrata,* but has paler maculations, lacks a mesopleural band and has a more robust form.

Specimens examined.—This species is known only from the type.

Nomada (Pachynomada) suffossa Cockerell

Nomada (Holonomada) suffossa Cockerell, 1922. Proc. U.S. Natl. Mus. 60:16.

Holotype Male.—"Mex 2320, Collection C. F. Baker; Type No. 24893." Type Depository, United States National Museum.

Diagnosis.—3 submarginal cells, terga with yellow transverse medial bands, sides of propodeum black (rarely with small posterior basal spot) with long pubescence, antennal scape globose, labrum concave in cross-section, strongly recurved at apex, evenly punctate.

Males.—Length 10.4–12.1 mm, forewing length 8.9–10.4 mm, hindwing length 6.9–7.9 mm; antennal scape globose, sparsely punctate anteriorly, more dense along outside margin, IPS polished; IOD = OOD < MOOM, MLOD < MOD; face densely punctate, glassy IPS, raised impunctate bump behind mid-ocellus; labrum bordered by a carina, broad impunctate median welt, much wider apically, apex of labrum strongly bent upward along entire apical margin; prelobar carina thickened; pronotal ridge rounded anteriorly; scutum deeply, densely, contiguously punctured with sharp, narrow interpunctural spaces; scutellum slightly depressed medially; metanotum not flattened medially; sides of propodeum deeply contiguously punctured, interpunctural spaces very narrow, clothed with long hairs (0.3 mm); mesopleuron deeply contiguously punctured, interpunctural spaces often reduced to a sharp ridge, IPS smooth, shiny ventrally, roughened dorsally; hypoepimeral prominence distinct; metapleuron ventrally smooth, shiny, sparsely punctate; procoxal spine rudiment absent; hind tibial apex with six straight, pale ferruginous bristles; forewing with 3 submarginal cells: COLOR: posterior of scape and first flagellar segment light ferruginous, anterior scape dark brown; two spots on supraclypeal area, sides of face halfway up to antennal socket (higher along compound eye), labrum, basal two-thirds of mandibles, pronotal ridge and lobes, outer two-thirds of tegulae, lobes of scutellum, metanotum, anterior mesopleural spot, apices of mid- and hind coxae, median lateral marks on tergum 1, transverse median band (narrowed medially) on tergum 2–4, slightly narrowed on tergum 5, lateral medial patches on sternum 3 and 4, yellow: remainder of body dark brown to black.

Females.—Length 10.9–11.9 mm, forewing length 9.3–10.0 mm, hindwing length 7.4–8.1 mm; differs from male in narrower abdominal banding, facial markings more ferruginous.

Discussion.—See *Nomada aztecorum.*

Specimens examined.—MEXICO: DURANGO: Hidalgo, 1 ♂, 24–IX–1938 (L. J. Lipovsky) SMEK; JALISCO: 9.7 km (6 mi) S. Ojuelos, 2130 m (6975′), (U. Kans. Mex. Exped.), SMEK, 2 ♂ ♂, 25–VII–1962 *Heterotheca;* Mexico: 35.4 km (22 mi) N. Toluca, 2590 m (8500′), 3 ♂ ♂, 17–VIII–1954 (U. Kans. Mex. Exped.) SMEK; 12.9 km (8 mi) N. Atlacomulco, 2520 m (8250′), 1 ♀, 30–VIII–1963 (Scullen & Bolinger), ORSU; Atlacomulco, 2610 m (8550′), 3 ♂ ♂, 1 + 30–VIII–1963 (Scullen & Bolinger) ORSU; MICHOACAN: 6.4 km (4 mi) N. Morelia, 1830 m (6000′), 1 ♂, 28–VII–1962 (U. Kans. Mex. Exped.) SMEK;

Nomada (Pachynomada) utahensis Moalif New Species

Holotype Male, Allotype Female.—Pinned with holotype "Topaz Ut. VIII–12–1949 Geo. E. Bohart, Helianthus annuus." Type Depository, United States National Museum.

Diagnosis.—3 sub-marginal cells, terga with yellow transverse median bands, sides of propodeum yellow, with long pubescence, antennal scape not globose (widest at apex or just below), yellow mesopleural band if complete (rare) is expanded upwards to pronotal lobe, mesopleural interpunctural spaces below scrobal suture reduced to thin lines.

Male.—Length 9.3–12.6 mm, forewing length 7.3–8.9 mm, hindwing length 5.8–7.8 mm; antennal scape widest at apex, shallowly punctured, IPS smooth and shiny; OOD < IOD < MOOM, MLOD = MOD; labrum produced into a beak apically; acetabular carina elongate, lamellate; prelobar carina thin, prominent; pronotal ridge rounded apically; scutal punctures with sharply angulate rims; tegulae evenly punctate, IPS polished; scutellum faintly depressed medially; metapleuron with ventral half punctate, shiny; procoxal spine rudiment present; hind tibial apex with 5 light ferruginous bristles; forewing with 3 submarginal cells; COLOR: scape, supraclypeal area, sides of face, clypeus, complete ring around compound eyes, labrum, basal two-thirds of mandibles, pronotal ridge and lobes, tegulae, sides of scutum and two parasagittal stripes (absent in northern specimens), axillae, scutellum, metanotum, sides of propodeum, anterior mesopleuron extending up to subaxillary sclerites, posteriorly attenuated longitudinal band, hypoepimeral prominence, posterior meso- and metasternum, coxae (except basal area), majority of legs, terga (except dark apical bands), sterna (except clear apical impunctate bands and dark brown base of sternum I), bright yellow: remainder of body black.

Female.—Length 9.6–11.5 mm, forewing length 8.0–9.9 mm, hindwing length 6.2–7.6 mm; differs from male in scape not inflated, facial markings frequently ferruginous, dark areas of integument commonly ferruginous, not black as in males, legs somewhat darker than males.

Discussion.—This species is very close to *vincta*. It is possible that it represents a western form of that species, but the authors feel sufficient structural differences justify its specific status. The shape of the antennal scape in male *Pachynomada* can vary and *utahensis* with unusually swollen scapes can be difficult to distinguish from *vincta* with unusually narrow scapes. The females of these two species can be difficult to separate, but the tergal banding and the dark color of the thorax of *vincta* females makes identification possible.

Paratypes.—UTAH: Cache Co., Cornish, 600, 7–VIII–1978 4 ♂♂, 15–VIII–1978, 3 ♂♂, 1–IX–1978, 7 ♀♀, 9–IX–1978, 9–IX–1978, 4 ♀♀, 15–IX–1978, *Helianthus annuus* (A. S. Moalif), 1 ♂, 27–VIII–1967 (G. F. Knowlton); Logan 1 ♂, 17–VIII–1950 *Helianthus annuus* (John V. Bruce); Newton, 1 ♀, 13–VIII–1958 *Helianthus annuus* (William P. Nye); Duschene Co., Myton, 2 ♂♂, 3–IX–1964 *Helianthus annuus* (G. E. Bohart); Millard Co., Delta, 2 ♂♂, 20–VIII–1963 *Helianthus annuus* (G. F. Knowlton), 1 ♂, 15–VIII–1952 *Helianthus annuus* (G. E. Bohart E. A. Cross); Work Farm, N. of Delta, 2 ♂♂, 6–VIII–1947 *Helianthus annuus* (G. E. Bohart); Topaz, 1 ♂, 1 ♀, 12–VIII–1949 *Helianthus annuus* (Geo. E. Bohart); IDAHO: Bingham co., Aberdeen, 1 ♂, 17–VIII–1954 (A. R. Gittins); Franklin Co., Weston, 1 ♂, 22–VIII–1967 *Helianthus annuus* (G. F. Knowlton);

Additional specimens examined.—U.S.A.: ARIZONA: 8.1 km (5 mi) E. Fort Apache, 3 ♀♀, 28–VIII–1964 (M. E. Irwin), 2 ♀♀, 28–VIII–1964 (P. A. Rauch), 2 ♀♀, 28–VIII–1964 (E. I. Schlinger); Apache Co., 36.5 km (22.7 mi) S. Sanders, 1 ♂, 1 ♀ 26–VIII–1986 *Helianthus* sp. (R. R. Snelling) LACM; 24.2 km (15 mi) N. alpine 2320 m (7600′) 1 ♀, 23–VIII–1986 *Helianthus* sp. (R. R. Snelling) LACM; Coconino Co., Flagstaff, 2 ♂♂, 7–9/VIII–1959 (K. V. Krombein) USNM, 1 ♀, 12–IX–1951 (J. G. Rozen), 2 ♀♀, 21–VIII–1939 (E. C. VanDyke), 1 ♂, 4–VIII–1934 (E. L. Bell); Snobowl, 24.2 km (15 mi) NW Flagstaff, 1 ♀, 12–VIII–1950 (Cohn, Boone, Cazier); COLORADO: 1 ♂, (C. F. Baker) BBSL; 1 ♀, (W. H. Ashmead) USNM; 1 ♀, ANSP; 4.8 km (3 mi) E Cortez, (U. N. Lanham), *Helianthus*, 6 ♂♂,

14–VIII–1976, 9 ♀♀, 14–VIII–1976, 5 ♂♂, 15–VIII–1976, 2 ♀♀, 15–VIII–1976; Boulder, 1 ♀, *Heliopsis* (W. P. Cockerell), 1 ♀, 15–VIII–*Helianthus coronatus–x* (Cockerell) Boul, 1 ♀, 2–VII–1929 (C. S. Williams) Boul, 1 ♀, 25–VIII–21 *Lepadenia marginata* (L. O. Jackson), 1 ♀, 1650 m (5400′) 27–VIII–1979 (Kristi Neff) Boul, 1 ♂, 3–VIII–1927 (E. C. Nelson), 1 ♀, 1650 m (5400′) 5–IX–1976 *Grindelia* (P. Robinson) Boul 12:30–13:45 p.m.; Canfield, 2 ♂♂, 15–VIII–1922; Denver, 1 ♀, –VII– 29 Boul, 1 ♂, –VII–1929; Fort Collins, 1 ♂, 11–VIII–1974, 1 ♂, 23–31/VIII–1974, 1 ♀, 23–31/VIII–1974, 1 ♀, 23–31/VIII–1974 Ft. C, 1 ♀, 25–VIII–1975 Ft. C, 1 ♂, 26–VIII–1973, 1 ♀, 5–IX–1973 Ft. C (all H. E. Evans), 1 ♀, 5–VIII–99 USNM, 1 ♀, 12–VIII–00 USNM; J.Martin Dam, Hasty, 1 ♀, 22–VIII–1960 (R., K. Dreisbach); Pikes Peak, 2440 m (8000′), 2 ♂♂, –VIII–1932 (Lee Jeppson) BYU; Pingree Park, 1 ♀, (C. Lynn Hayward) BBSL; Pueblo, 1 ♀, 23–VIII–1931 (H. G. Rodeck) BBSL; Rock Creek vic. Colorado Springs, 1 ♂, 19–VIII–1937; Boulder Co., 2 ♂♂, 14–VIII–1925 (chas. H. Hicks) Boul; Fremont Co., 9.7 km (6 mi) NE Florence, 1 ♀, 11–VIII–1964 (J. G., B. L., K. C. Rozen); Larimer Co., 3.2 km (2 mi) E. Wellington, 2 ♀♀, 29–VIII–1976 *Helianthus* (C. Lanham) Boul; Las Animas Co., Kim 51.7 km (32.1 mi) SW, 1 ♀, 22–VIII–1967 (R. R. Snelling) BBSL; Montezuma Co., 4.8 km (3 mi) W Arriola, 1830 m (6000′), 1 ♀, –IX–1975 (T. Marquardt) Malaise Trap; Pueblo Co., 16.1 km (10 mi) W. Pueblo, 1 ♀, 11–VIII–1964 (J. G., B. L., K. C. Rozen); IDAHO: Oneida Co., 6.1 km (3.8 mi.) W. Holbrook Summit, 1 ♂, 26–VIII–1969 (G. F. Knowlton); Holbrook Summit, 1 ♂, 2–IX–1969 (G. F. Knowlton), 1 ♂, 26–VIII–1969 (G. F. Knowlton); Ireland Canyon, 1 ♂, 2–IX–1969 (G. F. Knowlton), 1 ♂, 2 ♀♀, 26–VIII–1969 (G. F. Knowlton); NEW MEXICO: 20.9 km (13 mi) W. of Chama, 1 ♂, 24–VIII–1947 (Hugo G. Rodeck); Beulah, 2440 m (8000′), 1 ♂ (Cockerell), 1 ♀, 17–VIII– (H. Skinner); Cimarron, 1 ♀, 17–22/VIII–1914 (W. R. Walton); Koehler, 1 ♀, 12–VIII–1914 (W. R. Walton); Raton, 1 ♂, 6–VIII–1952 (R. R. Dreisbach) Mich, 1 ♀, 6–VIII–1952 (R. R. Dreisbach); White Mtns. S. Fk. Eagle Creek, 2440 m (8000′), 1 ♀, 8–16 (Townsend); Mckinley Co., 30.6 km (19 mi) N. Gallup, 1 ♂, 14–VIII–1972 (J. G. Rozen, R. McGinley); Valencia Co., Cubero, 1 ♂, 18–VIII–1948 (C&P Vaurie) USNM; San Mateo, 2130 m (7000′), 4 ♀♀, 18–VIII–1962 (R&K Dreisbach) Mich, 5 ♂♂, 18–VIII–1962 (R&K. Dreisbach); UTAH: Bryce Canyon, 1♂, (Vasco M. Tanner); Hooper, 1 ♀, 17–IX–1937 (D. E. Hardy); Sandy, 1 ♂, 27–VIII–1947 (E. I. Taylor); Zion Pk Junction, 1 ♀, 9–VIII–1936 (M. B. Jackson) SMEK; Box Elder Co., Collinston, 1 ♂, 2–IX–1908 (E. S. G. Titus); Curlew Valley, 1 ♂, 1–IX–1970 (G. F. Knowlton, J. H. Judd); Hansel Mtns., 2 ♂♂, 28–VIII–1974 (G. F. Knowlton); Snowville, 3 ♂♂, 1–IX–1970 (G. F. Knowlton, J. H. Judd), 1 ♂, 16–VII–1953 (W. G. Firestone), 1 ♂, 26–VIII–1953 (W. G. Firestone); Cache Co., 6.4 km (4 mi) NW Logan, (D. K. Broemeling), 8 ♂♂, 10–VIII–1985 *Helianthus annuus,* 6 ♂♂, 10–VIII–1985, 2 ♂♂, 1 ♀, 22–VIII–1985, 3 ♂♂, 22–VIII–1985 *Helianthus annuus*; Cornish, 4 ♂♂, 20–VIII–1970 (G. E. Bohart) 1 ♂, 24–VIII–1973 (P. F. Torchio), 4 ♂♂, 27–VIII–1967 (G. F. Knowlton), 6 ♂♂, 7–IX–1968 *Helianthus* (C. D. Michener) SMEK; Hyrum Dam, (D. K. Broemeling), 1 ♀, 13–VIII–1985, 1 ♂, 9–VIII–1985 *Helianthus annuus,* 1 ♂, 9–VIII–1985, *Helianthus annuus,* 1 ♀, 9–VIII–1985; Logan, 1 ♂, 1 ♀, 18–VIII–1949 (G. E. Bohart), 1 ♂, 30–VIII–1955 (W. J. Hanson) SMEK; Petersboro, 3 ♂♂, 11–VIII–1947 *Helianthus annuus* (G. E. Bohart); Duchesne Co., Myton, *Helianthus annuus,* 1 ♂, 1 ♀, 3–IX–1964 (G. E. Bohart), 1 ♀, 8–VIII–1966 (Bohart, Cross); Emery Co., 0.8 km

(0.5 mi) e Little Gilson Butte, 1 ♂, 1 ♀, 15–IX–1985 (D. K. Broemeling); 0.8 km (1/2 air mi) NE Little Gilson Bt, 1540 m (5050′), 2 ♂ ♂, 12–IX–1983 (Parkers/Griswold); 0.8 km (1/2 mi) E Little Gilson Butte, 1550 m (5100′), *Helianthus anomalous* 1 ♀, 27–VIII–1985 (T. L. Griswold), 4 ♂ ♂, 27–VIII–1985 (T. L. Griswold), 3 ♂ ♂, 2 ♀ ♀, 27–VIII–1985 (D. K. Broemeling); 3.2 km (2 air mi) W Little Gilson Butte, 2 ♂ ♂, 1 ♀, 15/17–IX–1980 (T. Griswold), 1 ♂, 15/17–IX–1980 (F. Parker), 1 ♀, 15/17–IX–1980 (D. Veirs); 4.8 km (3 mi) N Little Gilson Butte, 1 ♀, 29–IX–1984 (D. K. Broemling); 5.2 km (3.2 air mi) NE Little Gilson Bt., 1520 m (5000′), 1 ♀, 13–IX–1983 (Parkers/Griswold); 4.8 km (3 mi) SSE Temple Mt. SanRafaelDes, 1620 m (5300′), 1 ♀, 23–IX–1982 (FD/JH Parker); 6.4 km (4 air mi) N Gilson Bt, 1550 m (5100′0, 4 ♂ ♂, 4 ♀ ♀, 12/14–IX–1983 (Parkers/Griswold), 1 ♂, 16/17–IX–1980 (T. Griswold), 2 ♂ ♂, 1 ♀, 26–VIII–1985 (D. K. Broemeling), 6 ♂ ♂, 26–VIII–1985 (F. D. Parker), 1 ♂, 26–VIII–1985 (T. L. Griswold), 1 ♂, 16/17–IX–1980 (T. Griswold); Gilson Bt. Well, 1550 m (5100′), 1 ♀, 20–IX–1985 *Helianthus anomalous* (W. P. Nye); Goblin Valley in Sand Dunes, 2 ♂ ♂, 3 ♀ ♀, 16–IX–1979 (F. D. Parker/D. Veirs); 6 ♀ ♀, 16–IX–1979 (C. Hatley/G. Briggs); Little Gilson Butte E. side, 1590 m (5200′), 3 ♀ ♀, 22–IX–1982 (FD/JH Parker); San Rafael Desert nr. Goblin Vly., 1 ♂, –IX–1980 (G. E. Bohart); WildHorse Cr. N Goblin Vly, 4 ♂ ♂, 1 ♀, 13–IX–1983 (Parkers/Griswold); Garfield Co., 3.2 km (2 mi) NE Henrieville, 1 ♀, 30–VIII–1985 (F. D. Parker), 1 ♀, 30–VIII–1985 (D. K. Broemeling); 9.7 km (6 mi) SE Escalante, 1 ♂, 1 ♀, 30–VIII–1985 (D. K. Broemeling); Sandy Cr. SSE of Notom, 1590 m (5200′), 1 ♂, 16–IX–1983 (FParker/TGriswold), 2 ♀ ♀, 16–IX–1983 (FParker/TGriswold), 2 ♀ ♀, 16–IX–1983 (J. H. Parker); Millard Co., Delta, 2 ♂ ♂, 15–VIII–1952 *Helianthus annuus* (G. E. Bohart, E. A. Cross), 3 ♂ ♂, 1 ♀, 20–VIII–1963 *Helianthus annuus* (G. E. Bohart), 2 ♂ ♂, 5–VIII–1948 (G. E. Bohart); Work Farm, N. Delta, 4 ♂ ♂, 6–VIII–1947 *Helianthus annuus* (G. E. Bohart); Piute Co., Circleville, 1 ♀, 8–IX–1978 (J. B. Karren); Salt Lake Co., Salt Lake City, 1 ♂, 11–VIII–1951 (R. B. Selander); San Juan Co., 8.1 km (5 mi) N Blanding, 1 ♂, 24–VIII–1967 (J. C. Hall) UCR; Uintah Co., Lower Jensen, 4.8 km (3 mi) SW Jensen, (Ian L. Bell), 1 ♂, 16–VIII–1949, 1 ♂, 9–IX–1949; Vernal, 1 ♂, 16–VIII–1949 (Lynn R. Nielson), 1 ♂, 18–VI–1936, 1 ♀, 20–VIII–1949 (Lynn R. Nielson); Utah Co., Provo, 1 ♂, 16–VIII–1947 (G. F. Knowlton); Washington Co., 1 ♂, 12–VIII–1959 (G. F. Knowlton); Zion Park, 1 ♀, 6–VIII–1966 (J. Kefuss); Wayne Co., 6.4 km (4 mi) SE Hanksville, 1 ♂, 28–IX–1985 *Helianthus annuus* (D. K. Broemeling); WYOMING: 19.3 km (12 mi) E. of Gillette, 1 ♂, 31–VIII–1962 *Helianthus* (S. M. Walder); Fremont Co., Baldwin Creek 4.8 km (3 mi) NW of Lander, 1680 m (5500′), 4 ♂ ♂, 10–VIII–1963 *Helianthus* (W. E. LaBerge);

Nomada (Pachynomada) zebrata Cresson

Nomada zebrata Cresson, 1978. American Hymenoptera. Amer. Ent. Soc. Trans. 7:73.

Lectotype Male.—"Col. 2589." Type Depository, Academy of Natural Sciences of Philadelphia.

Diagnosis.—3 submarginal cells, terga with yellow transverse median bands, antennal scape globose in males, sides of propodeum ferruginous with posterior yellow mark, long pubescence, mesopleuron with a complete longitudinal yellow band, slightly narrowed medially, not expanded anteriorly towards pronotal lobe.

Male.—Length 9.9–11.6 mm, forewing length 8.1–9.2 mm, hindwing length 6.1–6.9 mm; antennal scape globose, densely punctured on anterior outside half, sparsely punctate interiorly, IPS smooth and shiny, posterior virtually impunctate; first flagellar segment 1.4 times as long as second; IOD = OOD = MOOM, MLOD = MOD; head densely, evenly punctate, smooth shiny IPS; IPS dull, roughened within ocellar triangle; labrum glassy, impunctate median strip, produced slightly into a broad apical beak; acetabular carina strongly lamellate; prelobar carina short, heavy; pronotal ridge rounded anteriorly, broadly depressed medially, inner third impunctate; scutum deeply contiguously punctured, interpunctural spaces sharpened apically; tegulae with densely, shallowly, evenly punctate surface, glassy; metanotum flattened, broadened medially; propodeal disk reticulate rugose, with long transverse dorsal rugae, curling downward; propodeum swollen laterally, densely contiguously punctured, impunctate roughened band below spiracle; metapleuron with punctate ventral half; procoxal spine rudiments lacking; hind tibial apex with 7 weakly curved, ferruginous bristles in single row; forewing with 3 submarginal cells: COLOR: base color ferruginous; sides of face to antennal insertion, supraclypeal area, labrum, basal two-thirds of mandibles, pronotal ridge and lobes, tegulae, scutellum, metanotum, sides of propodeum, longitudinal mesopleural band (narrowed medially), apices of coxae, distal mid- and hind femora, proximal tibiae, transverse median bands on all terga (interrupted on tergum 1), pygidium, spot on sternum 1, extensive bands on remaining sterna, creamy yellow.

Females.—Length 9.9–12.4 mm, forewing length 8.1–8.7 mm, hindwing length 6.3–6.6 mm; differs from males by antennal scape not inflated, supraclypeal area ferruginous instead of yellow.

Discussion.—Nomada zebrata seems at present to be restricted to the southwestern United States, but it will probably be found in northern Mexico. It is characterized by the very swollen antennal scape of the males and a complete longitudinal yellow mesopleural band. Its range overlaps greatly with *utahensis,* and slightly with *vincta* in eastern Colorado. Specimens reported from Kansas and the Great Plains have proven to be misidentified *vincta.* Cresson's type series includes at least 3 *vincta.* One of the cotypes of Cockerell's *vincta heterochroa* is actually a specimen of *zebrata.* Some specimens from a recent series collected in Texas have some of the ferruginous body markings replaced with black.

Specimens examined.—U.S.A.: Brevolt Co. 25.0 km (15.5 mi) E. ?, 1 ♂, 15–IX–1961 *Verbesina* (Timberlake) LACM; ARIZONA: 32.2 km (20 mi) E. Pearce, 1 ♀ ♀, 1–X–1967 (F. Werner) UNAr; Apache Co., 36.5 km (22.7 mi) S. of Sanders, 1 ♂ 28–VIII–1986 *Sphaeralcea* sp. (R. R. Snelling); Springerville, 1 ♂, 25–VIII–1970 (Bill Apperson); Cochise Co., 6.4 km (4 mi) W. Portal, 1 ♀ ♀, 26–IX–1982 (W. J. Pulawski); Onion Saddle, Chiricahua Mtns., 1 ♀ ♀, 3–IX–1959 (J. R. Powers); Coconino Co., 11.3 km (7 mi) S Flagstaff, 2 ♀ ♀, 12–16/IX/1961 *Grindelia* (G. Butler), 1 ♂, 12–16/IX/1961 *Grindelia* (G. Butler); 32.2 km (20 mi) SW of Flagstaff 1 ♂, 18–IX–1966 (R. S. Beal); Flagstaff, 1 ♀ ♀, 9–IX–1951 (A. T. McClay); Greenlee Co., 62.8 km (39 mi) S Hannagan Meadows, 1 ♂, 1 ♀, 13–IX–1985 *Helianthus* (d. K. Broemeling); Yavapai Co., Paulden, 3.2 km (2 mi N.), 1 ♂, 14–IX–1961 *Gutierrezia microcephala* (P. D. Hurd); COLORADO: Cabin Canon, 1 ♀, 31–VIII–1921 (Hugo G. Rodeck); Denver, 1 ♂, 10–VI–1960; Boulder Co., Boulder, 1650 m (5400′), 1 ♀, 5–IX–1976 *Grindelia* (P. Robinson); N. of

Marshall, 1 ♀, 12–IX–1946 *Grindelia* (Hugo G. Rodeck); El Paso Co., Colorado Springs, 1 ♀; Rock Creek vic. Colorado Sprgs, 1 ♂, 19–VIII–1937; Fremont Co., 8.1 km (5 mi) S. Coaldale, 2230 m (7300′), 1 ♂, 13–VIII–1969 (C. D. Michener); Las Animas Co., Kim, 37.0 km (23 mi) N., 1 ♀, 22–VIII–1967 *Haplopappus* (R. R. Snelling); NEW MEXICO: Grant Co., Hachita, 12.9 km (8 mi) W., 1 ♂, 5–IX–1972 (R. R. Snelling); Otero Co., Cloudcroft, 2590–2740 m (8500–9000′), 2 ♂♂, 6–IX–1963 (H. V. Weems, Jr.); Torrance Co., Town of Gran Quivira, 1990 m (6500′), 1 ♂, 20–VIII–1967 (Hugh B. Leach); TEXAS: Jeff Davis Co., High Lonesome Ridge, Davis Mts. 2320 m (7600′) 17 ♂♂, 3 ♀♀, 6–IX–1986 *Verbesina encelioides* (R. R. Snelling), 1 ♂ same but no floral record; Madera Can. rest stop on Rd. 118, 1 ♀, 16–X–1977 (James R. Zimmerman), NMex; Upper Limpia Cyn., Davis Mts. 1710 m (5600′) 30–VIII–1986 (R. R. Snelling), 3 ♂♂, (one each on *Bidens* sp. and *Verbesina encelioides*.

Bohartorum Group

Nomada (Pachynomada) bohartorum Moalif New Species

Holotype Female.—"Mex. Jalisco, Tepatitlan, X–3–66, GE & AS Bohart." Type Depository, United States National Museum.

Diagnosis.—3 sub-marginal cells, antennal scape not globose (slightly expanded apically), terga with complete transverse median bands, sides of propodeum black with long pubescence, thorax black or black with ferruginous (never entirely ferruginous), females with 5 hind tibial apical bristles, strongly curved, somewhat flattened.

Male.—Length 8.2 mm, forewing length 6.9 mm, hindwing length 5.3 mm; antennal scape moderately punctate anteriorly, impunctate posteriorly, IPS polished, somewhat roughened anteriorly, posterior quarter of scape apilose; first flagellar segment twice length of second; IOD < OOD < MOOM, MLOD < MOD; head densely, deeply punctured, glassy IPS; raised impunctate bump posterior to line between lateral ocelli; labrum distended into large flattened beak medio-apically; acetabular carina with distinct lamella; prelobar carina thin; pronotal ridge somewhat angulate anteriorly, broadly depressed medially; scutum with typical punctation; tegulae lightly punctured; scutellum distinctly depressed medially; sides of propodeum densely punctate, clothed with fine, long (0.15 mm) pubescence, broad, shiny, virtually impunctate band along lower margin, reaching dorsally to spiracular depression; mesopleuron with glassy IPS, roughened dorsal to hypoepimeral prominence; ventral half of metapleuron glassy, impunctate; slight procoxal spine rudiment present; hind tibial apex with 3 clear, long, rather strongly curved bristles; forewing with 3 submarginal cells: COLOR: face up to level of clypeus, short extension dorsally along compound eyes, basal half of mandibles, pronotal ridge and lobes, outer two-thirds of tegulae, scutellum, anterior of fore-femora, abdominal terga (T-1 divided medially), yellow; remainder of body dark brown to black.

Female.—Length 8.5 mm; forewing length 7.3 mm; hindwing length 5.6 mm; scape shallowly punctured, with shiny, shagreened interpunctural areas; IOD < OOD = MOOM, MLOD < MOD; impunctate, roughened median hump behind ocellar triangle; labrum produced into an apical wedge, bearing a narrow median impunctate band; acetabular carina strong, angulate; prelobar carina thick;

pronotal ridge rounded apically with smooth impunctate median area; scutal puncture rims angulate; tegulae evenly, shallowly punctate; scutellum depressed medially; sides of propodeum covered with long hairs (0.17 mm); hypoepimeral area not prominently swollen; metapleuron with ventral half highly polished, impunctate; pro-coxal spine rudiments lacking; hind tibial apex with 5 ferruginous spines, anterior 3 strongly curved, flattened; forewing with 3 submarginal cells: COLOR: scape, pedicel, first flagellar segment, ring around compound eyes, face to base of clypeus, labrum, basal two-thirds of mandibles, tegulae, most of mesopleuron, apices of coxae, legs, medial spot on sternum I, remaining sterna, ferruginous: pronotal ridge and lobes, scutellum, anterior mesopleural spot, divided median transverse band on tergum 1, tergum 2 and 3 except baso-medial inclusion and apical band, tergum 4 and 5 except apical band, transverse bands on sternum 2–5, yellow; remainder of body black.

Discussion.—Nomada bohartorum is a small western Mexican species. The flattened hind tibial bristles which are strongly curved apically are its most distinctive feature. These bristles are less pronounced in the males. The male is very similar morphologically to *tepoztlan,* but the integument of *bohartorum* is black rather than light brown, and the genital capsules are somewhat different.

Specimens examined.—MEXICO: DURANGO: 9.7 km (6 mi) W. Paraiso, 2010 m (6600′), 1 ♀, 23–IX–1950 (Ray F. Smith); SINALOA: El Palmito on Rt. 40, 1830–1990 m (6000–6500′), 1 M, 3–IX–1963 (H. V. Weems, Jr.);

Nomada (Pachynomada) tepoztlan Moalif New Species

Holotype Male.—"Tepotzlan(!), Morelos, Mex. 9–26–57, R. & K. Dreisbach." Type Depository, Michigan State University.

Diagnosis.—3 submarginal cells, antennal scape not globose, abdominal terga with complete transverse median bands, sides of propodeum with long pubescence, head and thorax a uniform light brown.

Male.—Length 7.4 mm; forewing length 6.2 mm, hindwing length 4.8 mm; scale slightly swollen apically, moderately punctate, IPS shiny, shagreened in places; IOD < OOD = MOOM, MLOD < MOD; labrum thickened medio-apically, narrow impunctate strip extending down middle; acetabular carina prominent; prelobar carina abbreviated; pronotal ridge polished, sparsely punctate, shallowly depressed medially, apex rounded, broad impunctate medial area; tegulae evenly, shallowly punctured, glassy; scutal punctures with angulate rims; scutellum slightly depressed medially; metanotum flattened; propodeum with highly polished impunctate lateral ventral band extending upwards to spiracle; ventral band extending upwards to spiracle; ventral half of metapleuron impunctate, highly polished; procoxal spine rudiment absent; hind tibial apex with 5 light bristles, curved at about half their length; forewing with 3 submarginal cells: COLOR: uniform light brown, except; clypeus, face below clypeo-frontal suture, labrum, basal half of mandibles, pronotal ridge and lobes, tegulae, scutellum, metanotum, apices of fore- and mid femora, tibial bases, fore- and mid tibial apices, fore- and mid tarsi, medially narrowed transverse band on tergum 1–5, broad transverse band on sternum 1, yellow.

Discussion.—This is the smallest of the species of *Pachynomada.* It is no larger than most *Nomadita* species, but it has all the distinguishing characteristics of the subgenus *Pachynomada.*

VITTICOLLIS GROUP

Nomada (Pachynomada) dreisbachorum Moalif NEW SPECIES

Holotype Male.—"Amecameca, Mex. 9–25–57, R. & K. Dreisbach." Type Depository, Michigan State University.

Diagnosis.—2 submarginal cells, antennal scape not at all swollen, propodeum and scape clothed with very long hair (more than two-thirds length of scape), body black with greatly reduced yellow markings, IPS of face dull and quite roughened, pro-coxal spine rudiment strong, hind basitarsus only slightly expanded medially.

Male.—Length 9.6–12.7 mm; forewing length 8.9–10.1 mm; hindwing length 6.9–8.1 mm; antennal scape not inflated (fig. 3), covered with unusually shallow, flattened punctures, IPS dull, coarsely shagreened; IOD < OOD < MOOM, MLOD < MOD; head covered with round, shallow punctures, IPS dull and coarsely roughened; labrum with IPS quite polished, apex produced into thick, prominent beak; acetabular carina unusually short but strongly lamellate; prelobar carina reduced to an angulation; pronotal ridge apex protruberant but rounded; IPS of scutum somewhat roughened; scutellum flattened dorsally, slightly depressed medially, entire IPS roughened; sides of propodeum densely, shallowly punctate, IPS quite roughened, covered with long slender hairs (0.22 mm); mesopleuron more sparsely punctured, punctures shallow, IPS dull, quite roughened; metapleuron with ventral half impunctate, shiny, only slightly roughened; pro-coxal spine rudiment strongly developed; hind tibial apex with long, thin, pale bristles, difficult to distinguish from surrounding hairs; forewings with two submarginal cells, but some specimens may bear a short rudiment of first transverse cubital vein, wings dark around outer margin, clear interiorly; sternum 1 with traces of a median longitudinal carina: COLOR: spot at apex of clypeus and at apex of compound eye, tips of pronotal lobes, pronotal ridge, two spots on scutellum, metanotum, thin transverse median band on abdominal terga, patches on sterna 1–3, yellow; remainder of body black.

Discussion.—This species is the furthest from the norm of *Pachynomada.* The genitalia are clearly that of *Pachynomada,* although the gonostylus is unusually short. One specimen examined shows a trace of the first transverse cubital vein in the forewing. This may mean that long series of *dreisbachorum* would contain specimens with 2 or 3 submarginal cells. The genus *Hypochrotaenia* (formerly the subgenus *Micronomada*) shows great variability in the number of submarginal cells, and there are a number of specimens which have 3 cells on one forewing and two cells on the other (pers. obs.). *Nomada dreisbachorum* can still be distinguished by the long pubescence on the antennal scape (which is not globose, as in many male *Pachynomada* species), and the dull, shagreened interpunctural surface of the head.

Paratypes.—4 males with same data as holotype. Three deposited at Michigan State University, and one in the Bee Biology & Systematics Lab in Utah.

Additional specimens examined.—MEXICO: 64.4 km (40 mi) W. of Puebla Pue., 2800 m (9200′), 1 ♂ 7–IX–1957 (H. A. Scullen) ORSU; D. F.: 29.0 km (18 mi) S. of Mexico City, 2800 m (9200′), 1 ♂, 10–IX–1957 (H. A. Scullen) ORSU;

Nomada (Pachynomada) vitticollis Cresson

Nomada vitticollis Cresson, 1878. Trans. Amer. Entomol. Soc. 7:78.

Holotype Female.—"Mex. 2562." Type Depository, Academy of Natural Sciences of Philadelphia.

Diagnosis.—3 submarginal cells, thorax almost entirely yellow except for brown sutures, sides of propodeum with long pubescence, interpunctural surface of face smooth, shiny.

Male.—Unknown.

Female.—Length 8.9–12.1 mm, forewing length 8.0–9.6 mm, hindwing length 6.2–7.3 mm; antennal scape sparsely, shallowly punctured, IPS shagreened; first flagellar segment subequal to second; IOD = OOD = MOOM, MLOD < MOD; head densely, evenly punctate with some deformation, IPS shiny, somewhat roughened; labrum sparsely punctate, shiny impunctate apico-medially, protruding wedge-shaped beak; acetabular carina small, distinctly lamellate; mandibles virtually impunctate; prelobar carina abbreviated, pronotal ridge rounded anteriorly, broadly depressed medially; roughened IPS postero-medially; metanotum shallowly and broadly punctured; sides of propodeum shallowly and broadly punctured, IPS shagreened, dull, pubescence 0.3 mm long; hypoepimeral area not strongly protruberant; ventral half of metapleuron glassy, impunctate; procoxal spine rudiment absent; hind tibial apex with 8 bristles; forewing with 3 submarginal cells: COLOR: scape, supraclypeal area, spot anterior to mid-ocellus, ring around compound eyes, pronotum (except anterior to pronotal ridge and between ridge and collar), lateral margins of scutum and two median longitudinal stripes, scutellum, metanotum, tegulae, axillary sclerites, propodeum (except median stripe), mesopleuron and metapleuron except sutures, legs (except dorsal stripe on fore- and mid femora, ventral hind femora, interior of hind tibiae), abdomen, bright yellow; remainder of body dark brown.

Discussion.—This species is similar to *dreisbachorum* in form; both species have a long, fairly thin body, unusually long pubescence and similar punctation patterns. *Nomada vitticollis* differs from *dreisbachorum* by its almost completely yellow head and thoracic pleura, 3 submarginal cells in forewings, distinctly inflated hind basitarsus, and the IPS of the face (shiny and smooth in *vitticollis,* dull and shagreened in *dreisbachorum*). The holotype is quite a bit smaller than the other specimens examined, and the majority of future specimens will probably be closer in size to the large specimens.

Specimens examined.—MEXICO: SAN LUIS POTOSI: 83.7 km (52 mi) S. of Tamazunchale, 1710 m (5600′), 1 ♀, 7–X–1957 (H. A. Scullen) ORSU; TAMAULIPAS: Rancho del Cielo 11.3 km (7 mi) W. Gomez Farias, 1 ♀, 4–6/XI/1972 (J. A. Gillaspy);

Asteris Group

Nomada (Pachynomada) asteris Swenk

Nomada (Homonamada) asteris Swenk, 1913. Nebr. Univ. Studies 12:89.

Holotype Female.—"Manhattan, Kansas, September 19, 1908, on *Aster paniculatus* (O. A. Stevens, No. 1203)." Type Depository, University of Nebraska, Lincoln.

Diagnosis.—3 submarginal cells, female rufo-ferruginous, abdomen lacking complete transverse bands; male antennal scape globose, abdomen with complete transverse median bands, sides of propodeum black with long pubescence, antennal scape uniform ferruginous color, mesopleuron ferruginous.

Male.—Length 8.9–10.4 mm, forewing length 5.9–7.0 mm, hindwing length 4.9–5.9 mm; antennal scape globose, densely punctate, glassy IPS, tuft of hair on posterior apical shelf; IOD = OOD, MLOD < MOD; labrum lacking median

impunctate strip, produced into small beak apically; prelobar carina somewhat thickened; pronotal ridge sharply angulate anteriorly; interpunctural spaces of scutum slightly rounded; tegulae moderately punctate, glassy; scutellum flattened, glassy, only slightly depressed medially, metanotum rather strongly rounded medially, roughened posteromedial interpunctural surface reduced; surface of metanotum glassy; propodeal sides deeply punctured, dull, rough IPS, pubescence long (0.2 mm); mesopleural surface quite shiny, only slightly roughened in places; metapleuron glassy, punctate; procoxal spine rudiment virtually absent; hind tibial apex with 7 or 8 thin, pale ferruginous bristles; metasternum grooved medially; pygidium rather broad, shallowly emarginate medially; forewing with 3 submarginal cells, apex somewhat darkened: COLOR: supraclypeal area, sides of face up to and around antennal sockets (extending along sides of compound eyes), labrum, clypeus, basal two-thirds of mandibles, malar space, ring extending behind compound eyes almost to vertex, pronotal lobes, ridge, tegulae, scutellum, metanotum, small anterior mesopleural spot, apices of coxae, transverse median bands on terga (emarginate antero-medially), creamy-white; antennae, legs, most of mesopleuron, abdominal sterna, ferruginous; remainder of body dark fuscous to black.

Female.—Length 7.7 mm; antennal scape heavily punctate, IPS shagreened to shiny, IOD = OOD, MLOD < MOD, head densely evenly punctate, IPS highly polished, supra-clypeal area prominent, labrum with strong triangular median sub-apical beak extending into a sub-apical ridge laterally; mandibles robust with a strong dorsal ridge; acetabular carina prominent, semicircular, slightly lamellate; pre-malar carina strong dorsally, undifferentiated ventrally; pre-occipital ridge rounded; pronotal ridge very thin medially; apex rounded; pre-lobar carina thick, sloping gradually; scutum deeply punctured (honey-combed), punctural rims sharply angulate, tegulae polished, densely punctured; scutellum highly polished, glassy, sparsely punctate, very slightly depressed medially; postero-medial IPS smooth, not shagreened or micro-rugose; metanotum very shiny, sparsely punctate; supra-spiracular ridge undeveloped; hypo-spiracular band impunctate with light vertical rugae, hairs 0.15 mm long, sparse; hypoepimeral prominence flattened; mesopleuron deeply, nearly contiguously punctured with smooth-shiny IPS; metapleuron shiny, punctate; pro-coxal spine rudiments lacking; hind tibial apex with 5 fine, evenly spaced, pale ferruginous bristles; hind basitarsus not as inflated as other *Pachynomada,* widest point closer to base; hindwings with 3 sub-marginal cells, smokey with clear sub-apical crescents; abdominal sterna punctate, heavily shagreened; terga densely, evenly punctate, heavily shagreened IPS; apical impunctate bands narrow: COLOR: body is uniform, light rufo-ferruginous; apex of mandibles, posterior-medial triangle on scutum, areas of abdomen darkened to fuscous, pronotal lobes, apices of pronotal ridge, scutellum, metanotum, medial lateral patches on terga 2, 3, and 4 creamy white.

Discussion.—Nomada asteris and *victrix* are sexually dimorphic, which is unusual in this subgenus. This rare species has only been collected in Kansas.

Specimens examined.—U.S.A.: KANSAS: Reece, 12 ♂♂, 7–IX–1949 *Amphiachyris dracunculoides* (Michener-Beamer);

Nomada (Pachynomada) besseyi Swenk

Nomada (Holonomada) besseyi Swenk. 1913. Nebr. Univ. Studies 12:85.

Holotype Male.—"Manhattan, Kansas, August 24, 1908, on *Helianthus tuberosus* (O. A. Stevens, No. 933)." Type Depository, University of Nebraska, Lincoln.

Diagnosis.—3 sub-marginal cells, antennal scape globose in males, propodeum black and appearing naked (pubescence is sparse and no longer than a puncture diameter).

Male.—Length 9.0–11.3 mm, forewing length 6.7–8.1 mm, hindwing length 5.0–5.9 mm; antennal scape globose, sparsely punctate, with smooth shiny IPS; labrum with small median wedge, apical margin upturned; acetabular carina strongly lamellate; prelobar carina thickened, sloping gradually to pronotal lobe; pronotal ridge rounded apically, very shallowly depressed, impunctate medially; scutum with contiguous, frequently reticulate punctures, punctural rims angulate; scutellum deeply depressed medially; metanotum protruberant; propodeum appearing naked (pubescence very sparse and short (0.05 mm)); mesopleural IPS glassy, shagreened dorsal to hypoepimeral prominence; ventral half of metapleuron glassy, impunctate; pro-coxal spine rudiment reduced to slight bump; hind tibial apex with six straight, pale bristles; forewing with 3 submarginal cells, brown with pale subapical area: Color: fuscous to black; with antennal base, interantennal area, sides of face to vertex, clypeus (except sutures and median band), labrum, small basal mandibular spot, partial ring behind eye, pronotal ridge and lobes, outer four-fifths of tegulae, lobes of scutellum, metanotum, longitudinal mesopleural band, apices of coxae, postero-apical stripe on femora, exterior of tibiae, posterior stripe on hind basitarsus, thin transverse median band on abdominal terga, sterna 2 and 3, broken band on sterna 4 and 5, yellow; antennal scape (in part), first flagellar segment, ferruginous.

Females.—Length 8.9–11.3 mm, forewing length 7.4–8.1 mm, hindwing length 5.5–6.2 mm; virtually identical to male except for terminalia and antennal scape not inflated.

Note.—There is a variant form with thicker tergal banding, middle of clypeus and supraclypeal area yellow. It has been collected from the same date and location as the typical form, so it does not constitute a subspecies.

Discussion.—Nomada besseyi is similar to the Vincta group, but the extremely short and sparse pilosity of the propodeum differs from that group. It is similar in this aspect to *asteris* and *victrix,* which have short pubescence. Their propodeal pubescence however, is fairly dense and about twice as long as that of *besseyi.*

Specimens examined.—U.S.A.: MARYLAND: near Plummers Id., 1 ♂, 29–VIII–1915 (R. C. Shannon); MICHIGAN: Kalamazoo Co., Gull Lake Bio. Sta., 1 ♀, 12–VIII–1969 (Roland L. Fischer), 1 ♂, 27–VII–1963 (G. C. Eickwort), 1 ♂, 1 ♀, 6–VIII–1959 (Roland L. Fischer), 1 ♀, 5–VIII–1969 (Roland L. Fischer); MINNESOTA: Carver Co., Zumbra Heights, 1 ♂, 31–VIII–1921 (Irwin C. Alfonsus); NORTH CAROLINA: Bryson City, *Helianthus atrorubens,* (J. C. Crawford), 1 ♂, 1 ♀, 20–VIII–1923, 1 ♀, 26–VIII–1923, 1 ♂, 31–VIII–1923 (J. C. Crawford) LACM, 5 ♂♂, 4–IX–1923 *Rudbeckia laciniata*; Marion, 4 ♂♂, 1 ♀, 2–IX–1929 NCSt, 1 ♂, 27–VIII–1930 NCSt, 1 ♂ 28–VIII–1930, 1 ♀ 28–VIII–1931, 2 ♂♂, 29–VIII–1928 *Heliopsis* (T. B. Mitchell), 1 ♀, 29–VIII–1929 Boul, q ♂, 29–VIII–1930 *Rudbeckia lanceolata* NCSt, 1 ♂, 29–VIII–1930 NCSt, 2 ♂♂, 30–VIII–1931, 1 ♂, 31–VIII–1929 NCSt; Raleigh, 1 ♀, 10–IV–1961; Valley of Black Mts., 1 ♀, 4–IX–1906 (W. Beutenmuller); Haywood Co., Lake Junaluska, 1 ♂, 5–VIII–1975 (H. V. Weems, Jr.); NEW JERSEY: Haddon Hts., 1 ♂, 10–IX–1939; NEW YORK: Armonk, 1 ♀, 25–VIII–1936 (L. L. Pechuman); West Point, 1 ♂, 2–IX–1923 (W. Robinson); VIRGINIA: Hunter, 1 ♀, 12–18/IX (R. A. Cushman); WISCONSIN: Milwaukee, 1 ♀, (W. H. Ashmead);

Victrix Group

Nomada (Pachynomada) victrix Cockerell

Nomada victrix Cockerell, 1911. Proc. U.S. Nat. Mus. 39:647.

Holotype Female.—"Victoria Tex, Nov. 6–'4, on Aster; Type no. 13436." Type Depository, United States National Museum.

Diagnosis.—2 submarginal cells, hind coxae with a posterior dorsal carina extending more than half the length of coxa, females rufo-ferruginous, abdominal terga with yellow maculations, males darker, scape somewhat swollen, sides of propodeum with dense, short pubescence.

Male.—Length 7.3–9.9 mm; forewing length 5.3–6.3 mm, hindwing 4.1–4.9 mm; differs from female in wide transverse yellow bands on all terga, sometimes narrowly interrupted medially; clypeus and sides of face, pronotal ridge and lobes, scutellum, yellow; antennal scape swollen, body fusco-ferruginous to black.

Female.—Length 8.9–9.3 mm, forewing length 5.9–6.1 mm, hindwing length 4.7–4.8 mm; antennal scape sparsely, shallowly punctured, IPS, shagreened; IOD = OOD = MOOM, MLOD < MOD; clypeus polished, more sparsely punctate than remainder of head; labrum carinate around margin, produced into a sharp ridge apically, lacking median impunctate strip, but apico-medial area impunctate; acetabular carina reduced to small basal lamella only; prelobar carina reduced; pronotal ridge rounded anteriorly; scutum with normal punctation; tegulae glassy, virtually impunctate; scutellum flattened, unusually sparsely punctate, highly polished, posteromedial portion without roughened interpunctural surface; metanotum not flattened; propodeal disk with delicate, arching apical rugae; sides of propodeum heavily punctured, clothed with short hairs (0.1 mm); metapleuron with ventral half highly polished, virtually impunctate; pro-coxal spine rudiment absent; hind tibial apex with six ferruginous, straight bristles; hind coxae with pronounced dorsal posterior carina, extending over one-half length of coxa; abdominal terga with punctures very shallow; forewing with two submarginal cells: COLOR: light ferruginous, scutum somewhat darker, terga 2, 3, and 4 with small, lateral medial cream colored patches.

Discussion.—The strong carina on the hind coxa of this species is unique within the subgenus. It can be immediately separated on this character without reference to the two submarginal cells of the forewing. This may be primarily a Mexican species whose range barely extends into the United States.

Specimens examined.—MEXICO: JALISCO: Lagos de Moreno, 1 ♂, 19–VIII–1960 (P. H. Arnaud, E. S. Ross, D. C. Rentz), CAS; VERACRUZ: Rio Metlac, Fortin de las Flores, 1 ♂, 3–IX–1975 (J. Powell) UCB; U.S.A.: TEXAS: Roosevelt, 1 ♂, 25–IX–1906 *Amphiachyris,* (F. C. Pratt); Victoria, 4 ♀♀, 6–XI–1904 *Aster*;

Acknowledgements

I extend my sincere thanks to Frank D. Parker and Terry L. Griswold of the USDA-ARS Bee Biology & Systematics Laboratory (BBSL) in Logan for advice and encouragement. I am indebted to the following persons for the loan of specimens and types in their care: roy R. Snelling, Natural History Museum of Los Angeles County (LACM); Donald Azuma, Academy of Natural Sciences of Philadelphia

(ANSP0; Brett C. Ratcliffe, University of Nebraska, Lincoln (UNEB); Wojiech J. Pulawski, California Academy of Science (CAS); Ronald J. McGinley, National Museum of Natural History-Smithsonian Institution (USNM); Marjorie Favreau, American Museum of Natural History (AMNH); Kathryn C. McGiffen, Illinois Natural History Survey (INHS); Url N. Lanham, University of Colorado, Boulder (UCM); Charles D. Michener, Snow Entomological Museum, University of Kansas (SMEK); Howard E. Evans, Colorado State University, Fort Collins (Ft. C); Saul I. Frommer, University of California, Riverside (UCR); John A. Chemsak, University of California, Berkeley (CIS); Robert O. Schuster, University of California, Davis (UCD); Louise Dumouchel, Biosystematics Research Institute, Agriculture Canada (CNC); George C. Eickwort, Cornell University (CORN); Carol S. Parron, North Carolina State University (NCSR); Sammie J. Merritt, Texas A & M University (TAMU); James E. Gillaspy, Texas A & I University (TAI); Richard S. Zack, Washington State University, Pullman (WSU); Robert C. Bechtel, Nevada Department of Agriculture, Reno (NDAg);

This is a contribution from the Utah Agricultural Experiment Station, Utah State University, Logan, Utah 84322–4810, Journal Paper No. 3481, and USDA-Agricultural Research Service, Bee Biology and Systematics Laboratory, Utah State University, Logan, Utah 84322–5310.

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PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 228–242

Descriptions of the Immatures of *Typocerus serraticornis* (Coleoptera: Cerambycidae), and New Observations on Biology, Including "Varnish" Production and Usage by the Larva

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Abstract.—The larva, pupa and egg of *Typocerus serraticornis* are described. Observations on the host plant *Oryzopsis hymenoides,* mating, oviposition, larval feeding and pupal cell construction follows. Parasitization of the larva by a Dipteran maggot *Arctophyto borealis* and the production and usage of "varnish" by the larva are also discussed.

INTRODUCTION

Typocerus serraticornis Linsley and Chemsak, 1976, was described from 27 specimens collected over a period of 35 years in the Great Basin and on the western slope of the Rocky Mountains. In the description the authors mentioned one male and two females having emerged from *Oryzopsis hymenoides* (Roem. and Schult.) Ricker. These three specimens had been sent to John Chemsak by L. Guerra S., a person working at the Desert Experimental Range, 27 miles west of Milford, Utah, [with no further contact being made (Chemsak, pers. comm.)]. In 1979 R. L. Penrose recorded the collection of *T. serraticornis* by himself and R. L. Westcott in southeastern Oregon on flowers of *Sphaeralcea grossulariaefolia* growing intermixed with *O. hymenoides* (for which the common name "Sand dropseed" was used in error; Westcott, pers. comm.). Additionally he mentions collecting the beetles at a point 22 mi NW (sic, should be "W," according to R. L. Westcott, in litt.) of Denio Junction, Humboldt Co. Nevada, with beetles abundant, having been on an "area of sand, covered almost exclusively with *O. hymenoides*. They were observed flying slowly about, and sitting and mating on this grass. Occasionally, females were noted crawling on the surface of the sand around the plant in search of oviposition sites. Larvae were found at both localities boring in the culm bases, below the soil surface, indicating at least a two-year life cycle."

Being fortunate in finding specimens of *T. serraticornis* in the field myself, I can now relate the association between plant and insect and other biological features. On June 13, 1985 L. Ford and I collected and made biological observations on the species at Larkin Dry Lake in Mono Co., California and 0.7 mi E of Larkin Dry Lake in Mineral Co., Nevada. During June 13–21 and December 27–30 of 1986 we collected at the two sites again plus 3 others: Green Springs, 7 mi E of Gabbs, Nye Co. and the SE shoreline of Smith Creek Dry Lake in Lander Co., Nevada; Tinemaha Creek, Inyo Co. California, and in Mono Co. California, 11 mi W of the state line, on Highway 167. In the first week in June, 1987, we returned for additional field work,

but because of overgrazing, the host plant at this last site was temporarily lost and we chose a new site 4.5 mi W of the state line also on Highway 167. Conditions at the Larkin Dry Lake site were normal and beetles were present. The occurrence of this species at three of the California sites are new records for the state.

Descriptions of the Early Stages

Mature larva.—Larvae were found at four sites, Larkin Dry Lake and its proximity, the sites 11 mi and 4.5 mi W of the state line, and at the Smith Creek Dry Lake site. This description is based on three living larvae varying in length from 13.8 mm (9/16 in) to 17.3 mm (11/16 in), one from each site, and 4 larval skins from Larkin Dry Lake.

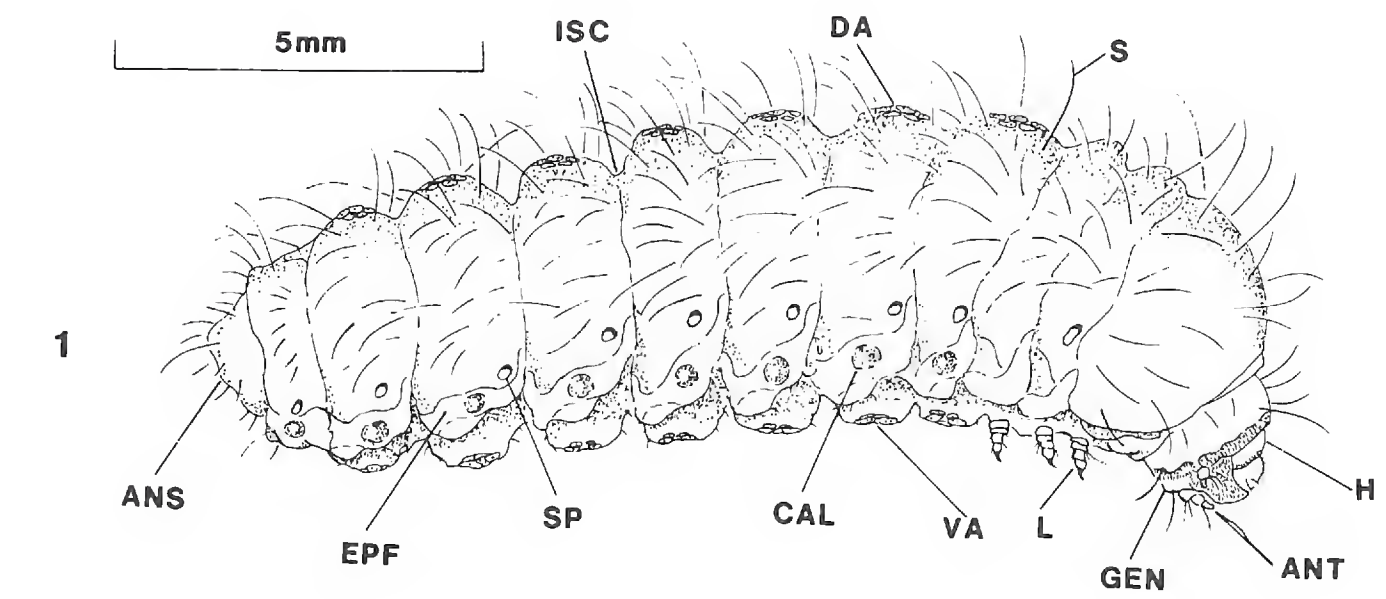
General. Usual cerambycid form, fleshy, elongate, nearly circular in cross-section, sub-cylindrical, tapering, widest just behind the head, somewhat compressed laterally. Living larva saffron-yellow (probably carotenoids from the host plant), the color concentrated in the adipose tissue. Integument transparent, shining, pale ivory in color. Prothorax unicolorous. Intersegmental constrictions deep, well defined. Lateral epipleural folds pronounced, a single large callosity on each fold. Eight pairs of spiracles on abdominal segments I–VIII and one pair on mesothorax; spiracles lightly pigmented, measurements (through vertical axis) abdominal .08 to .1 mm, thoracic .12 mm. Larval dorsum and venter somewhat wrinkled. Dorsum sparsely clothed with erect copper-colored setae, these somewhat more dense on sides, almost absent ventrally. Anal segment 3-lobed, unmodified and without plates or special modifications (Fig. 1). Asperites absent. Transverse ampullae on ventral side, from mesothorax to seventh abdominal segment, each consisting of two indistinct rows of callosities; and on the dorsal side of abdominal segments I–VII, each with three distinct rows; interstices depressed, sparse sensilla on periphery only (Fig. 2–3).

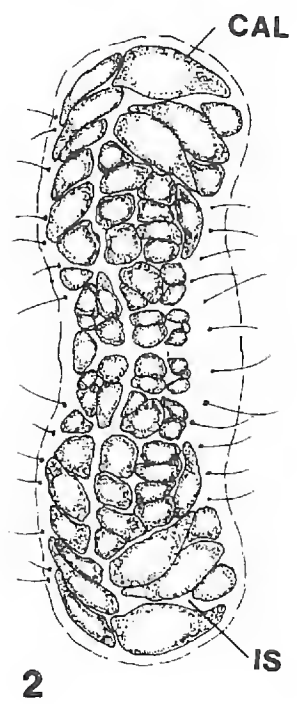
Head. Sub-orbicular, 2.9 mm wide, 2.6 mm long, top of epicranium to bottom of clypeus, sclerotized, mostly unpigmented, frons to buccal opening clothed with semi-erect setiform sensilla. Clypeus, buccal opening and mandibles medium to dark reddish brown, antennae and palpi pale to medium reddish brown. In frontal view, buccal opening oblong, antennal sockets above mid-line on genae. Labium and labrum ivory to pale reddish brown, lower lateral margins dark reddish brown. Stemmata absent. (Fig. 4 and Fig. 25).

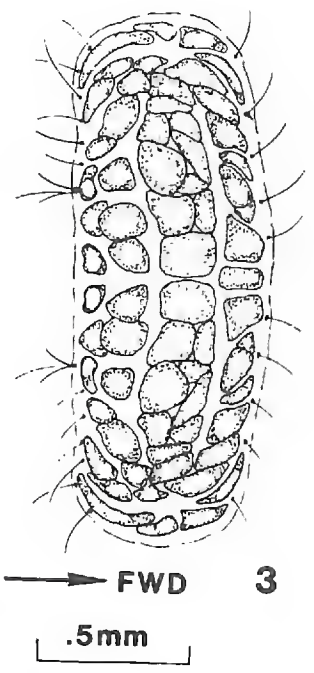
Mandible. Short, thick-prismatic in shape, concave on inner surface, with transverse cleft on side near labrum, anterior and posterior articular knobs prominent, apodeme broadly attached (Fig. 5 and Fig. 26). (Extremely hard, as shown by "flaking.")

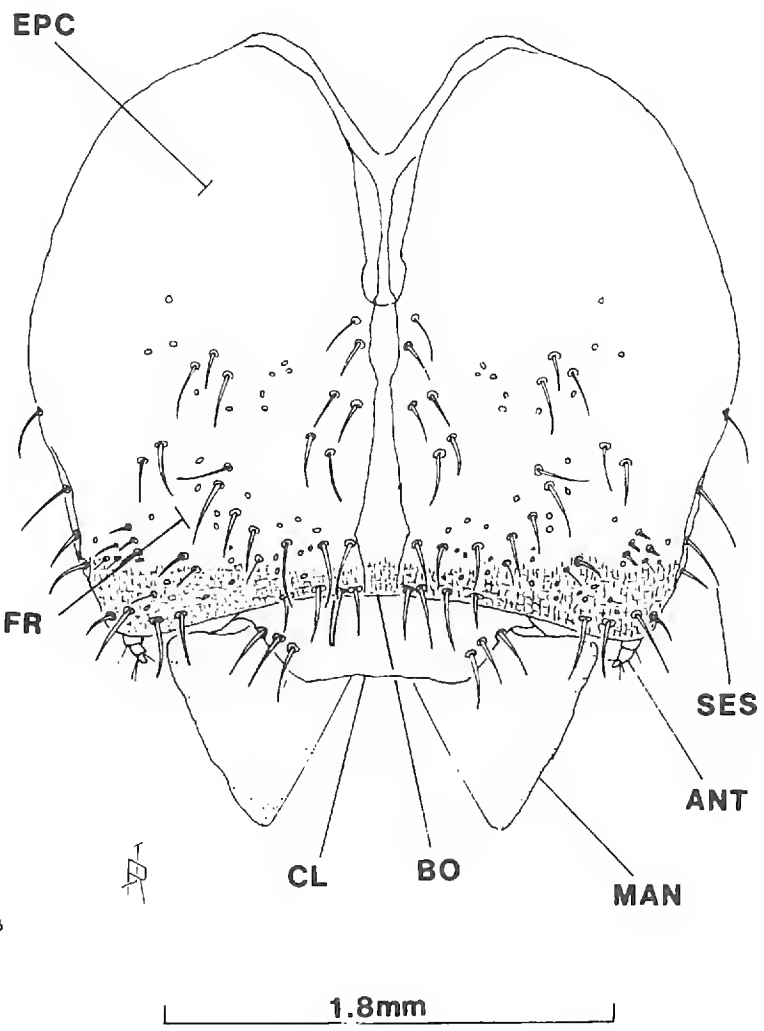
Antenna. Retractile, moving in and out of socket in living larva. Short, 3-segmented, segments cylindrical, abruptly narrower distally (stepped or "castled"), 2nd segment two-thirds diameter of first, third tapered, one-third diameter of second, steps with chaetiform sensilla, outer end with one large coniform and numerous setiform sensilla (Fig. 6 and Fig. 27).

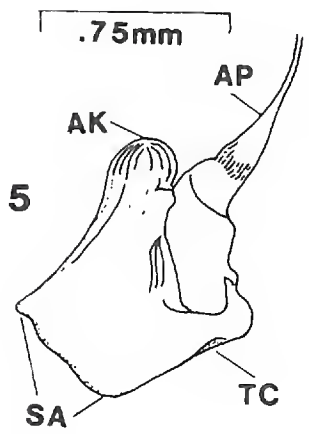
Labrum. Semi-circular, half as long as wide, outer surface with scattered setiform sensilla, these more dense along the circular margin, upper portion with generally small and oval alveoliform sensilla, two conspicuously larger and circular; inner surface densely covered with chaetiform sensilla along the circular margin and semi-erect acutiform sensilla arranged radially with apices pointing toward the middle (Fig. 7–8 and 28).

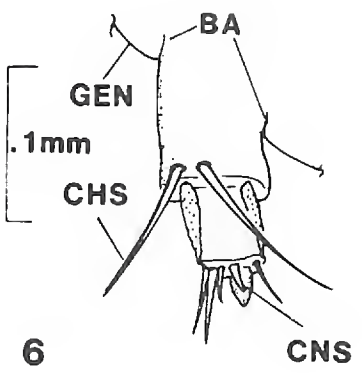




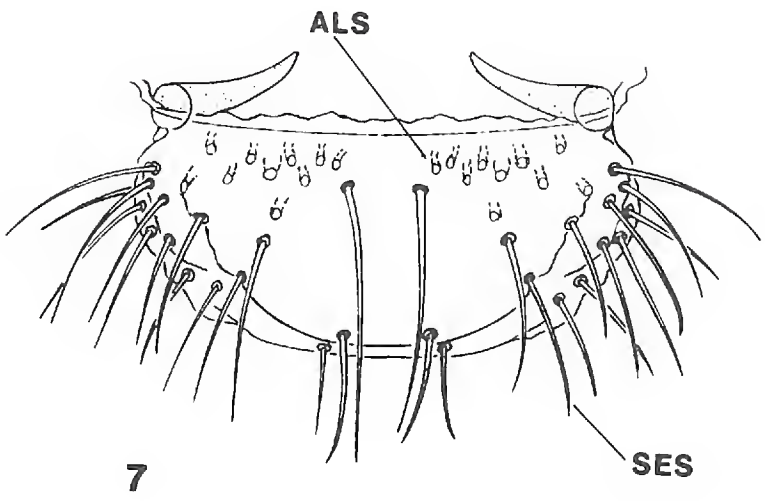


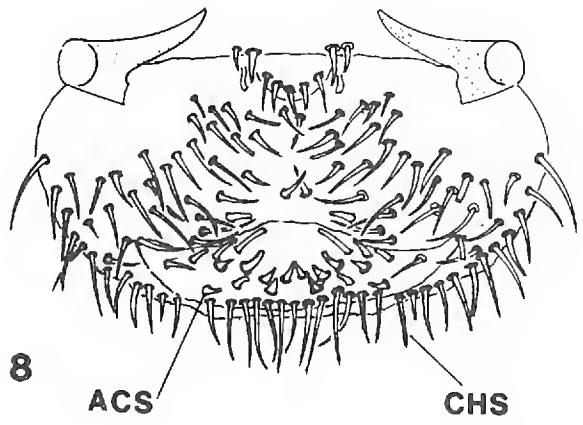


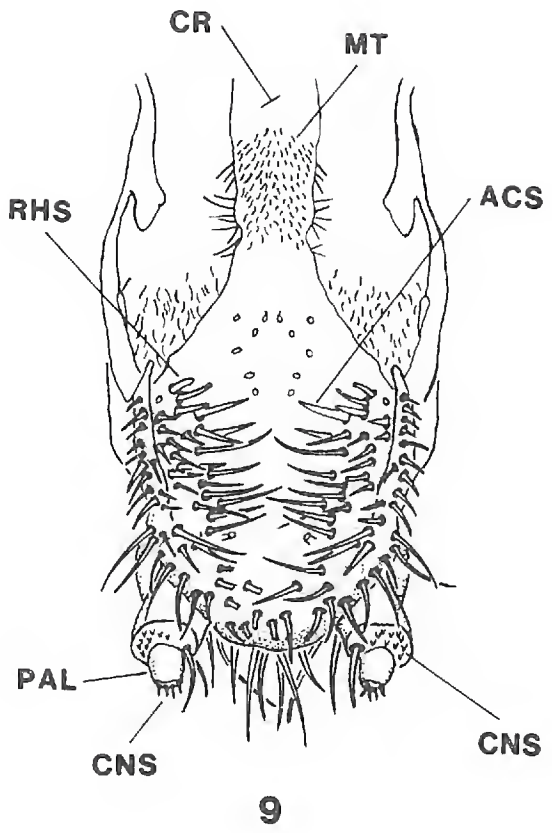


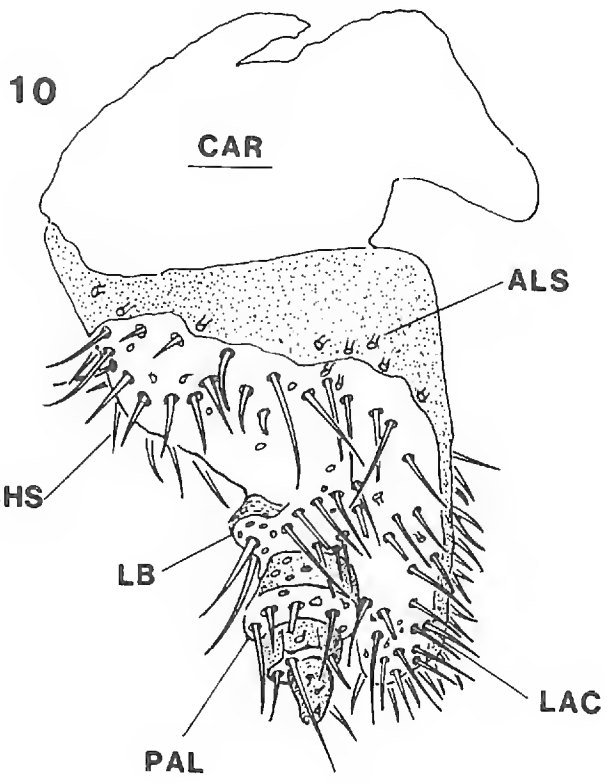


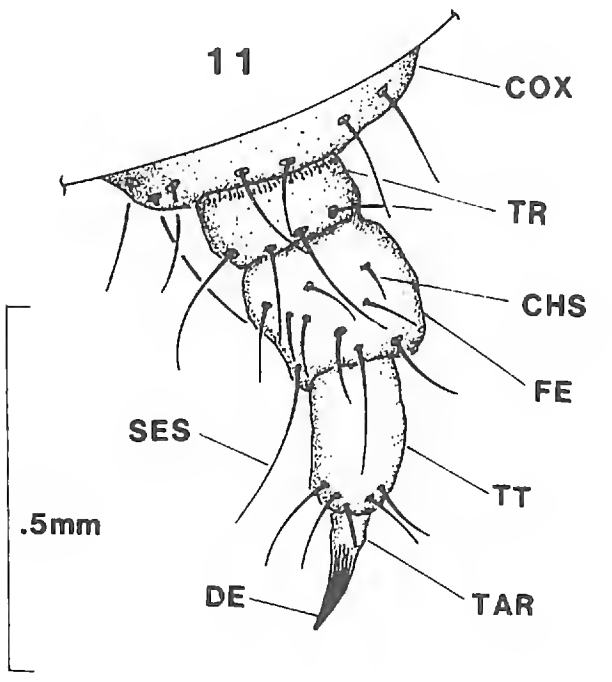
Figures 1–6. *Typocerus serraticornis,* larva. Figure 1. Larva, lateral view. ANS, anal segment; ANT, antenna; CAL, callosity; DA, dorsal ampullae; EPF, epipleural fold; GEN, gena; H, head; ISC, intersegmental constriction; L, leg; S, seta; SP, spiracle; VA, ventral ampullae. Figure 2. Ventral ampullae. CAL, callosity; IS, interstices. Figure 3. Dorsal ampullae. 4. Head, anterior view (labrum removed). ANT, antenna; BO, anterior margin of buccal opening; CL, clypeus; EPC, epicranium; FR, frons; MAN, mandible; SES, setiform sensilla. Figure 5. Mandible, left, inner view. AK, articular knob; AP, apodeme; SA, scissorial area; TC, transverse cleft. Figure 6. Antenna. BA, basal articulation; CHS, chaetiform sensilla; CNS, coniform sensilla; GEN, gena of head capsule.











Figures 7–11. *T. serraticornis* larval structures. All figures to the same scale. Figure 7. Labrum, anterior view. ALS, alveoliform sensilla; SES, setiform sensilla. Figure 8. Labrum, posterior view. ACS, acutiform sensilla; CHS, chaetiform sensilla. Figure 9. Labium, anterior view. ACS, acutiform sensilla; CNS, coniform sensilla; CR, central ridge; MT, microtrichia; PAL, palpi; RHS, rhabdiform sensilla. Figure 10. Maxilla, right, anterior view. ALS, alveoliform sensilla; CAR, cardo; CHS, chaetiform sensilla; LAC, lacinia; LB, lateral boss; PAL, palpus. Figure 11. Thoracic leg, left, anterior view. CHS, chaetiform sensilla; COX, coxa; DE, distal end; FE, femur; SES, setiform sensilla; TAR, tarsus; TR, trochanter; TT, tibiotarsus.

Labium. Linguiform, margins with chaetiform sensilla, acutiform, rhabdiform and digitiform sensilla arranged radially with apices pointing toward the middle. A patch of micro-trichia present on the central ridge (Fig. 9 and Fig. 28).

Palpus. Short, 2-segmented, segments cylindrical, abruptly narrower distally (stepped or "castled"), first segment two times diameter of second, with many coniform and several chaetiform sensilla on step, and numerous coniform sensilla on outer end of second segment (Fig. 9 and Fig. 29).

Maxilla. broadly triangular, angled slightly outward, forming a protruding lateral boss bearing the palpus; upper and inner portions pigmented, upper portion with digitiform sensilla, chaetiform sensilla present on the rest of surface including boss (Fig. 10 and Fig. 29).

Palpus. Three segmented, segments cylindrical, abruptly narrower distally (stepped or "castled"), truncated conical, second segment two-thirds diameter of first, third segment bluntly tapered, one-half diameter of second, more darkly pigmented, slightly longer than lacinia, with digitiform and chaetiform sensilla (Fig. 10).

Labrum, labium, maxilla and palpi tumid in living larva (Fig. 29).

Legs. All three pairs equal, .87 mm long, (coxa .1, trochanter .15, femur .3, tibiotarsus .17, tarsus .15); coxa dome-shaped, trochanter, femur, tibiotarsus all cylindrical, tarsus acutely tapered, distal end sclerotized, pigmented. All segments bearing chaetiform and setiform sensilla (Fig. 11).

Pupa. Pupal development begins in early May in the field. In grass samples collected at the sites in June and December 1986, placed in sand in screened cages for further observation at my home (Fig. 14), pupae began developing during late March and early April 1987. This description is of a live male pupa.

General. Typical exarate cerambycid pupa; pupal sac loosely bound, abdomen gyrates when pupa disturbed. Caudal margins of abdominal tergites bearing spines, in sub-medial groups on segments one through seven, a complete series across segments eight and nine; mesothorax with sub-medial patches. Each femur with a row of transverse spines on apex. Each tarsus with a single lateral spine on terminal segment. Antenniferous callosities and frons spined, spines sparse on prothorax. Head with a small carina on posterior margin (lacking in adult). Although adult beetles "squeak," the mesothoracic stridulatory ridge appears lacking (Fig. 12). Saffron-yellow color of larva carries over into pupa. Pupa initially un-pigmented except for eyes, pigmentation commencing in tarsi on tenth day; on legs, head and thorax on twelfth day, on abdomen on fourteenth day. Pupa moults at the end of the third week.

Egg. Based on eggs removed from a virgin gravid female preserved in 75% ethanol. Size.—3.12 mm × 1.03 mm. Shape.—Elongate fusiform (Fig. 30a). Ridges of chorion forming polygons (Fig. 30b). Color.—Whitish.

Given the female's swollen size (Fig. 16), I thought the number of eggs would be considerable. However, only 33 eggs were found. Her swollen body was the result of large egg size.

By comparison to other cerambycids, the egg is unusually large for this small lepturine. Many species of this and larger size have greater numbers of noticeably smaller eggs (Chemsak and Linsley, 1971:154; Leech, 1963:187; Hess, 1920:372, 377). The eggs are tightly packed linearly into the abdominal cavity, extending into the mesothorax.

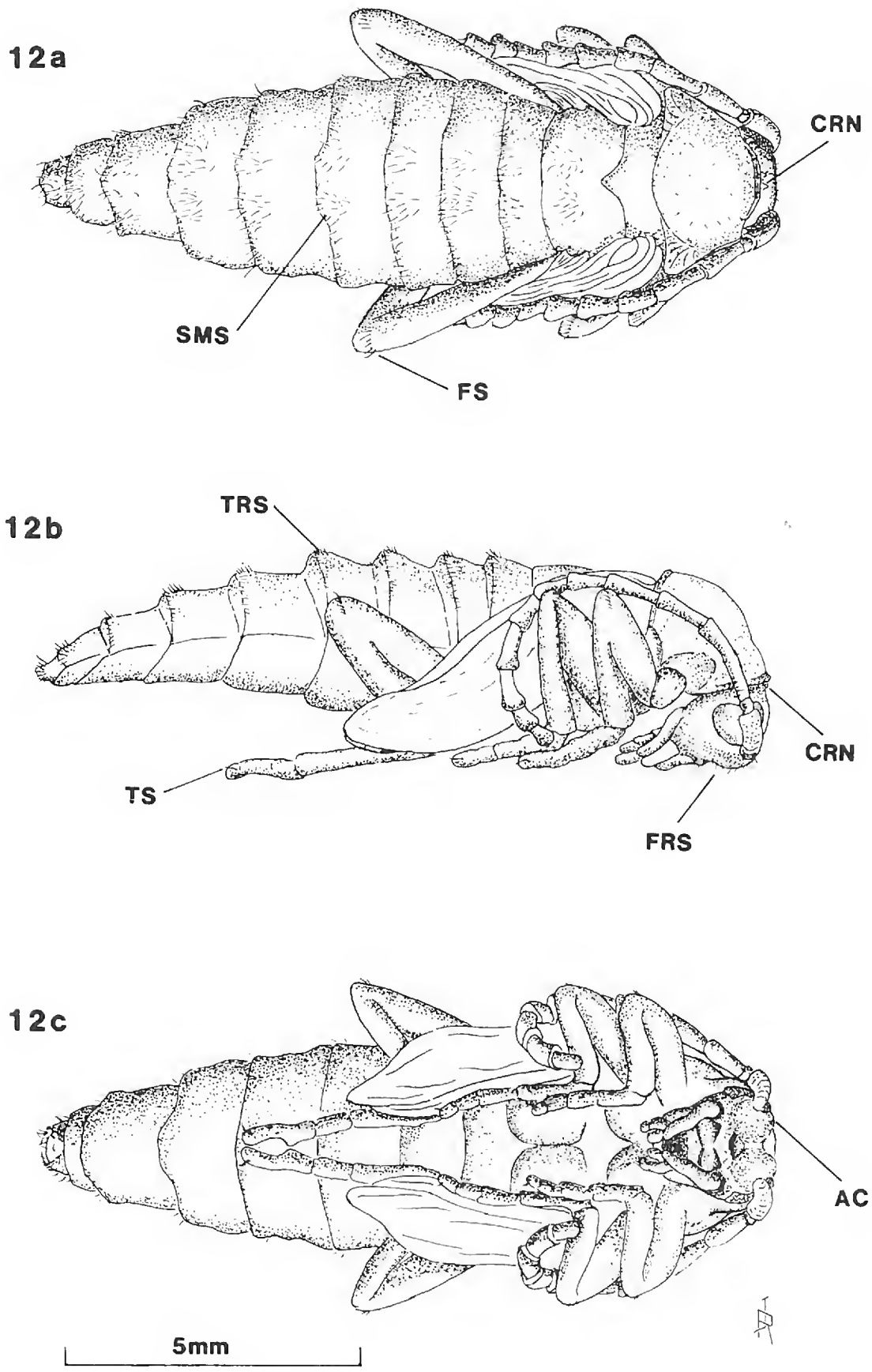


Figure 12. *Typocerus serraticornis* pupa. Figure 12a. Dorsal aspect. CRN, carina; FS, femoral spines; SMS, sub-medial tergal spines. Figure 12b. Lateral aspect. FRS, frontal spines; TS, tarsal spine; TRS, tergal spines. Figure 12c. Ventral aspect. AC, antenniferous callosities.

Biological Observations

The study sites. Six study sites were examined to ascertain what factors were conducive to beetle habitation (Fig. 13). (Soil terminology follows Stewert, et al. 1977; Pleistocene Lake geology follows Snyder, et al. 1964.)

Larkin Dry Lake is an extension of the northeastern corner of Pleistocene Mono Lake. At 2060 m (6,760 ft), it is confined on three sides by steep slopes of volcanic and upper volcanic rocks, mostly basalt, rhyolite and sparse andesite. Coarse sandy alluvial fans blend into playa deposits of soft fine sand. *Artemisia tridentata* Nutt. is the predominant plant with large patches of *Oryzopsis hymenoides* present. Smaller amounts of another grass, *Distichlis spicata* (L.) Greene, are interspersed with *Chrysothamnus nauseosus* (Pall) Britton, *C. viscidiflorus* (Hook) Nutt., *Haplopappus cooperi* (Gray) Hall, *Elymus* sp., and sparse *A. spinescens.* Sparser still, is *Eriogonum umbellatum* Torr. ssp. Many larvae and adults were found here.

Green Spring is located in the Paradise Range of the Toiyabe National Forest at 1829 m (6,000 ft). It is a narrow rocky canyon with steep slopes on either side composed of sedimentary, volcanic and intrusive rocks, with claystone, shale, siltstone and sandstone. The slopes are covered with *Pinus monophylla* Torr. and Frem., and *Juniperus osteosperma* (Torr.) Little. The stoney bottom contains *O. hymenoides, Purshia tridentata* (Pursh.) D.C., *Ephedra viridis* Cov., *Ribes velutinum* Greene, *C. nauseosus, C. viscidiflorus, Artemisia arbuscula* Nutt., *Gutierrezia sarothrae* (Pursh.) Britt. and Rusby, and *Asclepias* sp. Livestock had been feeding on the Indian Ricegrass and the rocky soil was not built up around the culms. There was no evidence of *T. serraticornis* here.

Smith Creek Dry Lake at 1829 m (6,000 ft) is in the middle of a large valley which was itself a much larger Pleistocene lake. The shore line is composed of playa deposits of soft sand with numerous dunes back of the shore, notably on the southeast side. Further back the soil is made up of coarse gravel, small rocks and occasional areas of desert pavement. Patches of *O. hymenoides* are found mixed with *Artemisia tridentata, A. arbuscula, C. viscidiflorus,* infrequent *Purshia tridentata,* and *Selaginella* sp. hugging the sand beneath the sage. Many larvae were found here. Much grazing on Ricegrass was evident.

The Mono Co. sites on Highway 167 are at 1966 m (6,450 ft). The sites are located between the present-day shoreline of Mono Lake and the ancient shoreline on a soft playa deposit. The plant associations are like those of Larkin Dry Lake. Numerous larvae of various instars were found. In early June 1987 at the 4.5 mi site we found teneral adults in pupal cells (Fig. 24) and active males and swollen gravid females were found on the foliage (Fig. 15 and 16). Live gravid females vary in length from 15 to 19 mm (somewhat greater than the dessicated specimens used in the original description).

The Tinemaha Creek site is situated on the alluvial slopes of the east side of the Sierra Nevada at 1219 m (4,000 ft). Because of past volcanism in the Owens Valley much lava and red and black cinder is abundant and "Apache Tears" (obsidian) are frequently found; the sand is coarse. Grazing was evident, possibly by elk which were occasionally seen. No evidence of *T. serraticornis* was found. Higher average temperatures occur in this area compared to the other sites and may well prove to be the modifying factor that precludes the beetle's occurrence in this area (Howden 1963). My findings indicate that the beetle is cold adapted. This may also be true in other areas where Ricegrass is found but the beetle has not been found, as yet.

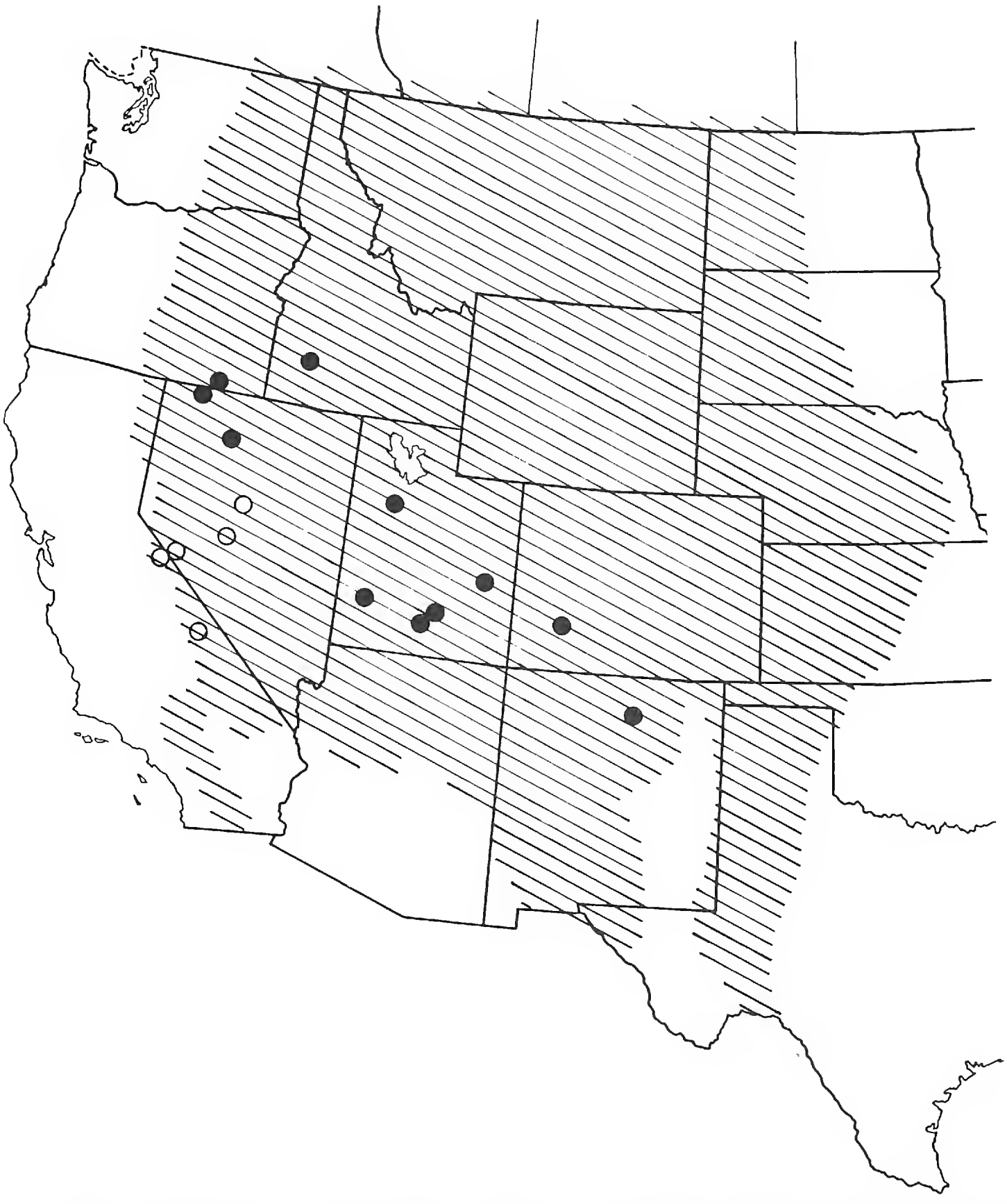


Figure 13. Distribution of *Oryzopsis hymenoides* in the United States (shaded). Recorded collecting sites of *Typocerus serraticornis* (black circles) and the study sites (open circles). Distribution of grass based on standard floras of states shown.

Host Plant. Oryzopsis hymenoides, commonly called Indian Ricegrass, is found on deserts and prairies, in foothills and mountains, from an elevation of 425 to 2745 m (1,400 to 9,000 feet). Its distribution in United States is shown in Fig. 13. It is a densely tufted perennial bunchgrass with leaves or blades mostly at the base. These are involutely wrapped around the stems which are somewhat spreading, forming a thick culm (30 to 70 cm tall) (Crampton, 1974:119). Great numbers of these culms grow tightly together forming a grass clump (Fig. 14). Typical of bunchgrasses, the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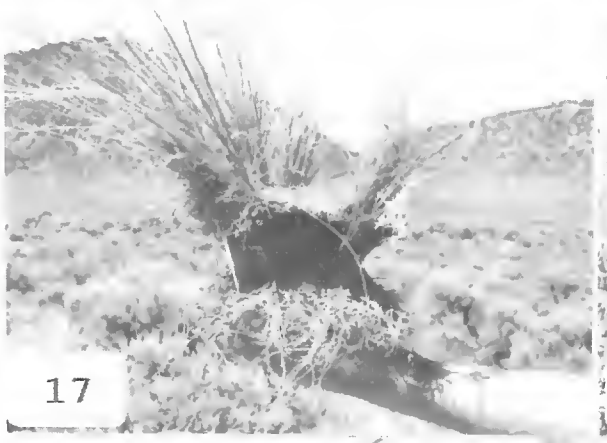
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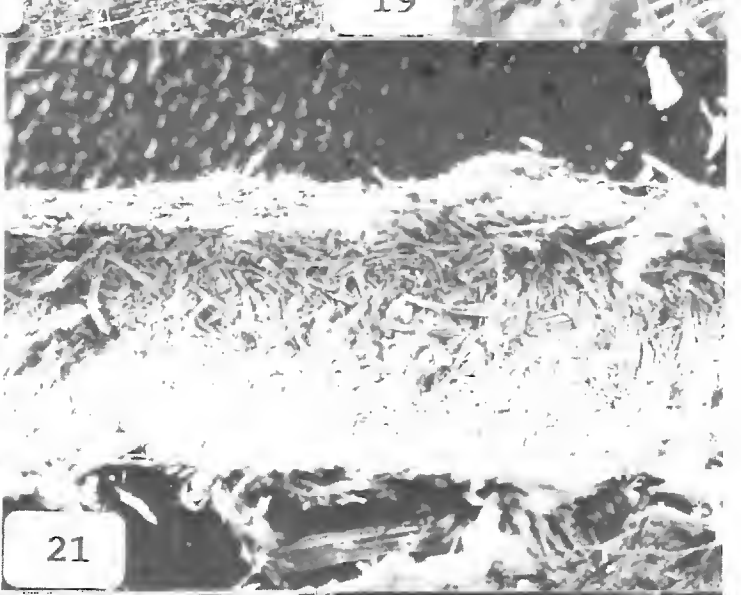
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center of the clump dies out leaving an outside ring of green and active growth spreading from the previous season's crown. These rings expand over the years, eventually overlapping their neighbors. Abundant seed production assures survival in a given area and its spread to other regions.

It is a native grass, well adapted to arid or semi-arid regions, sometimes abundant on light or sandy soils, especially the shore lines and dunes of dry Pleistocene lakes. In an area of soft sand the lower end of the culm will be covered with 4 to 9 cm (1.2 to 3.5 inches) of sand due to wind action (Fig. 17). Where it grows in harder or rocky soil, the lower portion of the culm is exposed (Fig. 18). The former situation encourages beetle survival because it is here that adults and larvae are readily found. They are not found in the latter.

Mating and oviposition. At collecting sites I observed males and females of *T. serraticornis* flying among the stems and seed heads of the Ricegrass in the typical bouncing manner of lepturines. Females alighting on the stems were rapidly joined by males. Upon assuming the superior position, the male curves the genital segment forward and inserts the phallus. Moving backwards he roughly extracts the female genitalia exposing the last three segments. Returning forward he causes the enjoined genitalia to be at right angles between them; then copulation is completed. Pairs copulated quickly in some instances, the males departing immediately afterwards. In others, coupling lasted for 10 to 15 minutes. A few minutes after separation the female slowly retracts the ovipositor.

Two methods of oviposition were seen: (1) following the male's departure, the female crawls up and down the stem portion of the culm, searching for an oviposition site. While facing upward at this site she chews part way through the stem, causing the part beyond the cut to break, and hang down. The female reverses her position on the stem to a downward facing attitude. She backs up to the cut, extends her ovipositor to it and curls and wipes it across the open break in several directions, depositing a single egg (apparently, eggs not seen) in the break. (2) the female crawls down the stem and culm to a point near the sand and turns about, facing up. She extends her ovipositor and pushes backwards with her forelegs forcing herself into the grass debris and sand to lay the egg (Fig. 19). The female then crawls to another stem or flies to another plant nearby, repeating the process.

Larval feeding. As the larva feeds within the culm, it travels up and down inside the tightly wrapped blades from the base of the culm to a point in the upper end of the narrowing blades. It does not eat through the outer blade and blade sheath. The length of the galleries will generally be below the level of the top of the surrounding

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Figures 14–24. Figure 14. *Oryzopsis hymenoides,* Indian Ricegrass in rearing cage. Figures 15 and 16. *T. serraticornis* male and gravid female on host plant. Figure 17. *O. hymenoides,* showing height to which wind-blown sand rises on the culms. Figure 18. *O. hymenoides* growing on rocky soil and fed on by livestock. Figure 19. Female *T. serraticornis* ovipositing on culm buried in litter. Figure 20. Opened pupal cell with empty skin of beetle larva and puparia of parasitoid fly. Note cell plug at lower left. Figure 21. Compacted and "varnished" wall of pupal cell. Figure 22. Adult parasitoid fly, *Arctophyto borealis.* (Figures 21 and 22 photography by C. L. Hogue). Figure 23. Opened pupal cell containing wasp pupa. Figure 24. *T. serraticornis* male adult in pupal cell.

sand. Returning to the lower end it bores laterally through the culm wall to an adjacent culm, feeding again. In this manner, five to a dozen culms will be fed through, with the galleries being loosely filled with chewed frass. Fecal material generated by the larva was not found.

Pupal cell and pupation. The cell is made by the larva from short fibrous leaf particles or frass produced by chewing adjacent outer blades at the base of several adjoining culms. The frass is forced upward between the culms as a densely packed elongate oval mass. The inside cavity of the cell is shaped by the force of the larval body as it pushes the structure into place (Fig. 20). The structure is fragile at this time, and if the grass culms are severely disturbed it falls apart. A close look at the wall of a finished cell reveals that fine sand grains are present also, and that the frass and sand are cemented together with a film of what is undoubtedly a larval secretion. This cementing process strengthens the wall and waterproofs it to prevent moisture penetration (Fig. 21). This may also shield against attack by fungi. The film is not present during construction, this would hinder the pushing action of the larva, but only after the cell has been occupied. The construction requires eight months to a year. Smaller instar larvae were found starting cells a year prior to pupation. After occupying the cell the larva closes it with a stout frass plug (Fig. 20).

Cells vary 3.2 to 7 cm (1 1/4 to 2 1/2 in.) in length, apparently in respect to the depth of the sand around the plant, the deeper the sand, the longer the cell. Thus the adult, upon emerging through the end of the cell, will crawl through only a minimum of sand to escape.

Enemies: Parasitoid and Livestock Grazing. At the Larkin Dry Lake site and the two sites on Highway 167, 55% of the pupal cells found showed successful emergences as shown by a hole cut in the outer end of the cell and the cell being empty. The other 45% were found closed on the outer end with an emergence hole on the bottom end. Inside the cell was the fed out skin of the larva and the empty puparia of a parasitoid fly (Fig. 20). Some puparia still contained pupae and adult flies have emerged in my rearing cages (The fly's emergence time lags the beetle's five to 10 days.) The fly was identified by B. Cooper as *Arctophyto borealis* (Coq.), a tachinid of the subfamily Dexiinae (Fig. 22). No evidence of the fly was found at the other collecting sites.

At what point in time of the beetle larval development does the adult fly deposit its egg? My findings, based upon the sizes of beetle larvae found, is that the larval stage lasts more than two years, certainly three and possibly four. This is entirely feasible because if one culm of grass dies out, the larva simply bores into an adjacent newly developing culm. Are the flies also as long lived, or are they placed in the feeding gallery or cell at the second or third year?

Indian Ricegrass is very nutritious and it is valuable livestock forage. In many areas of open range country the grass has been seriously overgrazed (Crampton, 1974) (as noted earlier at the 11 mile site on Highway 167). This greatly reduces the stand of grass and allows invasion of hardier plants. The results doubtlessly lower beetle populations (Fig. 18). Recovery is slow from the small amount of seed left behind because of unpredictable moisture and rodent or ant activity.

Associations. At the Larkin Dry Lake and Smith Creek Dry Lake sites some of the empty beetle pupal cells contained the intact "mud" pupal chambers of a predatory wasp and remnants of spider parts (Fig. 23). Adult wasps which emerged have been tentatively identified as *Pisonopsis occidentalis* Williams (Sphecidae) (known spider

predators) by R. Snelling. This wasp deposits its eggs and prey in existing cavities and apertures, in this case, the empty beetle pupal cell.

Discussion

Grass-feeding Cerambycids. Grass-feeding in cerambycids is rare. Cerambycid larva are wood borers, feeding in dead, dying, and occasionally, living trees. A few species feed on small woody annual and perennial plants and wild flowers, sometimes in the roots, sometimes in the stems, and larvae of the sub-genus *Homaesthesis* (*Prionus*) feed on roots of sod-forming grasses (Linsley, 1959:103). In instances recorded of grass-feeding, different parts of the plant are used by different species. The literature includes mention only of: "probably" feeding on the roots of Indian Ricegrass by *Prionus emarginatus* (Gwynne and Hostetler, 1978); *Typocerus octonotatus* (mis-identified as *T. sinuatus,* see Linsley and Chemsak, 1976:73) as feeding out the crown of *Andropogon scoparius* Michx., commonly known as Little Blue-stem (Wade, 1922); and *Derobrachus brevicollis* listed as a pest of bahia grass (*Paspalum notatum*), with larvae burrowing in soil and feeding on roots and stolons (Morgan, Tippens and Beckham, 1962). Having collected extensively in Japan, in the Holarctic faunal region, I know of numerous species in several genera of cerambycids that feed on the inside walls of several species of bamboo (Gramineae, as is Indian Ricegrass) (see Kusama, 1973).

Beetle and grass distribution and effects of temperature and moisture. Published collecting records of *T. serraticornis* show it occurs from 762 m (2500 ft) (Strike Lake, Idaho) to 2745 m (9000 ft) (Rico, Colorado). *O. hymenoides* has the same upper limit but occurs as low as 425 m (1400 ft) (Fig. 13). I think future collecting in areas further north of those recorded will find beetles at even lower elevations, because of generally lower temperatures. Based on Howden's postulates I do not think that beetles will occur in the southern extremes of the range of the grass at lower elevations because of the barrier of warmer temperatures. When collecting in December, with mid-day temperatures at 8°C (47°F) ambient, 3.3°C (38°F) on the ground (with patchy snow) and the ground frozen at 11 cm (4.3″) below the surface, I found larvae actively feeding and constructing pupal cells. The night-time low was −7.2°C (19°F). Examination of monthly average temperature/rainfall data for a thirty year period from Fallon, Nevada, at 1250 m (4100 ft) shows a low of −0.4°C (31.2°F) in January to a high of 22.7°C (72.9°F) in July, with a steady change of about 4°C (7.2°F) per month. Rainfall averages 12.7 cm (4.95″) per year, with some rain occurring each month. The direst months are July and August and heaviest rainfall occurs in May, 18.5 mm (.72″ (Rust, 1986). (May of 1987 had a record of 1.71 inches.)

Capture records show the heaviest flights of adults occur the last few days in May and the first week in June. Thus the beetles have emerged, mated, oviposited and larvae are boring into the host following the wettest season (agreeing with Howden, 1963) and 5 to 6 weeks before the warmest weather occurs.

These adaptations to cooler conditions may very well date back to Pleistocene times. Indeed, the beetles and grass may have been more abundant than now, with the current upper elevations of each being the result of increasing warmth and dryness. Pluvial paleoclimates for this region have been estimated as approximately 2.77°C (5°F) cooler than present with an increase in precipitation averaging 68% above the present Great Basin averages (Mifflin and Wheat, 1979).

"Varnish" usage and production. In the section on larval pupal cell construction mention was made of "cementing" of the pupal cell wall. Whether the material can be called "varnish" or "silk" or not, is a matter of conjecture. The material is generated by the larva. Arthropod silks come in many forms, including those described here, and have a number of highly complex formulae; there are several beetle families that are known to produce silk (Rudall and Kenchington, 1977:73–75) (in particular, *definition*). To my best knowledge, this is the first record of a cerambycid doing so, albeit tentative. Some *Moneilema* (Lamiinae) are known to combine secretions with the moisture of decaying cactus to cement the inner walls of their pupal cells (Linsley and Chemsak, after Raske, 1984:20).

The material used on the pupal cell wall is laid down as a thin film with infrequent stranding onto the short fibers forming the wall to act as binder, stiffener and protective sheathing. It shows itself as a somewhat glossy surface on the grass fibers and as a fillet radius at the interface of adjoining fibers. SEM photographs of the cell wall are shown in Fig. 31 and Fig. 32. In the rearing cage in one instance, two larvae in close proximity, having started separate cells merged into one. In the ensuing struggle which occurred between the two, both were liberally covered with the same substance and subsequently died. The same situation was found in the field in June of 1987.

Careful dissection of a freshly killed larva and close examination, including SEM photography, of the head and mouth parts (Figs. 25 and 26); and the anal opening and Malpighian tubules has failed to find any obvious origin for the "varnish." Observation of the living larvae has not disclosed details of the process.

Conclusion

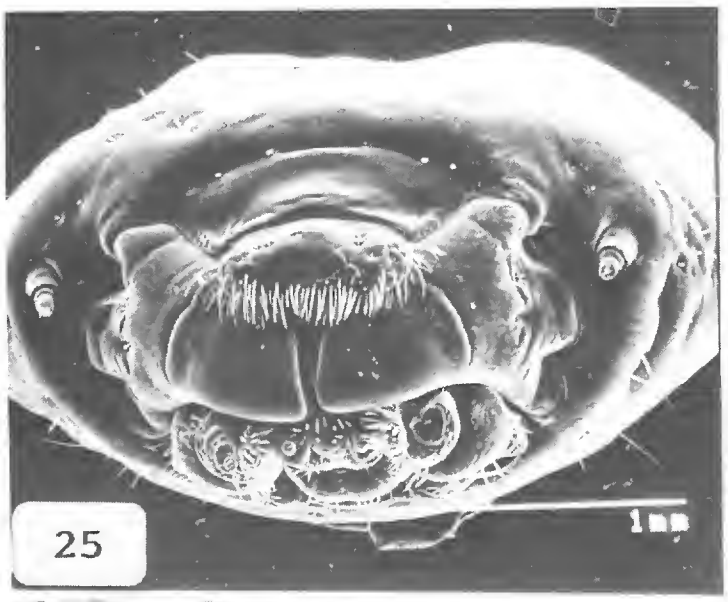
T. serraticornis occupies an ecological niche that ensures success of the species. Its eggs are large to reduce moisture evaporation, and egg-production is minimal.

Its host plant is wide-spread and abundant; adults and larvae are present in large numbers. The beetle is suited to its harsh environment.

Disposition of Materials

Specimens used for this study are deposited at the following institutions: California Academy of Sciences and the Canadian National Collection (tachinids, puparia and beetle larvae skins); Essig Museum of Entomology, Berkeley (eggs, beetle larva, tachinids and puparia); Los Angeles County Museum (slides, vials, eggs, larvae, pupae and adults of beetles, flies and wasps; pupal cells and puparia); and in the collection of the author.

Figures 25–32. SEM photographs of larval structures, egg and "silk" (photography by M. Obika). Figure 25. Upper frontal aspect of larval head. Figure 26. Mandibular attachment, left side. Figure 27. Larval antenna, left side. Figure 28. Looking into mouth. Labrum at upper left. Note discoidal flaking on left mandible, probably from biting on sand grains. Figure 29. Mouth parts, left and right maxilla and labium. Figure 30a. Egg of *T. serraticornis*. Figure 30b. Chorionic detail, showing polygonal shapes. Figure 31. "Silk" film with infrequent strands laid onto the grass fibers in pupal cell wall. Figure 32. 10× magnification of center of prior figure showing strand and film detail at interface of fibers.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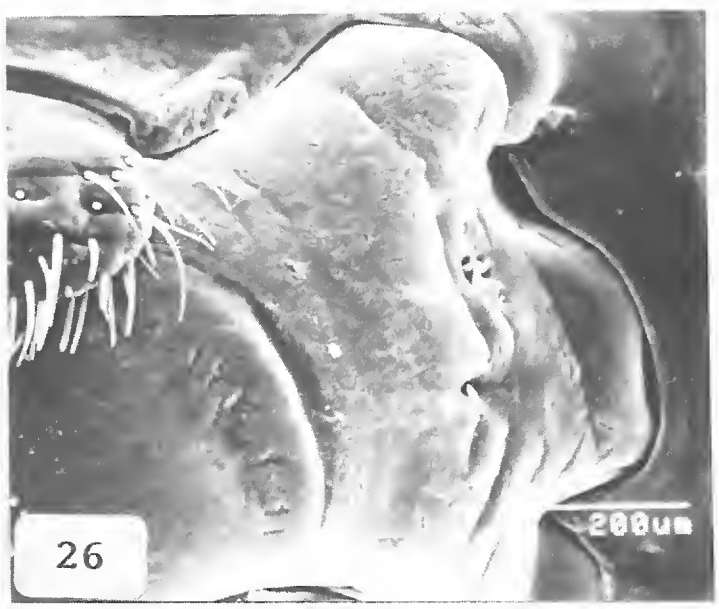
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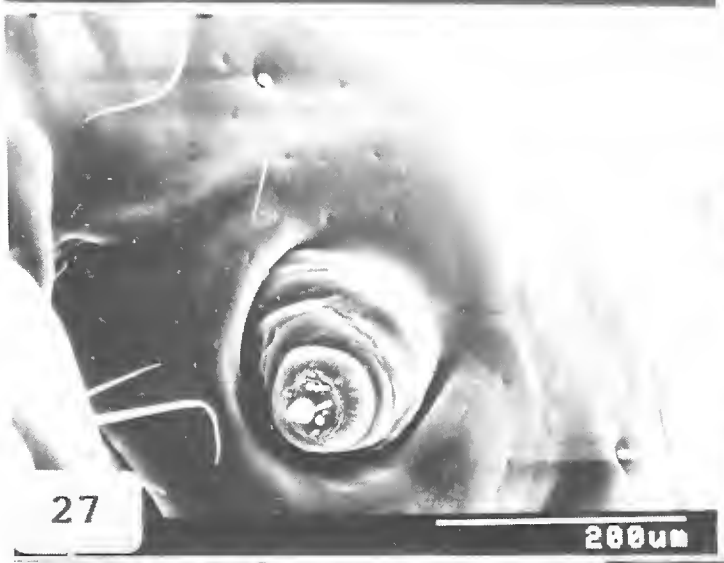
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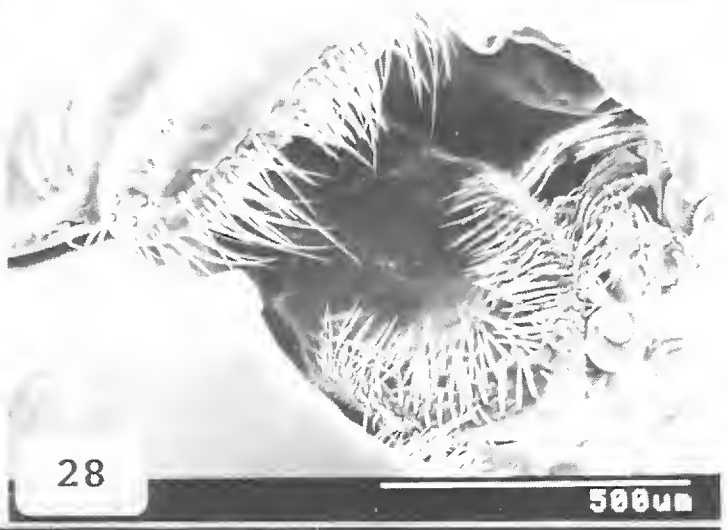
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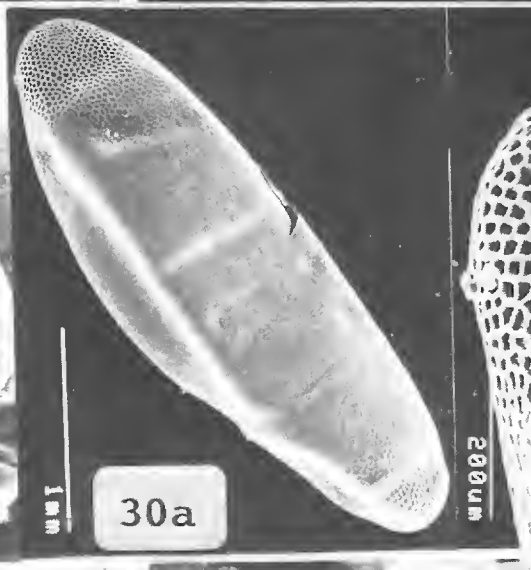
29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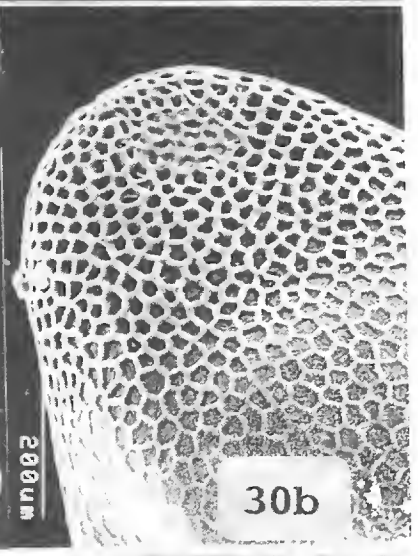
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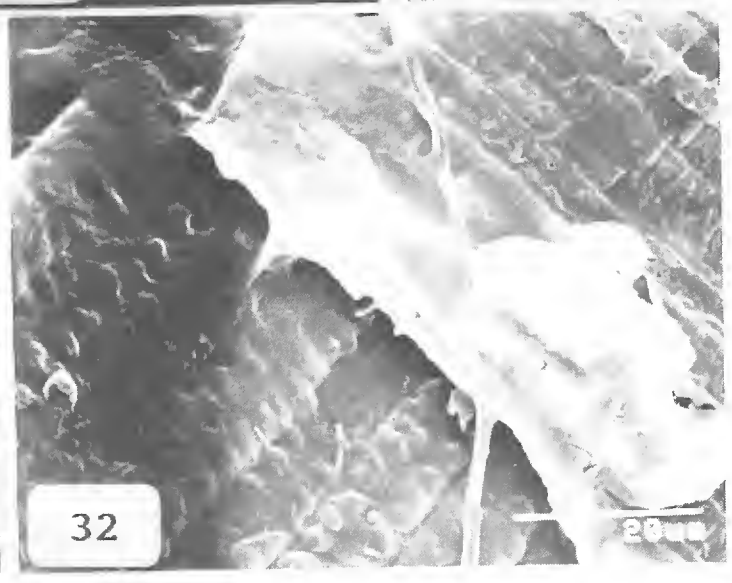
31


32

Acknowledgments

I would like to thank the following persons for their untiring help: John A. Chemsak, Essig Museum of Entomology, University of California, Berkeley, for encouraging me to publish my findings; Robert Gustafson and Gary Wallace, Los Angeles County Museum, and David Verity, University of California, Los Angeles, for the many plant identifications; Paul H. Arnaud, Jr., California Academy of Sciences and Bruce C. Cooper, Biosystematics Research Center, Agriculture Canada, Ottawa, for fly identification; Roy Snelling, Los Angeles County Museum, wasp identification; Masataka Obika, Keio University, Yokohama, Japan, for SEM photography; lastly and most importantly, Charles L. Hogue, Los Angeles County Museum for assistance with manuscript preparation and Lowell Ford, Torrance, California, for his endeavors in the field on behalf of this project.

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PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, p. 243–249

Isolation and Trail-Following Bioassay of a Decay Fungus Associated with *Reticulitermes hesperus* Banks (Isoptera: Rhinotermitidae)

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Abstract.—The brown-rot decay fungus *Oligoporus balsameus* (Pick) (Basidiomycetes: Polyporaceae) was isolated from a Douglas-fir timber inhabited by the western subterranean termite *Reticulitermes hesperus* Banks. Decay tests with white fir and red alder blocks were performed on malt agar media. Decayed white fir blocks were extracted by sequential soaking in petroleum ether, chloroform, and methanol, and these extracts assayed individually and in combination for their ability to induce trail-following in *R. hesperus* workers. The chloroform fraction, and combinations containing that fraction, elicited significant trail-following. However, the level of activity was much less than that reported for extracts of termite body parts containing trail pheromone, indicating either quantitative or qualitative differences in the active compound(s).

Introduction

Termite behavior and survival on cellulosic materials can be affected by the presence of decay fungi. For example, Hendee (1935) found that *Zootermopsis angusticollis* (Hagen) fed on decayed Monterey pine, *Pinus radiata* D. Don, and Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, consumed more wood and sustained less mortality than those fed on sound wood. Smythe et al. (1971) also reported greater feeding by *Reticulitermes flavipes* (Kollar) on decayed than on sound wood, but found that effects on termite survival varied greatly depending upon the species of wood, species of fungus, extent of decay, and whether or not the mycelium had been killed by oven drying. *Reticulitermes* spp. have also been observed feeding on basidiocarps in rotten logs (Waller et al., 1987), indicating a direct dietary role.

Effects on termite survival may be due to the nutritive value of the fungus itself, increased availability of nitrogen and soluble carbohydrates in the decayed wood, or neutralization by the fungus of toxic substances in the wood (Becker, 1971; La Fage and Nutting, 1977; Smythe et al., 1971). In tests with both sound wood and wood decayed by the brown-rot fungus *Gloeophyllum trabeum* (Pers. ex Fr.) Murr., Carter et al. (1972) and Carter and Smythe (1973) noted that differences in diet were reflected by differences in the composition of free amino acids and fatty acids in *R. flavipes*.

Whatever the nutritional significance of fungal decay, effects on termite behavior are well documented and have been reviewed by Amburgey (1979), Becker (1976), and Sands (1969). Esenther et al. (1961) first reported that an aqueous extract of

Pinus monticola Dougl. wood decayed by *G. trabeum* attracted or arrested *R. flavipes, Reticulitermes virginicus* Banks, and *Nasutitermes columbicus* (Holmgren). Several attractive compounds are present in *G. trabeum* extracts (Smythe et al., 1967b; Ritter and Coenen-Saraber, 1969; Watanabe and Casida, 1963). One of these compounds, (Z,Z,E) 3, 6, 8-dodecatrien-1-ol, is considered identical to a trail pheromone isolated from *R. virginicus* (Matsumura et al., 1968, 1969).

Although many termite species are attracted or arrested by extracts of *G. trabeum, Reticulitermes hesperus* Banks is affected to a lesser extent than other *Reticulitermes* species (Allen et al., 1964; Matsumura et al., 1972; Smythe et al., 1967a). *R. hesperus* is the most common subterranean termite along the west coast of North America, and a serious structural pest. Possible behavioral effects on *R. hesperus* by fungi co-occurring with this termite have not previously been investigated.

The chemical ecology of *R. hesperus* is not only of heuristic value. Naturally occurring attractants and repellents offer possible alternatives to the current reliance upon soil treatments using toxic chemicals for termite control. The development of toxic baits attractive to subterranean termites is one promising example (Esenther and Beal, 1979). Successful application of such techniques to the control of *R. hesperus* is dependent upon the isolation and identification of appropriate behavioral chemicals. Reported here is the isolation of the decay fungus *Oligoporus balsameus* (Peck) (= *Polyporus balsameus*) (Basidiomycetes: Polyporaceae) (Gilbertson and Ryvarden, 1985) from wood inhabited by *R. hesperus,* and the laboratory trail-following bioassay of solvent extracts of wood decayed by this fungus.

Materials and Methods

Source of Fungus and Insects.—The decay fungus was collected and cultured in August 1982, from a Douglas-fir *(P. menziesii)* 2×8 inch form board along a residential driveway in Berkeley (Alameda County), California. This board was embedded in the soil and inhabited by western subterranean termites, *R. hesperus.* These termites were used in on-going studies in our laboratory, necessitating the collection of a second colony for the behavioral assays with fungal extracts.

The second colony of *R. hesperus* was collected from Douglas-fir floor joists in a residence in Oakland (Alameda County), California, in July 1983. These were maintained in a humidity chamber (Grace, 1986) until behavioral assays were performed in May 1984. Because of their predominance in foraging activities, only workers (externally undifferentiated individuals older than the third instar, as determined by size) were used in these assays.

Fungal isolations were performed from visibly sound internal wood ca. 2 mm below the surface of *R. hesperus* galleries. Thin slivers of wood (ca. $5 \times 5 \times 2$ mm) were surface sterilized by a 30 second emersion in 0.5% sodium hypochlorite. These were placed on 2% malt agar in petri dishes. Seven days after inoculation, white mycelial growth (1–2 cm diameter) had radiated outward from some of the slivers. The leading edge of the mycelium was transferred to a clean plate (2% malt agar). Hyphal tips were retransferred four more times at 7–14 day intervals before transfer to slant tubes, which were refrigerated for 11 months before the decay tests. Under microscopic examination, clamp connections characteristic of basidiomycete fungi were clearly visible on the hyphae.

Decay Tests.—The ability of the fungus to decay wood was determined in agar-block decay tests, in which blocks of wood were placed on agar containing active fungal mycelia.

Glass bottles containing 75 ml of 2% malt agar were inoculated with 25 mm^2 slices of agar from fungal culture plates. Sterile strips (ca. 30 × 35 mm) of blotting paper (feeder strips) were placed on the surface of the agar as a nutrient source. Ten days after the fungal inoculation, sterile 26 × 26 × 10 mm blocks of white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.) (Pinaceae) sapwood (n = 21, av. wt. = 2.29 ± 0.04 g) were placed flat on the feeder strips with the end grain fully exposed to the fungal mycelium. White fir was the standard gymnosperm used in these tests. 18 blocks were exposed to the fungus and 3 blocks were placed on sterile agar as controls. Blocks were oven-dried before and after exposure to measure the weight loss due to fungal decay.

Single treatment blocks were removed at 2, 4, 6, and 12 weeks and the weight loss was measured. At 12 weeks, an additional treatment block and a control block were also removed, oven-dried and weighed to confirm the degree of decay.

Ten white fir treatment blocks were removed at 12 weeks, air-dried for 6 weeks on a wire rack, and weighed after desiccation for 24 hours. Five of these air-dried blocks were then extracted with solvents in order to determine whether behaviorally active compounds were present. The remaining white fir treatment blocks were removed at 15 and 17 weeks to extend the decay test to four months.

A second agar-block decay test was performed simultaneously with red alder (*Alnus rubra* Bong.) (Betulaceae) sapwood blocks to test the ability of the fungus to decay a representative hardwood (angiosperm). Six blocks were inoculated as previously described and removed and weighed at 4, 7, 10, and 12 weeks.

Solvent Extraction and Behavioral Assays.—Five white fir blocks, decayed to ca. 19% weight loss (av. wt. = 1.77 ± 0.04 g) by a 12 week exposure in the agar-block decay test and air-dried, were extracted by sequential soaking in petroleum ether, chloroform, and methanol for 48 hours each at room temperature (22–24°C). These solvent extracts were assayed for their ability to induce trail-following in *R. hesperus* as described by Grace et al. (1988). Assays were performed on a glass surface, uniformly illuminated by overhead fluorescent lighting (13.5–19.5 foot-candles), at room temperature (22–24°C).

In each assay, a straight 200 mm artificial trail (1–2 mm in width) was drawn on Monroe No. 41 tracing paper with a microliter syringe containing 4 μl (microliters) of solution. The solvent was allowed to evaporate for ca. 15 seconds, and a single *R. hesperus* worker was deposited from a glass vial onto one end of the trail. As a single measure of recruitment to the trail and orientation upon it, the distance traveled on the trail in a 30 second interval was recorded. Each insect and each trail were used only once to preclude trail reinforcement or behavioral conditioning.

The three solvent fractions were assayed both individually and in combination with each other to test for synergistic responses. Control trails drawn with a 1:1:1 mixture of the three solvents were also assayed. Distances traveled by 25 workers in each treatment were analyzed by the analysis of variance (ANOVA), and means compared by the Ryan-Einot-Gabriel-Welsch Multiple F Test, $\alpha = 0.05$ (SAS Institute, 1982).

Results and Discussion

The field-collected basidiomycete rapidly decayed both the gymnosperm and angiosperm (Table 1), the decayed wood had a brown cubical appearance, and the culture tested oxidase negative by no color change when drops of gum guaiac solution (0.5 g per 30 ml ethanol) were applied, all suggesting that it was a brown-rot

Table 1. Percent weight loss in ca. 2 g white fir and red alder blocks after inoculation with *Oligoporus balsameus* isolated from Douglas-fir inhabited by *Reticulitermes hesperus*.[a]

Weeks After Inoculation	Percent Weight Loss ± SEM	
	White Fir	Red Alder
2	0%	
4	8	7%
6	15	
7		20
8	11	
10		28
12	22 ± 3[b] (n = 2)	29 ± 4 (n = 3)
15	27	
17	34	

[a]Agar-block decay test. Blocks oven-dried before and after exposure to fungus. Weight of one block (n = 1) unless otherwise noted.

[b]Mean weight loss of 10 additional blocks air-dried for six weeks was 17 ± 2%.

fungus, rather than a white-rot type or a secondary saprophyte. It was subsequently identified as *O. balsameus,* a decay fungus which has not previously been associated with subterranean termites. In fact, only a few natural associations between termites and brown-rot fungi have been reported (Esenther et al., 1961; Williams, 1965). Waller et al. (1977) recently reported the isolation of thirty basidiomycetes from logs infested by *Coptotermes formosanus* Shiraki and *Reticulitermes* spp., all of which caused white-rot decays.

Hendee (1934) isolated six undetermined basidiomycetes from colonies of *R. hesperus* and two other termite species in California. However, her study focused on the role of fungi in the diet of *Zootermopsis angusticollis* (Hagen) (Hendee, 1935), and she did not attempt to distinguish between decay fungi and secondary saprophytes. Thus, to our knowledge, this represents both the first isolation of *O. balsameus* from wood adjacent to subterranean termite galleries and the first definitive isolation of a brown-rot fungus associated with *R. hesperus.*

When solvent extracts of the white fir blocks, decayed to ca. 19% weight loss, were assayed for their ability to elicit trail-following in *R. hesperus,* only trails containing the chloroform fraction were significantly different from the solvent controls (Table 2). Workers traveled the greatest distance (18.12 ± 0.83 mm) on trails drawn with the chloroform extract alone. The responses to the combination of the chloroform and petroleum ether fractions, and to the combination of all three fractions, did not differ significantly from the response to the chloroform fraction alone. These two combinations also did not differ significantly from the combination of chloroform and methanol. Neither the petroleum ether nor the methanol fraction alone, nor the combination of these two fractions, elicited any significant response. Thus, there was no evidence of activity in the petroleum ether and methanol fractions, nor of synergism among the fractions.

Table 2. Mean distance traveled in 30 seconds by *Reticulitermes hesperus* workers on artificial trails drawn with solvent fractions of *Oligoporus balsameus* decayed white fir blocks.

Solvent Fraction(s) on Trail[1]				
Solvent Control	Petroleum Ether	$CHCl_3$	CH_3OH	Mean Distance ± SEM (mm)[2,3]
	X			3.28 ± 0.28 c
		X		18.12 ± 0.83 a
			X	5.76 ± 0.42 bc
	X	X	X	14.92 ± 0.47 ab
	X	X		10.24 ± 0.53 abc
		X	X	7.12 ± 0.40 bc
	X		X	2.48 ± 0.20 c
X				1.84 ± 0.17 c

[1]Blocks were extracted by sequential soaking in Pet. ether, $CHCl_3$, and CH_3OH.

[2]Mean of 25 assays with individual *R. hesperus* workers.

[3]Means followed by different letters are significantly different (ANOV, REGW Multiple F Test, $\alpha = 0.05$).

Although statistically significant, the trail-following response elicited by the chloroform fraction was still substantially less than that reported by Grace et al. (1988) with extracts of *R. hesperus* sternal glands. On the basis of the weight of material extracted, the activity of the decayed white fir would be ca. 1/120,000 that of extracted insect sternites.

This low level of trail-following activity may have either a qualitative or quantitative basis. Extraction of decayed sawdust, rather than intact 2 g blocks, may yield more of the active material. Fungal culturing on Douglas-fir rather than the white fir test substrate employed as a standard in this study, may also enhance activity. Production of fungal compounds is known to vary with the wood substrate (Esenther and Beal, 1979) and with the specific fungal isolate (Amburgey and Smythe, 1977).

Most studies of associations between fungi and subterranean termites (Rhinotermitidae) have investigated the effects of known fungi from laboratory cultures or previously identified fungal metabolites, rather than using fungi isolated from field-collected wood to examine natural associations. However, it was field observations of *R. flavipes* foraging behavior and the subsequent isolation of eight fungi (five basidiomycetes) by Esenther et al. (1961) that led to the identification of the potent trail-following compound (Z,Z,E) 3, 6, 8-dodecatrien-1-ol. From both a basic and applied standpoint, examinations of natural fungal associations with termite species may prove more fruitful than screening known compounds or laboratory fungal cultures.

Acknowledgments

We are grateful to M. Blackwell (Department of Botany, Louisiana State University, Baton Rouge) and R. L. Gilbertson (Department of Plant Pathology, University of Arizona, Tucson) for the fungus species determination. We also thank N. D. Oldham (Forest Products Laboratory, UCB) and T. Matsumoto (Department

of Entomological Sciences, UCB) for their expert technical assistance. D. L. Wood, I. Kubo, and G. W. Frankie provided laboratory facilities, valuable advice, and comments on early drafts of the manuscript. This research was partially supported by the California Agricultural Experiment Station, the Division of Entomology and Parasitology (UCB), and National Science Foundation Grant BNS-8518195 (D. L. Wood and I. Kubo, principal investigators).

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64(3), 1988, pp. 250–254

Observations on *Megaphragma mymaripenne* Timberlake (Hymenoptera: Trichogrammatidae), an egg parasite of *Heliothrips haemorrhoidalis* Bouché (Thysanoptera: Thripidae)

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Abstract.—Preliminary biological studies were conducted on the trichogrammatid, *Megaphragma mymaripenne* Timberlake, a native egg parasite of the greenhouse thrips in California. The searching and oviposition behavior of this parasite are described. Although only uniparental reproduction was observed in the laboratory, one male was collected from the field, suggesting the occurrence of deuterotoky. The time required for development from egg to adult averaged 41.4 days. Thrips parasitization was estimated by taking monthly leaf samples from an avocado orchard in Santa Barbara County and one in Orange County, and recording numbers of thrips "egg blisters" showing emergence of thrips, of the parasite, or no emergence. Egg blisters showing evidence of parasitization ranged from 22–41% and 3–51% in the Santa Barbara and Orange County orchards, respectively. In both locations, highest parasitization occurred in the months of November and January.

The greenhouse thrips, *Heliothrips haemorrhoidalis* Bouché, is one of the major pests of avocado in California (Boyce and Mabry 1937, Ebeling 1959). Feeding by thrips on the fruit causes a brown scarring on the surface that results in reduced market value.

Few natural enemies have been reported for this pest (Boyce and Mabry 1937, Ebeling 1959, McMurtry 1961, McMurtry and Johnson 1963, Lewis 1973, Mound and Walker 1982, Ananthakrishnan 1984). The trichogrammatid, *Megaphragma mymaripenne* Timberlake, was first reported as a parasite of greenhouse thrips in California by Boyce and Mabry (1937). McMurtry and Johnson (1963) and Ebeling (1959) noted that the parasite sometimes attacks a high percentage of greenhouse thrips eggs, but it was not known whether it had a controlling effect. Taxonomic reports on *M. mymaripenne* include those of Timberlake (1923), Ghesquiére (1939), Doutt and Viggiani (1968), and Rao (1969). Doutt and Viggiani (1968) stated that *M. mymaripenne* is probably the smallest of all insect species. No information was available concerning its biology, effect as a controlling agent, or on how to culture it in the laboratory.

To better understand this parasite and its impact on thrips populations, preliminary biological studies were conducted in the laboratory, and field observations on percentage parasitization of *H. haemorrhoidalis* were made in two different localities.

Materials and Methods

Cultures were maintained and biological studies were conducted in the laboratory at 22–23°C and 10–42% RH. In order to culture *M. mymaripenne,* avocado leaves were placed in stainless steel pans, upper side up, on plastic foam pads soaked with distilled water. The leaves were bordered with strips of cellucotton® to reduce leaf dehydration and prevent the escape of thrips or parasites. Twenty field-collected adults of the greenhouse thrips were placed on each leaf. Three days later, five adult parasites that emerged from egg blisters on field-collected leaves were placed on the infested leaves.

A similar technique was used for biological studies of the parasite except that only one adult parasite was placed on each of 15 leaves. Egg blisters of the greenhouse thrips that were stung by the parasite were marked and dated. Behavior of the adults and developmental time was observed and recorded. Some adult parasites were occasionally mounted in Hoyer's media to determine their sex (presence or absence of an ovipositor).

Seasonal activity of the greenhouse thrips and the parasite were monitored in an unsprayed avocado orchard at Santa Barbara and a similar orchard on the University of California's South Coast Field Station, Irvine. The Santa Barbara orchard was surveyed from June, 1984, until May, 1985; the South Coast Field Station orchard from June, 1985 to May, 1986. Both orchards contained various varieties and hybrids previously used in breeding studies. A sample of 100 leaves was collected randomly from infested avocado trees from both orchards monthly. Ten infested leaves were taken from each sample to determine the percentage of emergence of both thrips and parasite. These leaves were placed dorsal side up on foam pads soaked in distilled water. An area of 2 cm^2 containing egg blisters of the thrips was marked on each leaf. Egg blisters were marked with different colors according to whether they showed no exit holes, thrips exit holes (evidenced by part of the egg chorion at the side of the blister), or parasite exit holes (large, round holes, usually in the middle of the blisters). Percentage of thrips and parasite emergence was calculated when leaves were brought from the field. Any subsequent emergence was determined by weekly examination of the egg blisters, previously showing no emergence of thrips or parasites.

Results and Discussion

Observations on the biology of M. mymaripenne:

After emergence from the thrips egg blister, the adult parasites took about 45–60 minutes to clean their bodies before starting to search for hosts and oviposit. No mating was observed. All 20 adults that were mounted from the culture were females.

Even though uniparental reproduction was observed in the laboratory, one male was collected from the field, indicating that *M. mymaripenne* occasionally exhibits deuterotoky. Like some other trichogrammatids, uniparental reproduction normally occurs but an occasional male is produced (Clausen 1956). Flanders (1945) stated that uniparental bisexuality probably is due to environmental factors such as type of habitat, season, temperature or nutrition. He reported that females of many hymenopterous species, influenced by environmental conditions, produce two kinds

of eggs; one yielding only uniparental females and another either uniparental or, if fertilized, biparental females.

The thrips fecal material seemed to be one of the main factors for illiciting probing or oviposition responses by the female. Dried fecal material sometimes induced a brief probing or oviposition response. However, egg blisters without fecal material were sometimes stung.

Before ovipositing, the female walked around the egg blister searching with her antennae for the softer exposed parts where stinging usually occurred. Eggs that were completely covered with fecal material were also stung, but a longer time was required. Of the 14 individuals observed, oviposition time ranged from 0.5–7.5 min., average, 3.2 min. No parasites emerged when oviposition time was less than 2.5 min. One adult female oviposited in eight egg blisters in 30 min. Another one took about two hours to oviposit in the same number of egg blisters, with intervals of drinking water and cleaning its body. During oviposition, the adult female puts its weight mainly on the hind legs and the wings, curving its abdomen forward and then inserting the ovipositor into the side or sometimes in the middle of the egg blister. The same egg blister was occasionally stung again by the same or a different parasite, suggesting the occurrence of superparasitism. After ovipositing in several egg blisters, the adult female cleaned her body and then walked or flew to another part of the leaf, where she resumed searching.

The developmental time (egg to adult) of 18 *M. mymaripenne* ranged from 36–46 days; average 41.4 days. Under similar conditions, the greenhouse thrips has a shorter developmental period, with a range of 24–36 days for 80 individuals, averaging 31 days (Hessein and McMurtry, unpubl.). Adult parasites lived approximately 48 hr. Adult thrips longevity ranged from 20–58 days, averaging 40.6 days for 24 individuals. The long time required for the parasite to complete its development might limit its ability to suppress increasing populations of thrips.

Parasitization by M. mymaripenne *at two field sites:*

In Santa Barbara (Table 1), the percentage emergence of thrips larvae from egg blisters varied from 20.2–42.2%; average 32.1%. The highest percentages occurred in November, 1984, and January, 1985. The percentage emergence of the parasite varied from 21.7–41.1%; average 33.4%. As with the greenhouse thrips, the highest percentages occurred in November, 1984, and January, 1985. There was always a substantial percentage (average 34.5%) of egg blisters from which neither thrips nor parasites emerged. Because the age of the egg blisters or the time of emergence cannot be determined on field-collected leaves, emergence in the laboratory may give a better indication of present activity. Parasite and thrips emergence was comparable except for August, December, February, and May, when the percentage of thrips emergence was distinctly higher than that of the parasite.

At the South Coast Field Station, the thrips emergence was generally higher and parasite emergence lower, compared to Santa Barbara. The percentage emergence of thrips larvae from egg blisters varied from 28.9–63.5%; average 41.7%. The percentage emergence of parasites varied from 3.2–51.0%; average 21.4%. The highest percentages occurred in November, 1984, and January, 1986. The average percentage of egg blisters from which neither thrips or parasites emerged (35.3%) was similar to that at Santa Barbara. Percentage emergence in the laboratory was

Table 1. Percentage emergence of the greenhouse thrips, *Heliothrips haemorrhoidalis* Bouché, and its egg parasite, *Megaphragma mymaripenne* Timberlake, from infested avocado leaves collected at Santa Barbara, 1984–1985.

	% Thrips Emergence			% Parasite Emergence			% No
Month	Field	Laboratory	Total	Field	Laboratory	Total	emergence
June *1984*	16.5	8.0	24.5	28.3	9.1	37.4	38.1
July	26.4	2.6	28.9	32.3	2.9	35.2	35.9
August	27.3	6.7	34.0	24.7	2.5	27.3	38.8
September	30.4	7.2	37.6	29.8	5.6	35.4	27.0
October	18.9	1.3	20.2	37.2	1.6	38.8	41.0
November	36.3	4.1	40.4	33.7	7.4	41.1	18.5
December	25.2	12.1	37.2	23.4	6.0	29.4	33.3
January *1985*	28.2	14.1	42.2	27.4	11.9	39.3	18.5
February	27.3	8.4	35.6	28.1	2.1	30.2	34.1
March	24.9	2.5	27.4	30.5	3.2	33.7	39.0
April	22.9	1.9	24.8	28.1	2.9	31.0	44.2
May	28.1	4.6	32.7	20.8	0.9	21.7	45.6
Mean	26.0	6.1	32.1	28.7	4.7	33.4	34.5

Table 2. Percentage emergence of the greenhouse thrips, *Heliothrips haemorrhoidalis* Bouché, and its egg parasite, *Megaphragma mymaripenne* Timberlake, from infested avocado leaves collected at the South Coast Field Station, Orange County, 1985–1986.

	% Thrips Emergence			% Parasite Emergence			% No
Month	Field	Laboratory	Total	Field	Laboratory	Total	emergence
June *1985*	50.8	7.4	58.2	12.7	0.5	13.2	29.1
July	25.0	7.4	32.4	13.0	3.1	16.1	51.5
August	35.6	6.1	61.7	2.9	0.3	3.2	35.1
September	54.4	4.5	58.8	2.6	0.8	3.4	37.7
October	39.6	2.8	42.4	9.0	4.4	13.4	44.2
November	18.3	10.6	28.9	43.3	7.7	51.0	20.2
December	31.9	3.5	35.4	28.1	8.7	36.8	27.8
January *1986*	30.0	2.6	32.5	37.3	9.7	46.7	20.5
February	40.6	2.9	43.5	15.3	2.6	17.9	38.5
March	30.9	3.5	34.3	20.7	2.5	23.3	42.4
April	25.0	4.2	29.2	10.6	2.2	12.8	58.1
May	48.9	14.6	63.5	11.4	6.7	18.1	18.4
Mean	35.9	5.8	41.7	17.2	4.1	21.4	35.3

usually higher for thrips than for parasites but the reverse was true in October, December and January.

Both of these orchards had heavy infestations of greenhouse thrips in the areas sampled but the populations were consistently higher at the South Coast Field Station orchard. Although parasitization by *M. mymaripenne* was higher in the Santa Barbara orchard, our observations suggest that percent parasitization did not increase proportionally with thrips population density to effect a decline in thrips populations. Therefore, it appears doubtful that this parasite, by itself, is a regulating factor of thrips populations in California.

Acknowledgments

We thank H. G. Johnson for obtaining leaf samples and Robert Velten for collecting and identifying the male *Megaphragma*.

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PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 255–257

Geographic Variation in Cooperative Colony Foundation in *Veromessor pergandei* (Hymenoptera: Formicidae)

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Abstract.—Veromessor pergandei queens are strictly haplometrotic at a site in California, while queens at sites in Arizona will found nests cooperatively. Possible explanations for this geographic difference include: higher success of brood raiding in Arizona, higher predation rates on young colonies in Arizona, and greater relatedness of colonies in Arizona.

INTRODUCTION

The desert seed-harvester ant, *Veromessor pergandei* (Mayr), founds colonies cooperatively in Arizona (Pollock and Rissing 1985); 68% of starting nests (n = 132) contained more than one queen. Starting colonies with multiple queens successfully brood raid and defeat singly founded colonies (Rissing and Pollock 1987). If proximity of starting nests affects the frequency of brood raiding, then a clumped distribution of young colonies would increase the frequency of brood raiding between young colonies. Thus spacing of starting nests could affect the success of single queen nests. Here I describe patterns of *V. pergandei* queen behavior and clumping at sites in the California and Arizona deserts. Differences between these sites may provide insight into factors regulating cooperative colony foundation by *V. pergandei* queens.

METHODS

The Arizona site was along the Tonopah Salome Highway 60 km west of Phoenix. Nests were censused in February 1987 along a 5 km roadside strip. Although the adjoining area was native Sonoran Desert habitat with *Larrea tridentata, Carnegia gigantea,* and *Prosopis velutina* as the dominant perennials, new nests were concentrated along the berm of a recently graded road. The California studies were conducted in February 1986 at the Boyd Deep Canyon Reserve, a part of the University of California Natural Reserve System. The dominant perennial plants were *Larrea tridentata, Hyptis emoryi,* and *Cercidium floridum.* The study site was a relatively homogeneous 3 ha area of alluvial fan habitat. At both sites, the starting colonies were visually located and censused by excavation. A typical *V. pergandei* starting nest is a semi-circular pile of soil or sand approximately 5 cm by 2 cm. These

diggings are most obvious a few days after a rainstorm, since the excavated soil will be darker than the background soil. Since *V. pergandei* is claustral, the oldest diggings will start to blend in with the background soil with each successive storm.

Results and Discussion

V. pergandei at Deep Canyon is strictly haplometrotic, colonies are founded by a single queen (N = 181), while 28 of the 98 Arizona nests had multiple foundresses ($\chi^2 = 43.6$, d.f. = 1, $p < 0.001$). Although the frequency of multiple queen starting nests in my Arizona site is not as high as the 90 of 132 nests with more than one queen reported by Pollock and Rissing (1985, Figure 2), it indicates that my excavation methods can detect the presence of multiple queens in starting nests. Queen tolerance for additional foundresses also varies at the two sites. Deep Canyon queens will fight when placed in the same vial, while I have never observed this behavior in queens collected from the Arizona site.

V. pergandei nests at Deep Canyon are initially clumped, then after the first workers emerge, the remaining nests are randomly spaced (Ryti and Case 1988). It is possible that some of these young colonies could have been destroyed through brood raiding (Rissing and Pollock 1987), or other factors, including: predation by long established conspecifics, predation by other ant species, or predation by spiders or rodents. Note that the spatial arrangement changing from clumped to random does not necessarily imply that there was selective attrition to clumps of starting colonies. Equal survivorship of the originally clumped starting nests would also produce randomly dispersed young colonies (Ryti and Case 1988). Newly founded nests are also clumped in Arizona ($n = 42$, $p < 0.001$, Rissing pers. comm.).

There are three potential selective mechanisms that may account for the geographical difference in the evolution of colony foundation. 1) Brood raiding affects young colony survivorship in Arizona and not in California. The frequency of brood raiding could be related to the spatial dispersion of nests when the first workers emerge. If Arizona colonies are clumped when workers emerge, then brood raiding could be a significant factor. The existing spacing data does not support this explanation, since both Deep Canyon and Arizona nests are initially clumped. However, colonies may be clumped in Arizona because of microhabitat selection. Pollock and Rissing (1985) noted that most queens found nests in wash bottoms. Arizona clumps may persist because of "better" physical conditions for brood rearing. Such microhabitat differences are not obvious between clump and non-clump areas at the Deep Canyon site. 2) Arizona single-queen nests are more vulnerable to predation. Colony predation rates may be higher in Arizona, and young colonies with more workers may survive predation episodes. 3) Cooperative colony foundation only occurs with queens that are closely related. Deep Canyon queens could be aggressive because outbreeding is relatively more common in California populations than in Arizona populations.

As a first step towards distinguishing between these possibilities, the spacing of foundress colonies in Arizona needs to be examined, especially after workers first emerge. These data, together with observations on the importance of predation, by ants and other species, and data on relatedness among colonies at these sites could explain the geographic differences in *V. pergandei* cooperative colony foundation.

Acknowledgements

I thank the staff of the Boyd Deep Canyon Research Center for logistical support during this project. G. Wheeler and J. Wheeler kindly verified that both the Deep Canyon and Arizona queens were ordinary *V. pergandei.* T. Case and R. Radtkey helped census founding nests. I thank S. Rissing and K. O'Neill for their suggestions on this manuscript.

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PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 258–260

Predation on Larvae of Douglas-fir Tussock Moth, *Orgyia pseudotsugata* (Lepidoptera: Lymantriidae), by *Metaphidippus aeneolus* (Araneae: Salticidae)

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Spiders are well-known predators of a variety of important forest insects (Allen et al. 1970; Bosworth et al. 1971; Jennings and Pase 1975; Loughton et al. 1963; Warren et al. 1967). Although spiders have occasionally been seen preying on small larvae of the Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough) (Wickman 1977), most field evidence of their predation on tussock moth has been either circumstantial (Dahlsten et al. 1977; Mason and Torgersen 1983; Mason et al. 1983) or from serological analyses (Fichter and Stephen 1984).[1] One of the most common arboreal spiders in fir forests of the Pacific Northwest is the salticid *Metaphidippus aeneolus* (Curtis) (Moldenke et al. 1987). These are small (<5 mm in length), gray and black spiders that are free-living and hunt for prey amongst the foliage. They are polyphagous predators and expert at stalking and pouncing on their prey. In extensive samplings of foliage of Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco, and the true firs, *Abies* spp., we found this species was ubiquitous in the mixed-conifer forests of the Pacific Northwest. We also observed that mature *Metaphidippus* spiders readily preyed on instars I and II of the Douglas-fir tussock moth when both species were confined together in a petri dish (Fig. 1). To examine further the predatory abilities of this group, we conducted an additional test under field conditions.

In late June 1981, shortly after natural egg-hatch of tussock moth, we selected nine white fir, *Abies concolor* (Gord. and Glend.) Lindl. ex Hildebr., in a mixed-conifer forest near Fort Klamath, Oregon. White fir is the principal host of the Douglas-fir tussock moth in that area. On each tree, we vigorously shook two 50-cm branches to remove all arthropods and then enclosed each branch separately in a nylon mesh cage slipped over the end of the branch. Five laboratory-reared tussock moth larvae (instars I–II) were stocked in each cage. We also added an adult *Metaphidippus aeneolus* in one of the two cages on each tree. All spiders were field-collected from the same stand. The cages were then closed at the base of the branch with a wire tie and left undisturbed.

[1]Fichter, B. L., W. P. Stephen, A. R. Moldenke, and D. L. Dahlsten. 1982. Arboreal arthropod predation on Douglas-fir tussock moth larvae (*Orgyia pseudotsugata*) (Lepidoptera: Lymantriidae) as detected by ELISA. USDA For. Serv. Coop. Aid Agreement. Oreg. State Univ., Corvallis. Final Rep. 42 p.

Figure 1. *Metaphidippus aeneolus* feeding on larva (instar I) of the Douglas-fir tussock moth.

After 3 weeks, we examined the contents of each cage over a drop-cloth. The results were:

Treatment	Number of larvae stocked *in nine cages*	Number of larvae surviving *after three weeks*	Percent *mortality*
Larvae + spider	45	6	86.7
Larvae only	45	40	11.1

Surviving larvae developed normally and had grown to instars III–IV when reexamined. Of five larvae lost in the control cages without spiders, three were missing and two died of unknown causes. No larvae survived in six of the nine cages with *Metaphidippus* spiders; cadavers of preyed-on larvae were recovered in most of these cages. Four of the six larvae that survived with *Metaphidippus* were in a cage in which the spider had spun a silken retreat and laid a cluster of eggs. Egg laying and subsequent guarding of eggs may have reduced the rate of her predation (Krafft 1982).

These results clearly show predation on the Douglas-fir tussock moth by *Metaphidippus aeneolus*. The degree of feeding on tussock moth may have been exaggerated, however, because the spiders were confined and other potential or favored prey excluded. Mortality of larvae in the natural population, as determined in other studies, averaged 77 percent for several years during the same period (Mason and Torgersen, 1987). Because of its abundance in the foliage, *Metaphidippus aeneolus* could have been responsible for much of this loss. We and others have suspected for some time that spider predation is a leading cause of mortality of small larvae in low-density populations of tussock moth (Mason and Torgersen 1983; Mason et al. 1983).[2] These results provide further support for that hypothesis.

We thank R. C. Beckwith, D. T. Jennings, W. Maddison, A. R. Moldenke, and T. R. Torgersen for their constructive reviews of an earlier draft.

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[2]See footnote 1.

PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 261–265

The Morphology of the Tarsal Sensilla in the Female Mite *Varroa jacobsoni*

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Abstract.—The group of hairs at the distal end and dorsal surface of the tarsus, consisted of varying size and shaped sensillae. In the center of this hair group was a pit containing a minute dome-like protrusion centrally located at the bottom. On the rim of this pit were small, fine, and differently shaped pegs measuring 3–4 um in height. The pit was surrounded by six sensillae, two of which were slender, curved, round tipped and porous, three of the remaining four were stout and one had a pointed tip. All pegs and six sensillae were stained with crystal violet, and pores were visible on the walls of the two slender and curved sensillae. Surrounding these small sensillae were 12–16 large hairs measuring 12–79 um in height. Two to three of the large hairs were slender, curved, and round tipped. They were also stained with crystal violet. Seven to eight stout, straight hairs, measuring 16–32 um in height were stained with crystal violet only at the tip. Three to four of the longest hairs measured 68–79 um in height and were not stained with crystal violet.

Introduction

The mite *Varroa jacobsoni* is a serious pest of the honeybee (Ritter, 1981), and although chemical control agents have been developed in Europe, effective control is difficult. Therefore, new approaches such as the use of pheromones and attractants for managing this pest, should be explored. Feeding and reproduction of the mite takes place in the brood cells, and drone larvae are preferred to that of the workers. This preference suggests that there are chemical cues in the drone cells which attract the mite, and it must be assumed that the mite is equipped with sense organs of relatively high specialization. A study of the olfactory system in *V. jacobsoni* would be desirable, since little attention has been given to the morphology and possible function of the different hairs in the sensorial field and tarsal organ (Langhe *et al.*, 1976). This study attempts to describe the variated cuticular morphology of the tarsal sensillae, in the sensorial field at the first pair of legs on the female mite, and determine their possible function.

Materials and Methods

The female mites were collected in Fireburg, West Germany, and kept in 8% EM grade gluteraldehyde (Polyscience, Warrington, U.S.A.). Specimens were prepared for scanning electron microscopy as described in a previous publication (Liu and Liu, 1984).

The crystal violet stain technique of Slifer and Brescia (1960) was employed for testing the permeability of the sensilla as described previously (Liu and Liu, 1984).

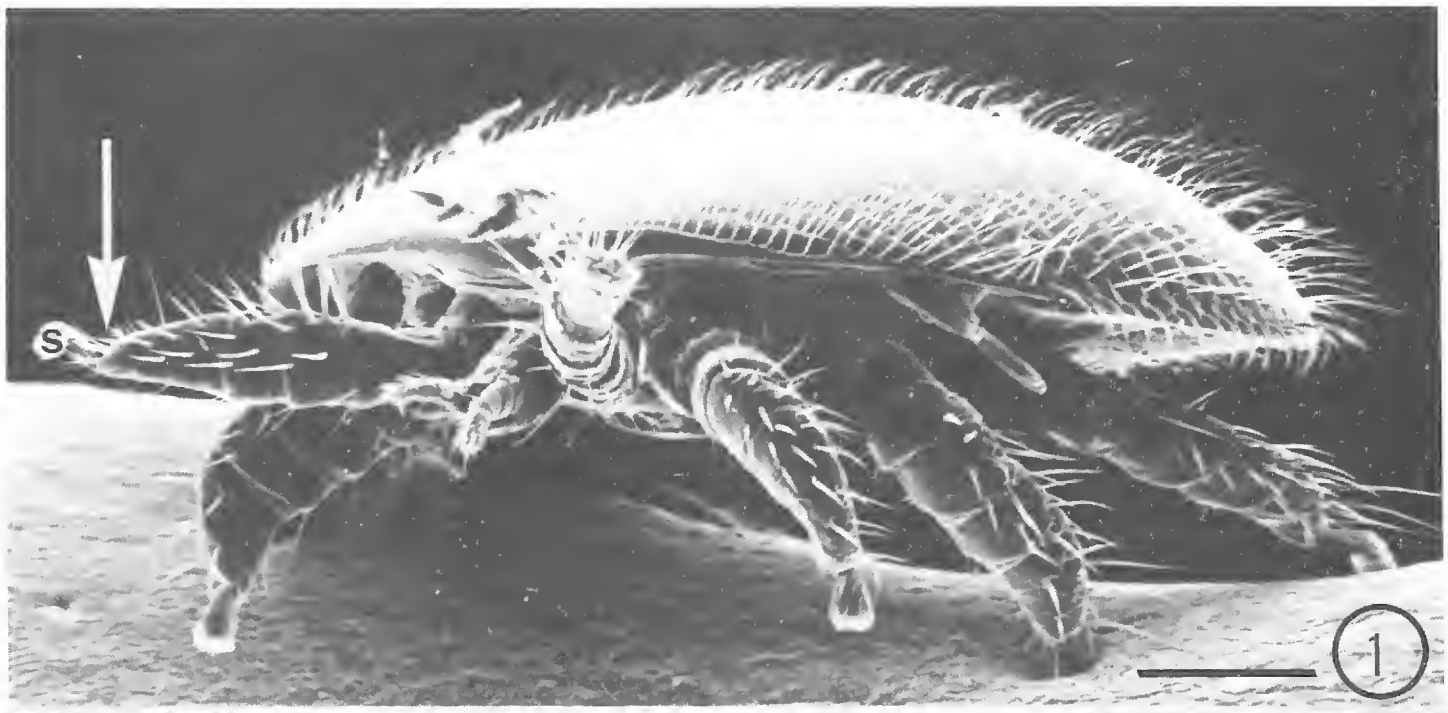
Gluteraldehyde fixed mites were washed with distilled water and again fixed in freshly prepared 5% gluteraldehyde in distilled water, after which they were then washed with distilled water alone. Washed specimens were twice immersed in 0.5% crystal violet in distilled water for 10 and 30 minutes respectively. Mites were removed from the stain, washed with distilled water, and blot-dried with filter paper. Dried mites were immersed in xylene for 60 minutes, and then mounted on glass slides with permount for microscopic examination. The sensilla height was measured from negatives or photographs by use of a video image analysis system equipped with a Kurta series 2 graphic tablet.

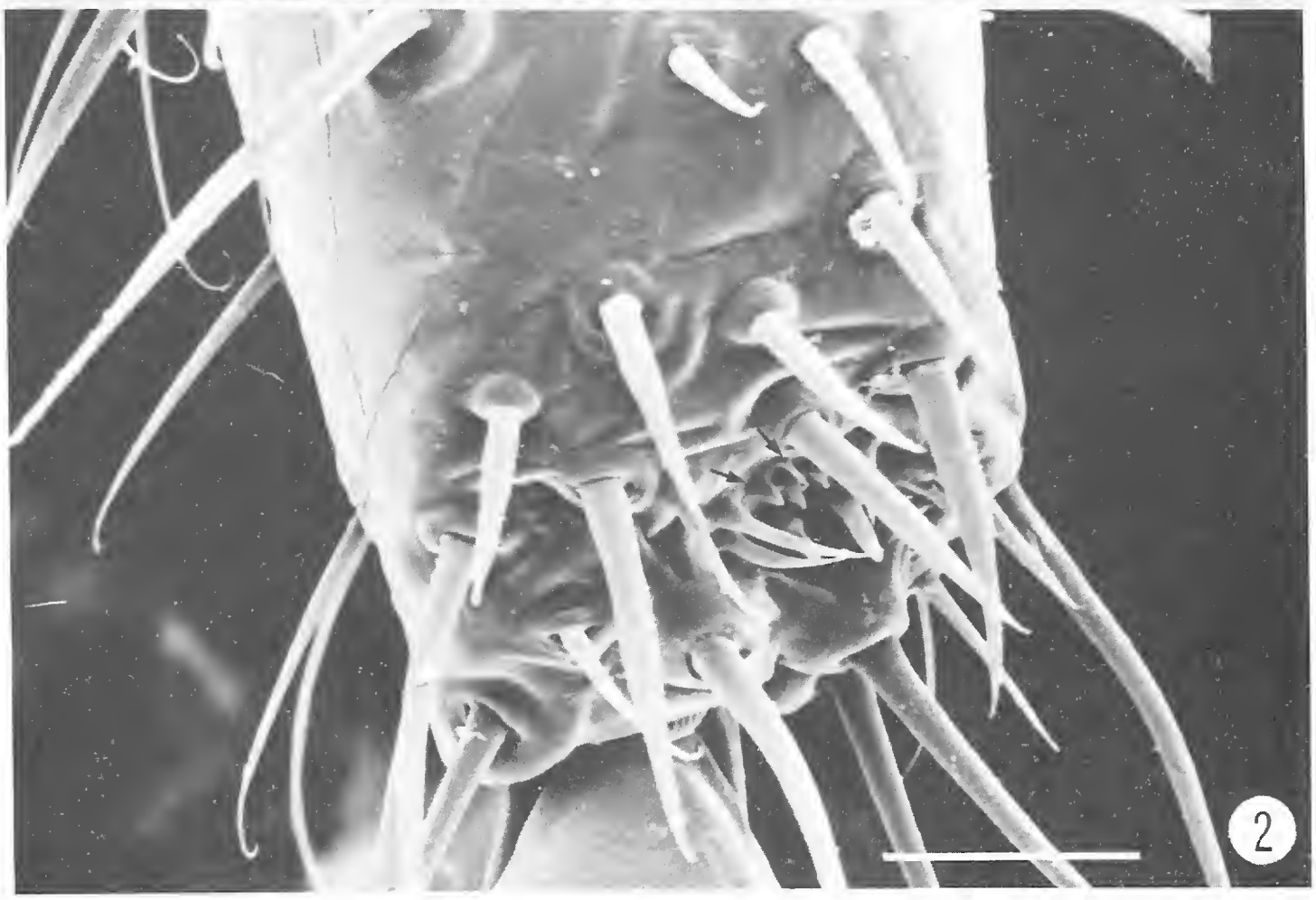
Results

There is a group of sensillae ventrally located at the distal end of the tarsus behind the pretarsus (Figs. 1 and 2). In the center of this sensillae group was a pit with a minute dome-like protrusion centrally situated at the bottom with pores visible on its surface (Figs. 3 and 4). The dome-like protrusion was surrounded by five fine smaller pegs 3–4 um in height, and they were situated on the rim of the pit (Figs. 2 and 5). One of these pegs was slender with a pointed tip, while the other was stout with a flat tip. The remaining pegs were stout with pointed tips (Figs. 2 and 5). All pegs stained brightly after 10 minutes in the crystal violet solution. There were six sensillae measuring 5.5–6.3 um in height, surrounding the pit (Figs. 2 and 5). Two of these sensillae were slender, curved, and round tipped (Fig. 5). Pores were visible on their surface (Fig. 6) and their diameter was from 0.08–0.12 um. Of the four remaining sensillae three were stout and one had a pointed tip (Figs. 2 and 5). All six sensillae were readily stained with crystal violet after 10 minutes in the crystal violet solution. There were 12–16 large hairs surrounding the small sensillae (Figs. 2 and 3), 2–3 of them appearing slender and curved, measuring 14–17 um in height. They were stained with crystal violet throughout the whole length, but no pores were visible. Seven to eight stout straight hairs with round tips measured 16–32 um in height. These hairs were stained with crystal violet only at the tip. Three to four of the longest hairs measured 68–79 um in height, but were not stained with crystal violet.

Discussion

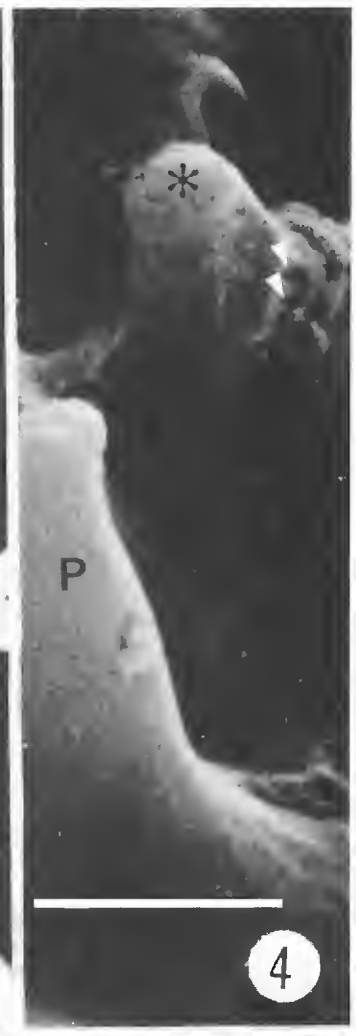
According to Langhe and Natzkii (1977) the tarsus on the first pair of legs of *V. jacobsoni* possess numerous grouped sensillae at the distal end and dorsal surface. This hair group is referred to as the sensorial field, and the tarsal organ is located at its center (Langhe et al., 1976). The present study reveals that sensillae in the sensorial field consists of both thick, and thin walled sensillae, along with longer tactile hair. The dome-like protrusion in the center of the pit may be similar to the coeloconic sense organ of insects (McIver, 1973). In the honeybee, coeloconic sensillae are sensitive to carbon dioxide, temperature, and humidity (Lacher, 1964). The five small pegs on the rim of the pit are thin walled sensillae which resemble the sensilla basiconica of insects. This type of sensillae may have external morphological differences, but all possess a multiporous wall. Therefore, Slifer *et al.* (1959) classified them together. Sensilla basiconica has been observed responding to a variety of chemicals except sex pheromones (Kaissling, 1971; Priesner, 1968; Schneider, 1965; Schneider and Steinbrecht, 1968; Schneider *et al.*, 1964). Slifer *et al.* (1959) also considers this type of sensillae to be the major olfactory organ used for locating odorous food. The six small sensillae surrounding the pit were all stained

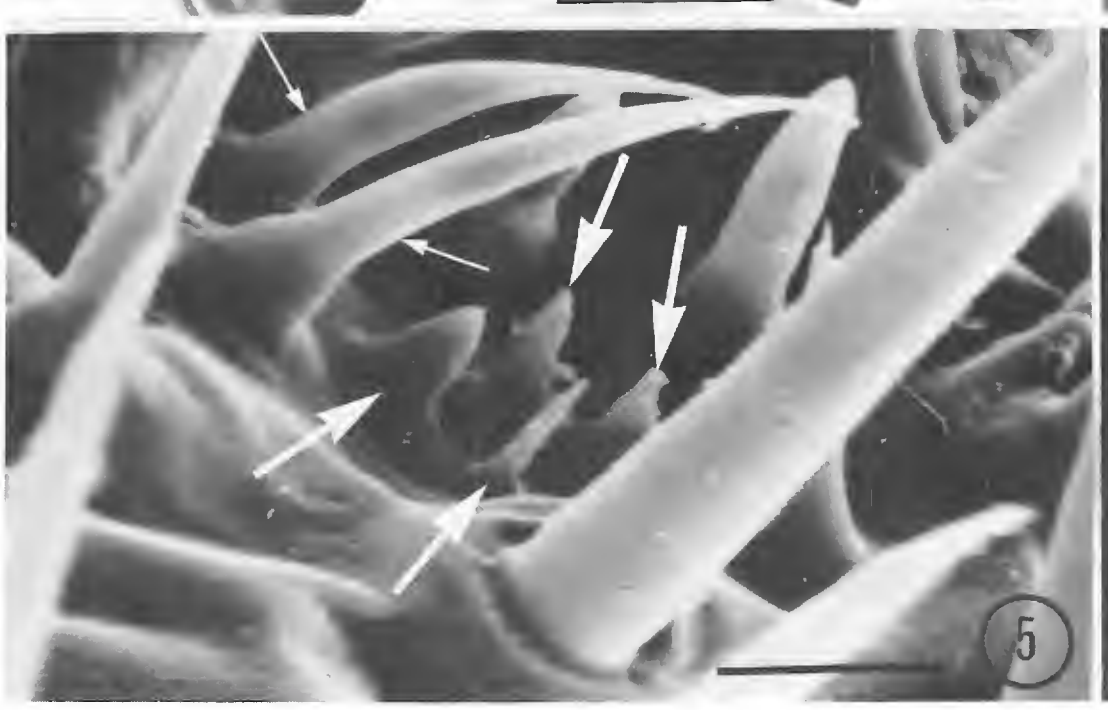


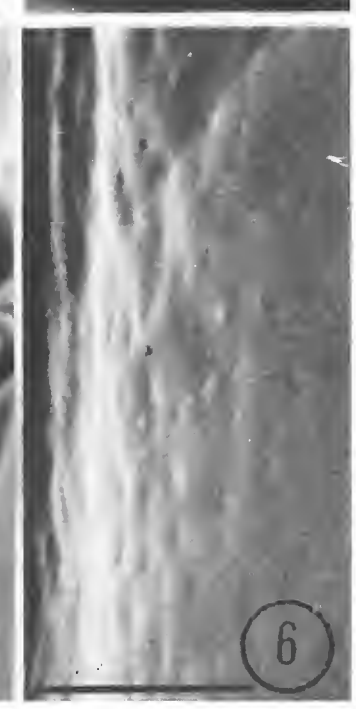


Figures 1–2. Figure 1. The sensorial field (arrow) is located at the distal end and dorsal surface of the tarsus, behind the pretarsus (S) sucker. Bar = 20 μm. Figure 2. The centrally located pit displays five small pegs located on the rim (arrows). Bar = 10 μm.

with crystal violet, which readily indicated that they are porous. Pores were also visible on the surface of the two curved sensillae which are different in shape and may resemble the sensilla trichodea (Steinbrecht, 1973; Albert and Seabrook, 1977; Albert *et al*, 1974; Liu and Liu, 1984). This type of sensillae contains pheromone receptors (Steinbrecht, 1973; Albert and Seabrook, 1973; Albert *et al.*, 1974). Two of the larger sensillae in the sensorial field are porous, and the external morphology is also similar to that of the sensillae trichodea. The large hairs which were stained with







Figures 3–6. Figure 3. The sensorial field consists of a hair group which contains sensillae of varying sizes and shapes. In the center of the sensorial field is a pit, a minute dome-like protrusion (arrow) is centrally located at the bottom of the pit, and five small pegs are located on the rim of the pit (shown in Figure 4). There are six small sensillae surrounding the pit itself. Bar = 10 μm. Figure 4. The dome-like protrusion (asterisk) at the bottom of the pit is porous (arrow heads). Small pegs (P) on the rim of the pit. Bar = 2 μm. Figure 5. On the rim of the pit are small pegs (arrows), while outside the rim are small sensillae. Two of these sensillae (small arrows) are slender, curved, round tipped and porous (pores are present on the surface of the two curved sensillae), while the others are stout and blunt tipped (arrowhead). Bar = 5 μm. Figure 6. Pores are present on the surface of the two curved sensillae shown in Figure 5. Bar = 1 μm.

crystal violet only at the blunt tips, indicated the presence of an apical pore. This type of sensillae may resemble the thick walled sensilla chaetica, which functions as a contact receptor (Slifer, 1970). The three longest hairs were not stained with crystal violet, hence indicating that they may be tactile hairs (Slifer, 1979). Langhe *et al.* (1976) suggested that the sensillae in the sensorial field, are thin walled chemoreceptors which may assist the mite in locating its phoretic host and suitable brood cells. The present study indicates that the sensorial field of *V. jacobsoni* consists of different sensillae types which may perform a variety of functions.

Acknowledgments

The author wishes to thank Dr. W. Ritter, Tierhygienisches Institut Freiburg, German Federal Republic for collecting the specimens and to G. E. Braybrook, Department of Entomology, University of Alberta for assistance in electron microscopy. To Greg Myrick for editing and Faye Swanson for typing the manuscript.

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PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 266–269

The Xylophilous Bees and Wasps of a High, Cold Desert: Leslie Gulch, Oregon (Hymenoptera: Apoidea, Vespoidea)

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Abstract.—The wood-loving bees of a high desert area in eastern Oregon were surveyed with trap nests. Eight species of bees and wasps, previously unknown from this part of the country, were recorded.

INTRODUCTION

The Owyhee region of Malheur County, Oregon, is a geologically unique area that contains a relatively large number of endemic plants. Within the region several state parks have been established to promote recreational use and to preserve portions of the Owyhee upland desert. Leslie Gulch has been designated by the Bureau of Land Management as an Area of Critical Environmental Concern (ACEC). The road passing through Leslie Gulch divides two wilderness study areas, thus the area has wilderness status until a final decision is made by the BLM. In 1983, we (DRF and WHC), began a study of the pollination biology of a rare and endangered rose, *Ivesia rhypara* (Ertter and Reveal) within Leslie Gulch. Since the gulch is known to contain at least eight rare plant species (Grimes 1984), we conducted a trap nest survey in order to estimate the composition of the species pool of available pollinators. This paper describes the results of that survey and reports range extensions for eight species of bees and wasps.

SITE DESCRIPTION

Leslie Gulch is a drainage of approximately 90 km that empties into Owyhee Reservoir, Malheur County, Oregon and has a complicated stratigraphy of volcanic rocks and sediments. The gulch's talus slopes are composed of sparse quartz and sanidine phenoclasts in a vitroclastic matrix and are named the Leslie Gulch Ash-Flow Tuff Member of the Sucker Creek Formation (Grimes 1984). Major components of the sparse vegetation in the canyon are: *Poa sandbergii, Agropyron spicatum, Eriogonum strictum, Physaria chambersii, Astragalus sterilis, Linum perenne, Penstemon acuminatus, Eriophyllum lanatum, Juniperus osteosperma,* and *Purshia tridentata* (Ertter and Reveal 1977). The three trapnest localities were: Leslie Gulch mouth at Owyhee Reservoir, T26S R44E S3 (elev. 825 m); Leslie Gulch at Juniper Gulch, T26S R44E S13 (elev. 1050 m); Leslie Gulch State Park at Runaway Gulch, T26S R45E S9 (elev. 1430 m).

Methods

Trap nests were made from 46.0 cm long *Sambucus* (elderberry) stems into which had been drilled a hole approximately 0.32 cm in diameter by 10.2 cm in length. The undrilled end was sharpened to facilitate placement in the ground (Parker and Bohart 1966). Sticks at each site were placed every 3 M in a straight line at each site and inspected periodically over the summer to ensure that none had been knocked over. Nests were placed at the following sites within Leslie Gulch: 99 sticks on 7 June 1984 at Owyhee Reservoir, 52 sticks on 23 April 1983 and 102 sticks on 7 June 1984 at Juniper Gulch, 51 sticks on 24 April 1983 and 99 sticks on 7 June 1984 at Runaway Gulch. After collection in the fall (12 November 1983 and 30 September 1984), nests were stored outdoors until they were dissected the following winter. The contents were placed in gelatin capsules (size 00) and incubated at 35°C until all specimens had emerged. Pinned insects were then identified and voucher specimens deposited at the USDA Bee Biology and Systematics Laboratory, Utah State University, Logan, Utah, and Orma J. Smith Museum of Natural History, College of Idaho, Caldwell, Idaho.

Results and Discussion

Of 403 stems, 392 were recovered and dissected. Table 1 details the species and numbers that were collected at each site. Overall, such a composition is fairly typical for high deserts in Western North America but eight of these species have not before been reported from this area.

Ceratochrysis enhuycki Cooper has previously only been known from the east (NY to FL) and southwest (TX, UT, AZ). Its host at Leslie Gulch is unknown but is probably one of the species of *Leptochilus* (Krombein 1959). Both *Leptochilus washo* Parker and *L. trachysomus* (Bohart) are known from the southwest (Krombein 1979, Parker 1966) but neither has been recorded this far north. *Ancistrocerus simulator* Cameron was previously reported only from Nevada and California (Krombein 1979), as was *Pisonopsis clypeata* Fox with the addition of a Wyoming locality (Evans 1969). The use of burrows in plant stems by wasps is unusual but is not entirely unknown (Evans 1969).

Little is known about *Hylaeus polifolii* (Cockerell), but to date it has been reported only from California (Hurd 1979). Two megachilids exhibit the greatest range extensions. Previously, *Ashmeadiella meliloti* (Cockerell) was thought to be confined to the deserts of the southwestern U.S. and northern Mexico. *Stelis lateralis* Cresson has not been reported on this side of the continental divide but has been collected from Maine and Ontario to North Dakota and south to Georgia and Texas (Hurd 1979). The host of *S. lateralis* at Leslie Gulch is not known.

The difference between the 3 sites in species composition and numbers are probably not significant and likely reflect sample size. Altitude varies only about 600 meters between the 3 sites and vegetation is similar. The Owyhee Reservoir site may have yielded fewer species and numbers because of a relatively greater abundance of grasses and paucity of vegetation. The species reported herein are only those that will build nests in wooden stems and are part of a much larger bee and wasp fauna. The entire Owyhee Uplift is home to a large number of rare and endemic plant species. In order to understand the reproductive ecology of those populations, it is necessary to account for both pollinators and other insect associates. This study has been part of that effort.

Table 1. Number of individuals and species trapped at all sites. 1983 and 1984 are combined.

TAXA	STUDY SITE		
	Runaway Gulch	Juniper Gulch	Owyhee Reservoir
LEUCOSPIDAE			
Leucospis affinis Say	11		
CHRYSIDIDAE			
Hedychridium soliérellae Bohart and Brumley	2		
Chrysis derivata Buysson	1	1	
Chrysis sp. #1	3	1	
Chrysis sp. #2		3	
Chrysis sp. #3		6	
Chrysura sp.		5	
Ceratochrysis enhuycki Cooper	5	5	3
MUTILLIDAE			
Sphaeropthalma s.l.			1
EUMENIDAE			
Leptochilus periallis Parker	4	1	
L. trachysomus (Bohart)	1	9	
L. washo Parker	7	26	
Stenodynerus blandoides Bohart	4	1	
Parancistrocerus acarigaster Bohart	6	5	3
Ancistrocerus simulator Cresson		17	2
PEMPHREDONIDAE			
Pemphredon lethifer (Shuckard)	2		
LARRIDAE			
Solierella peckhami (Ashmead)	1		
Pisonopsis clypeata Fox	3		
Trypoxylon sculleni Sandhouse	1		
COLLETIDAE			
Hylaeus polifolii (Cockerell)	3		
MEGACHILIDAE			
Stelis lateralis Cresson	11	12	12
Hoplitis albifrons (Kirby)	3	3	3
H. hypocrita (Cockerell)	66	19	23
H. grinnelli Cockerell	11	7	
H. sambuci Titus	1	1	
H. uvualis (Cockerell)	10		
Anthophora copelandica (Cockerell)		6	
Ashmeadiella melilotti (Cockerell)	25	1	110
Osmia bruneri Cockerell	2		
O. kincaidii Cockerell	16	119	
O. cyanella Cockerell		6	
O. sp. nov.	86	14	
Megachile montivaga Cresson	9	44	
Coelioxys banksi Crawford	17	27	
ANTHOPHORIDAE			
Ceratina pacifica Smith	3	3	
Total Species	28	25	8

Acknowledgments

M. Clark, C. Clark, and E. Clark assisted with field work. The United States Department of Interior, BLM, Vale District gave permission to conduct the research. We had valuable discussions concerning local flora with B. Ertter, J. Grimes, E. Joyal, and P. Packard. This research was supported by the Utah Agricultural Experiment Station, Utah State University, Logan, Utah. Journal paper number 3488.

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PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 270–274

A New Species of *Neurotoma* From Michigan (Hymenoptera: Symphyta, Pamphiliidae)

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Abstract.—A new species of sawfly is described in the small pamphiliid genus *Neurotoma* Konow. Only 3 male specimens are available, all from the same collection in Michigan. Males of two closely related species, *N. crataegi* and *N. willi* are figured and compared. A key to North American species is included.

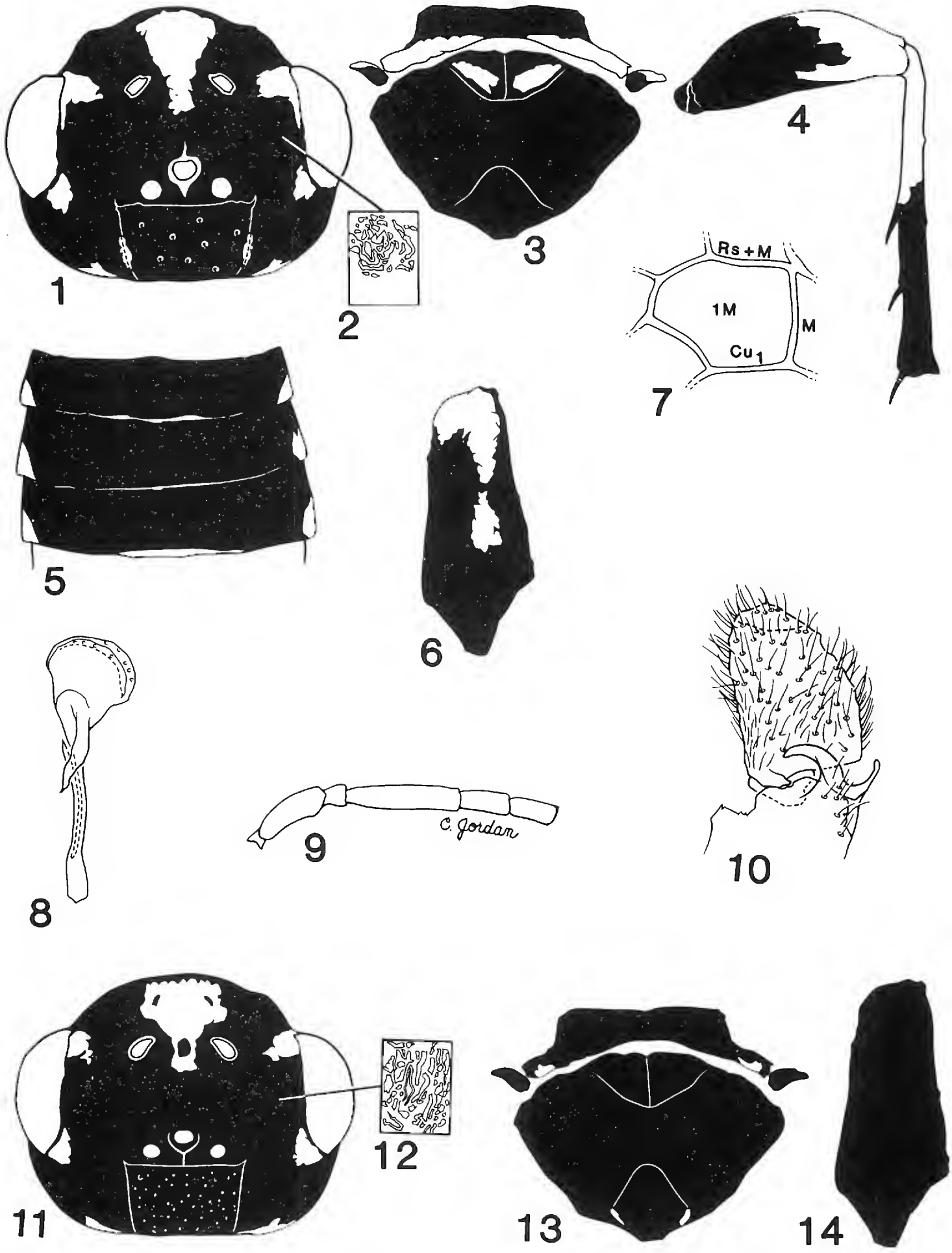
The sawfly genus *Neurotoma* Konow is Holarctic in distribution with the presently described species adding [one] to the four previously described in the Nearctic fauna (Middlekauff, 1940, 1958, 1966; Smith, 1979). The remaining twelve in the genus are found from Europe to Japan and Korea. With but one exception, a Japanese species found on *Quercus* (Shinohara, 1980), all others, where the host(s) are known, feed on the foliage of rosaceous trees and shrubs of the genera *Amelanchier, Cotoneaster, Crataegus, Prunus, Pyrus* and/or *Sorbus*.

This article includes the description of the new species, a key to Nearctic species of *Neurotoma* and comparative notes on the males of two closely related species.

Key to Nearctic species of *Neurotoma*

The new species *nigra* will run to *willi* in Middlekauff's 1958 key, thus necessitating a new one.

1. Tegula black (Fig. 13) ..... *crataegi* Middlekauff
— Tegula completely or mostly pale (Figs. 3, 26) 2
2. Femora and tibiae entirely pale 3
— Femora and basally & tibiae apically marked with black 4
3. Wings hyaline, perhaps a very faint infuscated band below stigma; legs beyond coxae mostly pale reddish brown ..... *inconspicua* (Norton)
— Basal two-thirds of wings heavily infuscated; legs beyond coxae pale yellow ... . *fasciata* (Norton)
4. Pronotum (Figs. 3), mesepisternum (Fig. 6), prescutum (Fig. 3), and lateral margins of abdominal tergites (Fig. 5) with white areas; cell 1M as in Fig. 7; vertex wider than long (Fig. 1); paraantennal field finely rugose (Fig. 2) .... *willi* Middlekauff
— Pronotum (Fig. 26), mesepisternum (Fig. 24), prescutum (Fig. 26), and lateral margins of abdominal tergites (Fig. 27) entirely black; cell 1M as in Fig. 19; vertex longer than wide (Fig. 20); paraantennal field smooth, shining (Fig. 21) ..... *nigra* n.sp.



Figures 1–10. *Neurotoma willi* Middlekauff, male. Figure 1, head, dorsal view. Figure 2, Inset, paraantennal field. Figure 3, Thorax, dorsal view. Figure 4, Hind femur and tibia, lateral view. Figure 5, Abdominal segments III–V, dorsal view. Figure 6, Mesepisternum. Figure 7, Cell 1M, forewing. Figure 8, Penis valve. Figure 9, Antennal segments 1–5. Figure 10, Right half of genital capsule, ventral view. Figures 11–14. *Neurotoma crataegi* Middlekauff, male. Figure 11, Head, dorsal view. Figure 12, Inset, paraantennal field. Figure 13, Thorax, dorsal view. Figure 14, mesepisternum.

Neurotoma nigra, new species
(Figs. 20–28)

Male, holotype. Head black with whitish yellow markings only on frons and in the supra ocular areas as in Fig. 20. Antenna entirely black, the scape and pedicel darker. Mouthparts dark brown (alaglossa and paraglossa), with the apical 3 segments of the maxilla and 2 of the labium, whitish yellow. Mandible whitish yellow at base, darker brown to black in middle and reddish brown apically.

Thorax except for the whitish yellow tegula, entirely black (Fig. 26). Coxa black basally, whitish yellow apically. Trochanter whitish yellow. Fore and mid femur basally, black. Hind femur with a black spot basally as in Fig. 28, remainder of femur whitish yellow. Tibia whitish yellow becoming dark brown to black over a lesser area from the fore to hind leg as in Fig. 28. Tarsus brownish the posterior ones somewhat darker. Wings hyaline. Venation, except for the whitish yellow base of 1A, dark brown, the stigma black. Abdomen entirely black (Fig. 27). Harpes pale yellowish brown.

Clypeus rounded in front. Frons swollen, forming an elongate rounded ridge extending onto the swollen clypeus. Median fovea absent. Ocellar basin distinct, crescent shaped in front. Lateral transverse suture becoming faint and disappearing behind lateral ocellus (Fig. 20). Lateral suture diverging so that a line extending it forward would miss the lateral ocellus by two ocellar widths (Fig. 20). Post ocellar area longer than that of *willi* (Figs. 20, 1). Post genal carina distinct extending around vertex to within 2 ocellar widths of lateral suture. Entire head and face, except for shining impunctate paraantennal fields (Fig. 21), with distinct punctures becoming almost coriaceous. The postocular and vertex areas also punctate, but the spaces between these punctures polished. Antenna 19-segmented; A (segment) III:AIV 2.3:1; AIII:AIV + V 1.1.16 (Fig. 25).

Prescutum slightly rugose. Mesoscutum impuctate except for a narrow mid band of shallow punctures, otherwise shining, pebbled under higher magnification. Mesoscutellum depressed, flattened, punctate, antero-laterally carinate but not posteriorly where it rounds off towards the post-tergite. Mesepisternum with numerous shallow punctures each with a long, single hair giving it a distinctly hairy appearance.

Genital capsule (lateral half) as in Fig. 22. Penis valve as in Fig. 23.

Measurements of holotype (in mm): body length 7.9; forewing 7; head width 2.25; antennal scape length 0.56; pedicel 0.25; segment III 0.94; segment IV, 0.37; segment V, 0.37.

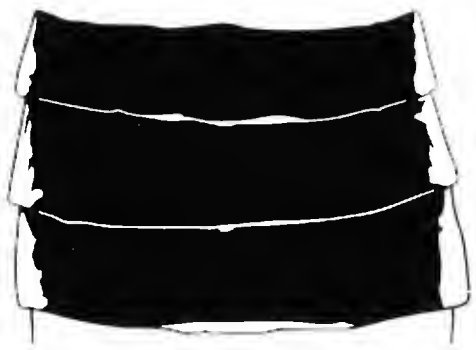
Female.—Unknown.

Host(s).—Unknown.

Distribution.—Michigan.

Type.—Holotype, male: Roscommon County, Michigan, 5–31–57 (R. & K. Dreisbach). Paratypes: Two males with same data as holotype. In Michigan State University, East Lansing and Essig Museum, University of California, Berkeley. The holotype will be deposited in the collection, U.S. National Museum, Washington, D.C.

Discussion.—This species is quite distinct from the related *N. willi* (Middlekauff, 1958) and *N. crataegi* (Middlekauff, 1940). Except for the frons and a small supraocular spot the head is entirely black as are also the thorax and abdomen;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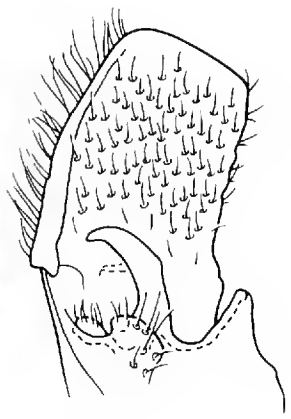
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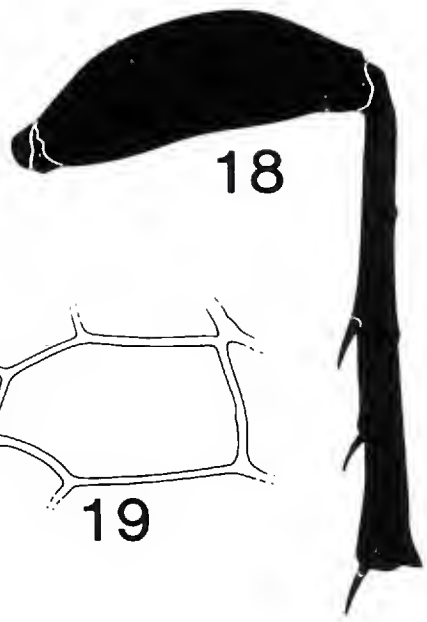
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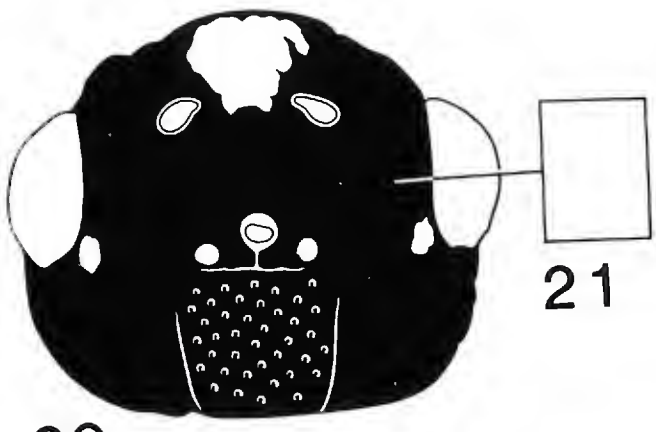
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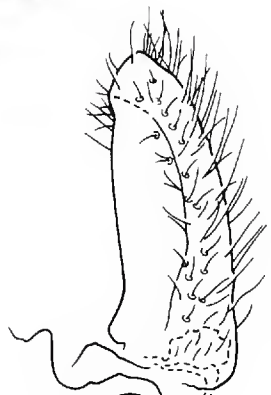
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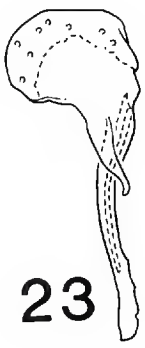
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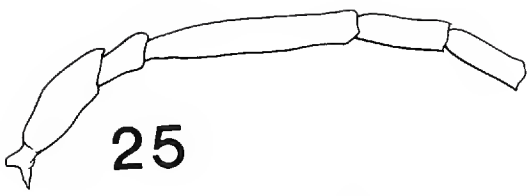
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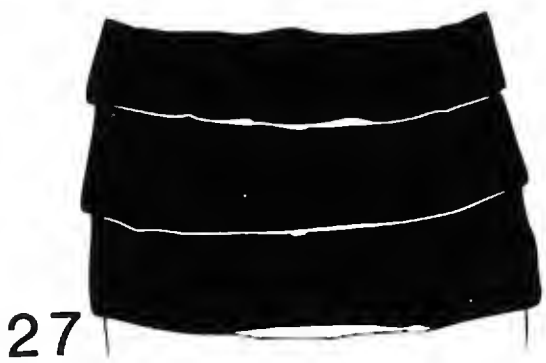
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Figures 15–19. *Neurotoma crataegi* (con't.). Figure 15, Abdominal segments III–V, dorsal view. Figure 16, Left half of genital capsule, ventral view. Figure 17, Penis valve. Figure 18, Hind femur and tibia. Figure 19, Cell 1M, forewing. Figures 20–28. *Neurotoma nigra*, n.sp., male. Figure 20, Head, dorsal view. Figure 21, Inset, paraantennal field. Figure 22, Right half of genital capsule, ventral view. Figure 23, Penis valve. Figure 24, Mesepisternum. Figure 25, Antennal segments 1–5. Figure 26, Thorax, dorsal view. Figure 27, Abdominal segments III–V, dorsal view. Figure 28, Hind femur and tibia.

antennal segment III is longer than segments IV and V combined; the lateral sutures on the vertex are divergent, not parallel; the postocular area is longer; there are more numerous and larger punctures on the head; the 1st medial cell (discoidal)is 2X longer than the basal width, *willi* is only 1.5X longer.

The name *nigra* is given because of the predominant black coloration of the head thorax and abdomen.

Neurotoma willi Middlekauff
(Figs. 1–10)

Comparative comments: *N. willi* is similar to *nigra* in some respects but differs in the points given in the key to species and shown in Figs. 1–10. In addition the post ocular area is finely grained (or pebbled) and lacks pits; some specimens have one or two small white spots laterally on the mesonotum; a few specimens have the tegula completely black; the basal two-thirds of vein 1A is black; base of mandible black; the lateral white spot on each abdominal tergite extends ventrally on the posterior third of the spiracle bearing lateral tergites; sternites III–VII, each has a white area on the mid-apical border; harpes black, never yellowish brown; frons and clypeus impunctate; the mesoscutellum is distinctly carinate except for a small medial posterior area.

Neurotoma crataegi Middlekauff
(Figs. 11–19)

Comparative comments: *N. crataegi* is also similar to *nigra* in some respects, but is apparently not quite as closely related as is *willi*. Many of the differences are given in the key to species and in Figs. 11–19. In addition to these the clypeus and frons are rugose, lacking distinct pits; the post ocular area and vertex are also rugose with a few scattered shallow pits; rarely is the pronotum completely black; occasional specimens have small white spots on the prescutum while others may have the mesoscutellum completely black; all wing veins are completely brownish black and the wings are entirely lightly infuscated; base of mandible is black; the lateral white spot on each abdominal tergite extends from the spiracle as a narrow band, only expanding slightly on posterior border; harpes black; the mesoscutellum is distinctly carinate laterally.

Acknowledgments

I am indebted to Dr. David R. Smith for sending me the above specimens and to Christina Jordan for the illustrations.

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PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 275–279

Further Notes on Halictine Bees (Hymenoptera: Apoidea) Visiting *Isomeris arborea* in Southern California

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In a brief earlier report (Linsley, 1986) records of three species of small halictine bees visiting *Isomeris arboreus* at Desert Hot Springs, California, on December 25, 1985, were provided. In early February 1987, further samples from the same site revealed some interesting comparisons with the earlier collections.

Isomeris arboreus is a member of the Caparidaceae (caper family) and is most commonly known as "bladder-pod" because of the elongate, inflated seed pods. It is particularly abundant along the western edge of the California deserts but occurs elsewhere including southern California sea cliffs. In the desert it is said to bloom whenever it rains. The plant is a densely branched shrub, growing mostly four to five feet tall when mature. When in bloom the numerous flowers with their four yellow petals make the plant conspicuous from a distance. The four stamens and the pistil are equal in length (see photograph). The thread-like staminal filaments cannot support honeybees, which visit the flowers primarily for nectar, but easily sustain the small halictines. These bees land directly on the anthers and frequently crawl from anther to anther by reaching out with the forelegs. Nectar is obtained from the base of the flower. The significance of this plant in the present study is that, as a perennial, it is one of the first plants to bloom in the desert and thus able to provide forage for these early emerging polylectic bees.

Moldenke and Neff (1974) list seven species of small halictines taking nectar from *Isomeris*. In addition to those referred to below, they recorded *Lasioglossum sisymbrii* (Cockerell) (3♀), *L. trizonatum* (3♀), and *Evylaeus argemonis* (Cockerell) (2♀), and *Dialictus microlepoides* (Ellis) (3♀), each from Riverside County, California; and *Dialictus hyalinus* (Crawford) from Los Angeles County. They also list a female of *Augochlorella pomoniella* (Cockerell) taking nectar at this plant in San Diego County. Moure and Hurd (1977) include these records in their tabulations, adding only one more halictine, *Agapostemon mexicanum* from Baja California and Sonora.

Between February 2 and 9, 1987, eight samples of bees were taken from plants at the exact site that was utilized in the December 1985 collections. This area is in an old wash bordered on the west side by a high embankment, and is subject to strong winds which may temporarily remove the bees from the plants or complicate their flight patterns. However, the bees persist in collecting pollen, even in the face of winds which, when gusting, made it difficult for me to control the net. The site was bordered by pavement laid out for future development and the plants were concentrated near the edge of the paved areas, but were also scattered on the land nearby. The surface soil was composed of coarse sand and gravel with a few large

boulders—an unpromising area for ground nesting bees. In fact a casual search revealed no sign of nesting nearby.

The small sample (12 specimens) taken in December contained six females of *Dialictus microlepoides* (Ellis) and one female of *Evylaeus amicus* (Cockerell) which were gathering pollen and five females of *Evyaeus pulveris* (Cockerell)[1] which were taking only nectar. However, species abundance in the early February samples was reversed. The 248 females of *E. pulveris* collected were all gathering pollen, but the two females each of *Dialictus microlepoides* and *Evylaeus amicus* were taking only nectar, as were one each of *Dialictus albohirtus* (Crawford) and *D. hyalinus* (Crawford) (all kindly identified by George C. Eickwort). Earlier, Moldenke and Neff (1974) had recorded 18 females of *Evylaeus ruficornis* (Crawford) (det. Timberlake) taking nectar from *Isomeris* in Riverside County, California, but did not give the dates of capture[1]. Our 1987 collections and associated data (temperatures averaged for each period) were as follows:

Evylaeus pulveris
Feb. 2, 23♀P (1230–1300, broken sky, variable wind, temp. 24°C)
Feb. 3, 11♀P (1830–0900, overcast, windy, temp. 20°C)
Feb. 5, 19♀P (0830–0900, overcast, variable wind, temp. 19°C)
Feb. 6, 95♀P (0930–1030, clear, no wind, temp. 27°C)
Feb. 7, 19♀P (0630–0700, overcast, no wind, temp. 18°C)
Feb. 8, 27♀P (1015–1030, overcast, no wind, temp. 20°C)
Feb. 8, 8♀P (1500–1515, broken sky, no wind, temp. 27°C)
Feb. 9, 26♀P (1015–1030, broken sky, no wind, few rain drops, temp. 20°C)
Evylaeus amicus
Feb. 2, 1♀N (as above)
Feb. 8, 1♀N (as above)
Dialictus albohirtus
Feb. 6, 1♀N (as above)
Dialictus hyalinus
Feb. 2, 1♀N (as above)
Dialictus microlepoides
Feb. 2, 1♀N (as above)
Feb. 7, 1♀N (as above)

Bees of the genus *Evylaeus* are eusocial although they differ in levels of sociality (Packer and Knerer, 1985; Eickwort, 1986). In those species which have been studied, fertilized females overwinter to initiate the populations of the following year (usually two generations). Thus the data recorded here and previously are based upon early emergence of overwintering females and the absence of males is to be expected.

Most previous records for the species listed above are to be found in Moldenke and Neff (1974). They list 214 females of *Evylaeus amicus* from 33 flowering plants

[1]Ronald McGinley (in litt.) has indicated that there are unresolved problems with the identity of this species. Both he and George Eickwort suggest that the Moldenke and Neff (1974) records under the name *E. ruficornis* also apply here. However, for the sake of consistency and future reference we have continued to use the name "*pulveris*" until the matter is cleared up.

Upper: wind-blown plants of *Isomeris* at Desert Hot Springs in foreground; Mt. San Gorgonio in background (Photographs by J. M. Linsley). Lower: Female *Evylaeus pulveris* taking pollen from *Isomeris* flowers (Photograph by Kim Hoelmer).

(including *Isomeris arborea*) but taking pollen only from *Adenostoma, Ceanothus* and *Clarkia,* and record the flight period as from February 21 to May 11. No males were reported. The name "*Evylaeus pulveris*" does not appear in their listings, nor does that of *Dialictus albohirtus*. For *Dialictus hyalinus,* they include an extensive list of flowers visited for nectar by males and/or females during a flight period extending from February 18 to November 13. Although they do not give dates with the individual records, presumably the males were taken during the latter part of the flight period. The same is true for *Dialictus microlepoides,* although among the nectar plants they include *Isomeris arboreus.*

From our data at this site, there is no indication as to the number of generations involved in the annual cycle of *Evylaeus pulveris,* but the females that are active in December must represent the overwintering generation newly emerged and not yet collecting pollen. They became extremely active by early February. A visit to the area in early June, 1987, revealed that the plants were no longer in bloom, and no sign of the halictines or honey bees was evident on any other flowers in the area. Unfortunately, the precise site of our collections was being bulldozed for housing construction and will be unavailable for further study. (This calamity has overtaken us in numerous desert localities in the Southwest!)

With regard to these same species we have taken males previously in Arizona and published records are also available for some:

Evylaeus amicus have been collected by us in large numbers at flowers of *Cercidium microphyllum* at Gila Bend, Arizona, on May 11, 1978, where they were present throughout the day. The females, as expected, are polylectic and we have found them taking pollen from *Larrea divaricata, Cercidium microphyllum,* and *Parkinsonia aculeata* in Arizona and southern California deserts.

We have captured males of *E. pulveris* (identified by Timberlake) at flowers of *Cercidium microphyllum* in the Arizona desert, once at Gila Bend and once near the Colorado River in Yuma County--both collections in mid-May.

Aldred (1969) reported the capture of 33 males and three females of *Dialictus albohirtus* at the Nevada Test Site. He lists a variety of herbaceous plants and shrubs from which collections were made in June (mostly) and July, but does not provide data as to sexes associated with individual plants. He states that the most common host was *Asclepias erosa.* This is a good nectar plant but, of course, not a source of pollen for bees.

In earlier collections by us, a male of *Dialictus hyalinus* was taken with a few pollen- and nectar-gathering females at flowers of *Cercidium microphyllum* at Gila Bend, Arizona, on May 11, 1978. Four other males were captured at *Tamarix aralensis* at Keeler, Inyo County, California, on June 15. Our earliest capture of a male in Arizona was on May 12, 1978. Pollen-gathering females were found at *Larrea tridentata* in Arizona and southern California in March and April.

Dialictus microlepoides is a widespread common polylectic species, especially in the southwestern deserts and northwestern Mexico. Aldred listed males and females from the Nevada Test Site in June (mostly) and July, most commonly at *Viguieria multiflora.* We have captured males with females taking pollen in Oro Valley, Pima County, Arizona, on May 28, 1976, from *Cercidium microphyllum,* and large numbers of males (41) along with pollen- and nectar-seeking females at the same host, on May 21, 1978. At Palm Springs, California, only females taking pollen were present at flowers of *Larrea tridentata* on July 6, 1975.

It is regretted that circumstances beyond our control prevent further attempts to clarify the seasonal pattern of activity of these bees in the vicinity of Desert Hot Springs, but we provide these limited data in the hope that future studies may clarify their occurrence in the western Colorado Desert during the summer, fall and early winter.

Acknowledgments

Acknowledgment is due to George C. Eickwort, for patiently determining the specimens collected and for comments on the manuscript, to Ronald McGinley for calling attention to problems with the identification of *Evylaeus pulveris,* Howell V. Daly, who sampled honey bees at the site while we were there, for reading the manuscript. Thanks are also due to Kim Hoelmer for the photograph of this species taking pollen from the anthers of *Isomeris*. Finally, I wish to express my appreciation to my wife, Juanita M. Linsley, who accompanied me on each of my sampling trips and collected assiduously, adding materially to the field data and providing one of the photographs of *Isomeris* plants accompanying this article.

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PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 281–284

The Apoidea Collection of the California Insect Survey (C.I.S.) at the Essig Museum of Entomology, University of California, Berkeley

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History of the Apoidea collection

The insect collection of the University of California at Berkeley was established in 1940 as a project of the California Agricultural Experiment Station and officially designated as the "California Insect Survey". Prior to 1940, A. T. McClay had managed the collection. At the urging of E. G. Linsley and R. L. Usinger, the insect collection was given formal recognition by E. O. Essig, who was Chair of the Department of Entomology during 1943–1952. P. D. Hurd Jr. supervised the collection from 1947–1962 and from 1963 to the present it has continued under the leadership of J. A. Powell. Since 1967 the collection has been housed in parts of three floors remodeled for this purpose in Wellman Hall on the main campus in Berkeley. The parasitic Hymenoptera are maintained by the Division of Biological Control at the Gill Tract in Albany, CA. In 1972 the collection and associated facilities were named the Essig Museum of Entomology. For further historical information see: Linsley, E. G. [1955. The Department of Entomology and Parasitology (Berkeley-Davis). Entomol. News 66:133–138], Powell, J. A. [1972. The California Insect Survey. Div. Entomol. Agric. Exp. Sta. Univ. Calif., Berkeley 22 pp. (mimeo)] and Powell, J. A., et al. (1973. Entomological collections of the University of California. Bull. Entomol. Soc. Amer. 19:100–102).

The principal contributors to the growth of the bee collection were E. G. Linsley, and his students P. D. Hurd and J. M. MacSwain. National Science Foundation grants awarded to Linsley and MacSwain during the 1950's promoted apidology, particularly pollination biology. As part of their doctoral dissertations, collections were deposited at the C.I.S. by J. S. Rozen (now at Amer. Mus. Nat. Hist.) and R. W. Thorp (now at Univ. Calif., Davis), both Linsley's students, and G.I. Stage (now at Stafford Springs, CT), Hurd's student. These early contributions have been supplemented by the efforts of J. A. Powell, J. T. Doyen, J. A. Chemsak, H. V. Daly and others. In addition to P. H. Timberlake (Univ. Calif., Riverside), other researchers who have identified considerable portions of our bee collection are: C. D. Michener (Univ. Kansas, Lawrence) and R. R. Snelling (Los Angeles County Museum, CA) (Colletidae); G. Hackwell (Turlock, CA), W. LaBerge (Ill. Nat. Hist. Surv. Insect Ident., Urbana), R. Thorp (Andrenidae); G. Eickwort (Cornell Univ., Ithaca, NY), R. McGinley (USNM, Washington, DC), Michener and R. R. Roberts (Rutgers Univ., New Brunswick, NJ) (Halictidae); A. A. Grigarick (Univ. Calif., Davis), G. E. Bohart, T. Griswold and F. Parker (all at the Bee Biol. Lab.,

Logan, UT), Michener and T. B. Mitchell (Univ. North Carolina, Raleigh) (Megachilidae); Griswold and Thorp (Apidae); Bohart, R. W. Brooks (Univ. Kansas), LaBerge and Snelling (Anthophoridae) and others.

Holdings and their curatorial condition

The Apoidea collection houses about 314,000 bees in 521 drawers including 114 drawers (22% of the total) that contain material identified only to genus or family. Most specimens on loan have not been included in the count. The C.I.S. ranks among the three largest bee collections in North America. In terms of identified species/subspecies it probably has the most extensive holdings of bees from western North America.

Western North America is defined here as the area circumscribed by the states or provinces of: Alaska, Northwest Territories, British Columbia, Alberta, Washington, Oregon, Idaho, Montana, Wyoming, California, Nevada, Utah, Colorado, New Mexico, Arizona and Baja California. The Essig Museum of Entomology has specimens of 54% of the reported species/subspecies for western North American bees (47% Colletidae, 100% Oxaeidae, 53% Andrenidae, 58% Melittidae, 55% Halictidae, 71% Megachilidae, 42% Anthophoridae, 80% Apidae) and 47% of the reported species/subspecies for North America (55% Colletidae, 100% Oxaeidae, 47% Andrenidae, 44% Melittidae, 41% Halictidae, 66% Megachilidae, 34% Anthophoridae, 79% Apidae) [Krombein, et al. 1979. Catalog of the Hymenoptera in America North of Mexico. Vol. 2. Apocrita (Aculeata). Smithsonian Institution Press. Washington, D.C.].

C.I.S. holdings are abundant for the Nearctic region, especially southwest United States. Mexico and Central America, particularly Costa Rica, are also well represented; there are lesser collections from other Neotropical areas. Collections received incidentally from the Palearctic, Ethiopian, Oriental and Australian regions, usually have been deposited at the California Academy of Sciences or at the University of California, Davis. Table 1 summarizes the estimated number of specimens, number of genera and species/subspecies, as well as the amount with type material, voucher specimens and nest materials per family. The 224 name-bearing types are on loan of indefinite duration to the California Academy of Sciences, San Francisco, CA.

Hurd and Linsley supervised major curatorial work, primarily undertaken by K. Sorensen during the 1960's and 1970's. Most of our holdings are at curatorial level 6 but not all geographical codes have been added (curatorial level 6 = properly curated, United States National Museum classification; McGinley, pers. comm.). Holdings, types, and loans are currently being placed in a computer information retrieval system to facilitate multiple access (level 7).

Loan Policy

Currently, loans are made for three years and are renewable following notification. Loan requests should be addressed to Dr. John A. Chemsak (same address as authors).

Table 1. Summary of the Apoidea holdings of the Essig Museum of Entomology, University of California, Berkeley

Family	Estimated number of specimens	Number of genera	Species and subspecies					
			Total number	Number with type specimens			Number with vouchers[3]	Number with nest materials
				Name-bearing[1] type	Allotype[1]	Paratype[2]		
Colletidae	6,000	13	118	6	5	11	0	0
Oxaeidae	1,000	4	13	2	3	4	0	0
Andrenidae[4]	70,000	17	786	165	87	284	7	9
Mellitidae	3,000	1	14	0	0	0	0	0
Halictidae	36,000	33	291	9	3	10	0	0
Megachilidae	73,000	29	519	5	2	23	2	2
Anthophoridae	85,000	51	678	37	28	67	21	12
Apidae	40,000	30	246	0	0	5	0	0
Totals	314,000[5]	177	2,665	224	128	404	30	23

1. Deposited on indefinite loan at the California Academy of Sciences, San Francisco, as of December, 1986.
2. In Essig Museum
3. Mostly of pollination biology studies
4. Also 21 species with stylopized representatives
5. Not included in our summary are about 20,000 bees in Schmitt boxes and most of the specimens on loan to specialists.

Acknowledgments

We wish to thank J. A. Chemsak for allowing JASB to undertake the inventory/curation of the bees while working as Research Assistant at the Essig Museum of Entomology. E. G. Linsley and J. A. Powell provided most of the historical information and reviewed the typescript.

PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, p. 285–289

A Population Estimate of Mdh Allozyme Frequencies for the Honey Bee, *Apis mellifera* L. (Hymenoptera: Apidae)

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ABSTRACT

Gene frequencies of allozymes of malate dehydrogenase (Mdh-1) were presented for a population of honey bees located in Davis, California. Two different estimates were made that represented population gene frequencies in 1977 and 1978. Genotype frequencies did not differ significantly from those expected under Hardy-Weinberg equilibrium conditions. Frequencies were compared with an additional estimate made prior to 1977. There were no significant differences between these three generations. The combined gene frequency estimate is 0.77, 0.08, and 0.16 for the slow, medium, and fast alleles, respectively. These frequencies differ significantly from those reported for populations of Africanized honey bees in Brazil.

INTRODUCTION

The process of "Africanization" of honey bee populations in South and Central America has become an issue of major importance in entomology because of its potential impact on agriculture and public health in the United States and also because of its significance as a natural study of population biology (Taylor 1985; cf Rinderer 1986). The genetic mechanisms of Africanization remain virtually unknown due to a lack of population genetic studies. The discovery in the summer of 1985 of a presumed Africanized honey bee colony in southern California, and the extensive attempt to determine the impact of that colony on the genetic structure of the local honey bee population (Gary et al. 1985), demonstrates the need for data on the genetics of honey bee populations.

Africanization of the southern United States is expected to begin between 1988 and 1990 (Taylor 1985). Allozyme analysis may be a useful method for studying gene flow from South American populations, however, at this time we lack the necessary baseline population gene frequency data. Preliminary data suggest that sufficient differences may exist in frequencies of different allozymes of malate dehydrogenase (Mdh) between North American and South American populations for them to be useful markers for measuring gene flow (Sylvester 1976; Contel et al. 1977; Nunamaker and Wilson 1981). Gene frequency data are needed for areas where populations are currently free from introgression, but likely to become Africanized, so that comparisons can be made during and after changes in behavior occur that are associated with Africanized honey bees.

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In this paper, we present an estimate of allozyme frequencies of Mdh-1 for a honey bee population in Davis, California, an area likely to become Africanized. We demonstrate that the frequencies of alleles in this population are stable over several years and are significantly different from those reported for Africanized honey bees in South America.

Methods

Two independent methods yielded 11 distinct estimates of population gene frequencies of alleles of Mdh-1: 1. The gene frequencies in 20 queens were determined by analyzing haploid sons, and 2. the frequencies of males were determined by analyzing worker daughters of 10 queens.

Study site

This work was conducted at the Bee Biology Facility, University of California, Davis, California during 1979. At that time, the University of California maintained approximately 200 experimental colonies. Most queens of these colonies were produced annually and mated with local drones. Gary (1963) identified a single drone congregating area near the research apiaries where at least some local queens and drones mate.

Davis is located in the Central Valley of California at the southern limit of what consitutes the commercial queen-rearing region of northern California, an area likely to become Africanized (Taylor 1985). This area has a high concentration of commercial beekeepers engaged in the business of raising and selling queens and packages of bees. It is likely that there is considerable gene flow between local commercial populations and those maintained at the University.

Genotypes of queens

Honey bee larvae and adults express 6 distinct electrophoretic phenotypes for Mdh-1 corresponding to homo and heterodimeric forms of 3 allozymes designated Mdh^{A}, Mdh^{B}, and Mdh^{C} (Contel et al. 1977) and redesignated as $Mdh^{1.00}$, $Mdh^{.63}$, and $Mdh^{.50}$ based on their electrophoretic mobilities (Sylvester 1976). (Sheppard and Berlocher [1984] reported an additional allozyme Mdh-1^{87} at very low frequency in a European population, but this allele was not present in any of our samples.) We will refer to the three different allozymes present in our study as the fast (F), medium (M), and slow (S) alleles.

Twenty colonies, each with a single 1-year-old, naturally-mated queen were selected at random from among 4 apiaries located within about 5 km of the Bee Biology Facility. The colonies used in this study were not part of ongoing experiments and had not been used in research for at least 2 years. Six drone larvae were collected from each colony and were analyzed for allozymes of Mdh-1 using the buffer systems described by Sylvester (1976) and the starch preparation and electrophoresis apparatus of Metcalf et al. (1971). Male honey bees are haploid and are derived directly from the egg gametes of the queen. Since the queens lay the vast majority of the eggs in a colony, both male and female, this sampling method yields a 96% probability of correctly determining the genotype of each queen.

Genotypes of mates

Queens mate with many different drones and have mechanisms to mix the spermatozoa (Page 1986). Therefore, assuming random mating, each queen carries within her spermatheca a sample of the male gene pool that can be sampled independently by the following method:

Ten queens that were determined to be homozygous for the slow (most common) allele were selected for further sampling. The number of workers that were analyzed varied among colonies (see Table 2). Since each queen in this study was homozygous for the slow allele, each of her diploid (worker) progeny expressed one slow allozymic form (allele) and an additional allele that she inherited from her own father, either slow, medium, or fast. Therefore, the genotypes of male mates are easily determined.

Samples between years

The sampling methods used allowed comparisons of gene frequencies between years. Queens were raised in 1978 and represent 1978 gene frequencies. The drones with which they mated were produced by queens of the generation belonging to the mothers of the 1978 queens and were probably raised in 1977. Therefore, the male frequencies represent the queen frequencies of the previous year.

Results and Discussion

The frequencies of the fast (F), medium (M), and slow (S) alleles estimated from queen genotypes as determined by the genotypes of their drone progeny were 0.075, 0.075, and 0.85 respectively (Table 1). The observed frequencies of homozygotes and heterozygotes were not significantly different from those expected under standard Hardy-Weinberg conditions ($X^2 = 0.00$, $P > 0.05$ with 1 degree of freedom) suggesting that the population was panmictic.

The frequency of F, M, and S allozymes estimated from the genotypic frequencies of worker progeny of SS queens did not differ significantly from those estimated from queen genotypes (Table 2). Both estimates were similar to those of 0.20, 0.11, and 0.70 for the F, M, and S allozymes, respectively, found by Sylvester (1976). The consistency of these estimates with different years suggests that they may reflect a true "population" estimate of the allozyme frequencies at this particular locale. The combined average of three independent estimates (giving equal weighting to each)

GENOTYPE	EXPECTED	OBSERVED
SS	14	14
SM	3	3
SF	3	3
MM + FF + MF	0	0

Table 1. Expected (under Hardy-Weinberg conditions [see Crow and Kimura 1970]) and observed genotypes of queens.

Table 2. Worker genotype frequencies for 10 queens that were homozygous SS. Frequencies of genotypes SS, SM, and SF correspond to allele frequencies of S, M, and F, respectively. The progeny of each queen constitute a separate sample of alleles from the drone gene pool. The asymmetrical confidence limits on gene frequencies were derived by first performing an angular transformation on the data, multiplying the transformed standard error by 2.262 (t for alpha = 0.05 with 9 degrees of freedom), then back transforming (Sokal and Rohlf 1969, pp. 386–387).

Queen	Worker Genotype Frequencies			
	SS	SM	SF	Total Counts
1	0.85	0.02	0.15	52
2	0.64	0.06	0.30	321
3	0.58	0.15	0.26	65
5	0.88	0.12	0.00	8
7	1.00	0.00	0.00	23
8	0.27	0.11	0.62	352
11	1.00	0.00	0.00	8
14	0.43	0.00	0.57	7
15	0.89	0.02	0.09	53
16	0.94	0.04	0.02	52
Mean	0.75	0.05	0.20	
S. E.	0.080	0.018	0.074	
95% confidence limits of allele frequencies				
	S	M	F	
L_1	0.96	0.08	0.31	
L_2	0.58	0.00	0.01	

Table 3. Estimates of Mdh-1 allozyme frequencies of Africanized honey bees from Brazil. The frequencies shown are all outside of the 95% confidence limits on the estimation from Davis, California (see Table 2).

No. of colonies	Allele Frequencies S	M	F	Reference
34	0.01	0.16	0.84	Sylvester (1976)
78	0.03	0.20	0.77	Contel et al. (1977)
12	0.04	0.03	0.93	Nunamaker and Wilson (1981)

for the three alleles are 0.16 ± 0.042 E., 0.08 ± 0.017, and 0.77 ± 0.044 for F, M, and S, respectively (95% confidence limits determined for the angular transformed data are 0.02-0.38, 0.02-0.17, and 0.55-0.93, respectively).

These estimates differ considerably from those published for Africanized honey bees in South America where the F allele is the most common (Table 3). They may be useful as indicators of gene frequency changes within the population as a consequence of Africanization of the honey bee population if it occurs as predicted (Taylor 1985; Rinderer 1986). Page and Erickson (1985) point out the major difficulties with using allozyme data for identification of colonies of Africanized bees,

however, allozyme frequencies may still be useful indicators of gene flow providing population estimates exist prior to changes in the gene pool. Gene frequency changes, if they occur, could be a consequence of differential gene migration from South to North America or a consequence of a physical replacement of North American colonies of bees by those from South America. Current data are insufficient to distinguish between these alternative potential mechanisms of Africanization.

It is of course possible that commercial beekeeping practices around our study site could alter the population gene frequencies before Africanization occurs. However, if commercial populations throughout North America have similar gene frequencies there will be no net change. A general survey of North American gene frequencies is needed to determine if the large differences in gene frequencies observed between Davis, California and Brazilian Africanized bees is "typical".

Acknowledgement

We thank Gene Robinson for his editorial suggestions on an earlier draft of this manuscript.

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PAN-PACIFIC ENTOMOLOGIST
64(3), 1988, pp. 291–295

A Concentration Site for Cerambycidae in Jalisco, Mexico (Coleoptera)

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Early in July, 1987, J. A. Chemsak, E. G. Linsley and J. M. Linsley visited the Estacion de Biologia Chamela in Jalisco, Mexico to gather additional data for the expanding list of Cerambycidae already known from the environs of the Estacion. At this time the rainy season had not yet begun at the Estacion and the deciduous trees were mostly bare and in the surrounding area poinciana (introduced ornamental) and plumeria (a white-flowered ornamental used in other tropical countries but not an attractive anthophilous insect plant) provided about the only color in the environment. Under the circumstances, any hope for finding diurnal flower and leaf inhabiting cerambycids was out of the question and efforts at the station were directed to nocturnal (light) collecting, which was only moderately productive.

We were informed by Steve Bullock that the region immediately south had received more rain and that the season had progressed much more than at the station. He also suggested that the sign along the highway advertising the Fiesta Americana Hotel might be worth checking for specimens. This sign is about 5.5 meters high and 7.5 meters wide and is located off the highway at the entrance road to the hotel to the right heading south (40 km S. of the station, 21 km N Melaque junction). The sign has colored lettering on a white background and is situated 6–7 meters above the side road. Two large white lights illuminate the sign all night until about 7:00 AM.

We first stopped at this location on July 9 at about 9:00 AM. At this time the sun was fully shining on the surface. It was immediately apparent from the road that many insects were still present on the sign. This initial effort produced 54 specimens of 19 species of Cerambycidae. Subsequently, six early morning (6:00–6:30 AM) visits were made to this site.

F. Hovore arrived at the station on July 15 and was informed of the site and its attractiveness to Cerambycidae. Subsequently he made daily collections for another six days and his results have been incorporated in the table.

As a result, the thirteen days of collecting at the sign produced nearly 1700 specimens representing 101 species. Among these, the largest numbers of specimens are in the tribe Elaphidiini which accounted for 1059 individuals of 35 species. Significantly, the period of Hovore's sampling produced about 400 more individuals but only about 20 more species. Seasonal progression and intervening rainfall probably account for the increased numbers.

Also of interest is the fact that the first series of collections contained about 15 species not collected by Hovore and the second series included about 20 species not encountered earlier.

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Daily totals of Cerambycidae collected at Fiesta Americana Hotel sign during 9–22 July, 1987.

	9	10	11	12	13	14	15	17	18	19	20	21	22	Total
Eburia nigrovittata Bates	1					2		1	1	1				6
Eburia sp.	6	3	2	5	3	1		12	15	14	9	7	3	80
Eburodacrys callixantha Bates	1					2	1	2	1	2	1	2	1	13
Austrophanes robustum Chemsak & Linsley	1		2	2	1	1			2					9
Consosphaerion concolor concolor Linsley	1	2	2	3		1		5	1	3	2	2	2	24
Pseudoperiboeum subarmatum Linsley	1				1	1	1	8	6	5	3	5	4	35
Eutrichophoroides jansoni (Bates)	11	5	2	16	23	32	12	38	40	37	45	28	21	310
Elaphidion mimeticum Schaeffer	1	1					1							3
Orwellion gibbulum gibbulum (Bates)	3	1	3	2			1	5		1	1	1	2	20
Anelaphus nitidipennis Chemsak & Linsley	1	2	1	2	2	1	1			1		2		13
Ironeus submetallicus Chemsak & Linsley	11	2	4	16	9	6	3	18	16	29	14	13	9	150
Neocompsa puncticollis asperula Martins & Chemsak	4	3		22	11	5	2	3	3	3	2	3	5	66
Obrium ruficolle Bates	1	1		8	3	3	1		2	2	5	6	4	36
Gnaphalodes trachyderoides Thomson	1								1					2
Hippopsis sp.	1													1
Aegomorphus chamelae Chemsak & Giesbert	1	1			1			1		4	5	3	1	17
Aegomorphus sp.	6	3	1	3	3	1		5	1	1	2	2		28
Olenosus serrimanus Bates	1			1			1			1		1	1	6
Lepturges angulatus (LeConte)?	1	1					1	1	3	1	1			9
Strongylaspis corticaria (Erichson)		3		4	3			7	9	2	2	4		34
Eburia laticollis Bates		1		5	5		2	2	3	4	3	5	2	32
Eburia juanitae Chemsak & Linsley		1		1										2
Eburodacrys hesperidis Chemsak & Linsley		1	1	1					1	2		2	1	9
Peranoplium sp.		1												1
Ironeus pulcher Bates		1	2	15	5	6	3	8	20	17	11	15	13	116
N. sp. near Ironeus		1	1	3	2	2	2							11
N. gen., N.sp. near Ironeus		1	2	12	10	15	9	10	9	11	10	12	6	107
Psyrassa cylindricollis Linsley		1	2	7	4	5	3	7	4	3	1	1	3	41
Psyrassa nigricornis Bates		1		1		4	4		1			1	1	13
Elytroleptus scabricollis Bates		1												1
Aegomorphus sp.		1						1	1		1		1	5
Lepturges limpida Bates		2		1			2	1						6

Cymatonycha n.sp.	4	2	13	2	6	4	3	7	2		1	2	46
Derobrachus sulcicornis LeConte		2		3	2	3	1	3	1	3	2	2	22
Peranoplium sp.		1											1
Eutrichophoroides albisparsus (Bates)		1				2							3
Neotrichophoroides decipiens (Bates)		1		1		2	5	3	1	1	2	3	19
Micropsyrassa pilosella (Bates)		3	2	1	1		1			1	1		10
Psyrassa sthenias Bates		1	3	1	3	2	7	16	3	2	2	5	45
Psyrassa sp.		4		3	1	2	2	1	1	1		2	17
Anopliomorpha reticolle (Bates)		2	1	2	1		3	6	12	5	6	6	44
Psyrassa sp.		1											1
Triacetelus sericatus Bates		1											1
Lepturges sp.		1	3	2	1	4							11
Leptostylus sp.		1								1			2
Stenodontes lobigenus Bates			2			1		1	1			1	6
Malacopterus tenellus (Fabricius)			2	4			1	4	3	3	5	4	25
Eburia perezi Chemsak & Giesbert			1					1	1			1	4
Xeranoplium puncticolle Chemsak & Linsley			1								3		4
Gymnopsyra sp.			1	7	1	2	5	3	4	5	1	1	30
Stenosphenus sp.			2					1	2		1	2	8
Micropsyrassa doyeni Chemsak & Giesbert		2	1	2			2	3	2	1	2		15
Psyrassa sp.		1											1
Aneflomorpha rectilinea rectilinea Casey		2		7	1	2	2	1	2		2		19
Neocompsa exclamationis (Thomson)		1		1							1		3
Obrium giesberti Hovore & Chemsak		1							1	2	2		6
Cacostola sp.		1					1						2
Aegomorphus sp.		1											1
Eutrichillus comus (Bates)		1											1
Eburia sp.			1										1
Peranoplium sp.			1										1
Ironeus mutatus Bates			1		1								2
Psyrassa aliena Linsley			2	1	3	4	2		2	2	1		17
Psyrassa sp.			1				1	1		2			5
Heterachthes sp.			1					1					2
Cosmisoma reticulata Bates			1										1
Lochmaeocles n.sp.			1							3			4

Stenodontes dasytomus dasytomus (Say)	1								1
Eburia hatsueae Chemsak & Giesbert	1			1	1		1		4
Eburia paraegrota Chemsak & Linsley	1							2	3
Xeranoplium pubescens Chemsak & Giesbert	1						1		2
Aneflomorpha giesberti Chemsak & Linsley	1					2		1	4
Plagiohammus imperator (Thomson)	1			1					2
Alcyopis chalcea Bates		1			1		1		3
Estoloides sp.		1		2			1	1	5
Oncideres sp.		1							1
Acanthocini		1							1
Erosida yucatana Giesbert			1						1
Aneflus rugicollis Linsley			1	5	1	1	4	1	13
Stenosphenus sp.			1	1	1				3
Elaphidiini sp.			1		1	1			3
Compsibidion vanum Thomson			1	1		1			3
Lochmaeocles cornuticeps pacificus Dillon & Dillon			1	1	1		3		6
Megapsyrassa linsleyi Chemsak & Giesbert				1		2		2	5
Schwarzerion holochlorum holochlorum (Bates)				1					1
Ornithia mexicana (Sturm)			1						1
Achryson surinamum (Linnaeus)					1				1
Aegomorphus sp.					1			3	4
Atrypanius conspersus (Germar)					1			1	2
Antodice sp.					1				1
Elaphidiini sp.							1		1
Neocompsa alacris (Bates)							1		1
Acyphoderes amoena Chemsak & Linsley							1		1
Ecyrus lineicollis Chemsak & Linsley							1		1
Leptostylus gibbulosus Bates							1		1
Stizocera plicicollis (Germar)								1	1
Neocompsa agnosta Martins								1	1
Oreodera glauca glauca (Linnaeus)								1	1
Eupogonius sp.								1	1
Ptericoptus sp.								1	1
Urgleptes sp.								1	1
									1664

Figure 1. The sign after cerambycidae had been collected.

In order to further determine the productivity of this collecting site, J. A. Chemsak & J. A. Powell visited Chamela from October 16 to 22, 1987. An early morning (October 17) trip to the sign provided disappointing results. Only 25 specimens representing 7 species were encountered. One more attempt on October 22 produced 26 specimens (9 species). Since all of these species (*Aneflus bullocki, Malacopterus tenellus, Olenosus serrimanus, Aegomorphus* sp., *Lochmaeocles* sp., *Brasilianus mexicanus, Derobrachus sulcicornis,* and 4 species of Acanthocini) were present in greater numbers at the Estacion, further attempts to collect at the sign were not made.

In general, during this beginning of the dry season, light collecting for Cerambycidae was rather poor in the entire region. That is, poor in relation to the peak of the season in July. The species composition also differs with only a few of the July species being present in October.

We gratefully acknowledge the authorities of the Instituto de Biologia, UNAM and Luis Alfredo Perez J., Chief of the Estacion de Biologia Chamela, for making the excellent facilities of the station available for our use. Juanita M. Linsley provided the photography as well as valuable field assistance.

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Essig, E. O. 1926. A butterfly migration. Pan-Pac. Entomol., 2:211–212.
Essig, E. O. 1958. Insects and mites of western North America. Rev. ed. The Macmillan Co., New York, 1050 pp.

Abbreviations for titles of journals should follow a recent volume of *Serial Sources for the Biosis Data Base,* BioSciences Information Service. For **Scientific Notes** the citations to articles will appear within the text, i.e. . . ."Essig (1926, Pan-Pac. Entomol., 2:211–212) noted. . . ."

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Vol. 64 October 1988 No. 4

THE PAN-PACIFIC ENTOMOLOGIST

SAN FRANCISCO, CALIFORNIA • 1988
***Published by the* PACIFIC COAST ENTOMOLOGICAL SOCIETY**
***in cooperation with* THE CALIFORNIA ACADEMY OF SCIENCES**

The Pan-Pacific Entomologist

Published quarterly in January, April, July, and October with Society Proceedings appearing in the October number. All communications regarding nonreceipt of numbers, requests for sample copies, and financial communications should be addressed to the Treasurer, Dr. Wojciech J. Pulawski, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

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The annual dues, paid in advance, are $15.00 for regular members of the Society, $7.50 for student members, $30.00 or more for sponsoring members, or $20.00 for subscription only. Members of the Society receive *The Pan-Pacific Entomologist.* Single copies of recent numbers are $5.00 each or $20.00 a volume. See back cover for prices of earlier back numbers. Make checks payable to the *Pacific Coast Entomological Society.*

Statement of Ownership

Title of Publication: The Pan-Pacific Entomologist.

Location of Office of Publication, Business Office of Publisher and Owner: Pacific Coast Entomological Society, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118-4599.

Editor: J. A. Chemsak, 201 Wellman Hall, University of California, Berkeley, California 94720.

Managing Editor and Known Bondholders or other Security Holders: None.

This issue mailed March 17, 1989

The Pan-Pacific Entomologist (ISSN 0031-0603)
PRODUCED BY A-R EDITIONS, INC., MADISON, WI 53703, U.S.A.

PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 297

IN MEMORIAM
Pedro W. Wygodzinsky
1916–1987

Dr. Pedro W. Wygodzinsky, world authority on Reduviidae, Dipsocoroidea, Simuliidae, Microcoryphia, and Thysanura, and Curator of Entomology at the American Museum of Natural History, died at a nursing home in Middletown, New York, on January 27, 1987, after several years of declining health, at age 70. Born in Bonn, Germany on October 5, 1916, of Czechoslovak parents, he recalled an early interest in *Helix* snails, at the age of 4 or 5, that was nurtured by his mother, and "from there to insects was a small step." Attending the University of Basel, in Switzerland, from 1935–1939, he received his Doctorate degree under the direction of Prof. Eduard Handschin. His first research and publications dealt with the Diplura and Thysanura. He was a linguist and published his scientific papers in English, French, German, Portuguese, and Spanish.

In 1941, Wygodzinsky decided to emigrate to Brazil, first working in the Malaria Service. From 1943 to 1948 he was employed as Systematic Entomologist with the Ministry of Agriculture, Rio de Janeiro. The first of his numerous publications on Reduviidae appeared in 1943. In 1948, in a move to Argentina, he was appointed

Pedro W. Wygodzinsky, taken at Tucumán, Argentina, in 1951 (Edward S. Ross photo).

Chief of the Department of Entomology, Instituto de Medicina Regional, at the University of Tucumán, and from 1959–1962, as Professor of Entomology on the Faculty of Exact and Natural Sciences at the National Museum of Buenos Aires. In 1949, he commenced a series of papers on Argentine and Neotropical Simuliidae. Wygodzinsky held two Guggenheim Fellowships to study in the United States, in 1955–56, and 1960–61, at which time he was associated with Dr. Robert L. Usinger, at the University of California, Berkeley.

Appointed an Associate Curator in Entomology at the American Museum of Natural History in 1962, Wygodzinsky was promoted to Curator in 1966. He was very dedicated to his research, paying no attention to an eight hour working day, which permitted his publishing over 250 papers that included several thousand of his own detailed line drawings. Wygodzinsky made available to the English reading public one of the works of Willi Hennig through his translation from the German of "The Diptera Fauna of New Zealand as a Problem in Systematics and Zoogeography," published as Pacific Insects Monograph Number 9 in 1966.

This warm man with the sparkle of humor always in his eyes was much admired by students and colleagues, many of whom became his good friends. A man of great personal and professional integrity, Pedro (Petr, Pete, Wygo) is fondly remembered for his humanity as well as for his accomplishments.

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PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 299–312

High Altitude Flower-Breeding *Drosophila* (Diptera: Drosophilidae)

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Abstract.—Four new species of **Drosophila** (Diptera: Drosophilidae) which breed in flowers in the region of Bogota, Colombia are described and named here. *D. chisaca* breeds only in the flowers of *Espeletia hartwegiana. D. acuminanus* breeds in *Liabum megacephalum* while *D. colmenares* and *D. franii* breed in both *L. megacephalum* and *Bidens rubifolia.* They are characterized by wide ovipositor plates with many stubby teeth. The eggs lack filaments and are laid between the buds of the disc flowers of these composites. The 4 species belong to the group of six anthophilic *Drosophila* previously described from the same region.

Over 100 species of *Drosophila* have been reported to breed in flowers (Brncic, 1983). Many of these utilize decaying flowers and the larvae feed on microorganisms. For example, cosmopolitan species such as *D. immigrans* Sturtevant and *D. busckii* Coquillett are polyphagous and the larvae develop in a variety of decaying plants. *Drosophila* which require living flowers for larval development have been described by Pipkin (1964, 1966), Heed (1968), Lachaise (1974) and other workers listed in the review by Brncic (1983). I have described 5 new species of obligate flower breeders from altitudes of over 2,000 m. in Colombia (1979). Relatively few collections of *Drosophila* have been made at higher elevations, but Heed, Carson and Carson (1960) reported associations of Drosophilidae with flowers of the Bogota region of Colombia. In continuing these studies I have found 4 more new species which breed in the flowers of several species of composites. Their descriptions follow.

Drosophila chisaca, NEW SPECIES
(Figs. 1 & 2)

External characters of imagines.—Arista with 3 dorsal and 1 ventral branches in addition to terminal fork. Basal antennal segments pale gray; 3rd segment light tan (brown on allotype female); 1 medium and 1 long bristle on 2nd segment. Frontal and ocellar triangles pale grey (darker on allotype female). Anterior proclinate orbital bristle 2/3 length of posterior reclinate; anterior reclinate 1/3 of posterior. Face very pale grey; carina high, narrow, slightly sulcate. Cheeks gray, wide; 1 long oral bristle; 2nd bristle 1/2 length of 1st. Distance from border of eye to base of 1st oral 1/5 of greatest diameter of eye. Eyes light plum; fine yellow pile; eye index (height divided by width) 1.1. Palpi pale gray with 1 long, several medium length hairs.

Acrostichal hairs in 5–6 rows between dorsocentrals; no prescutellars; anterior scutellars divergent. Thorax, including pleurae and scutellum uniform gray (allotype

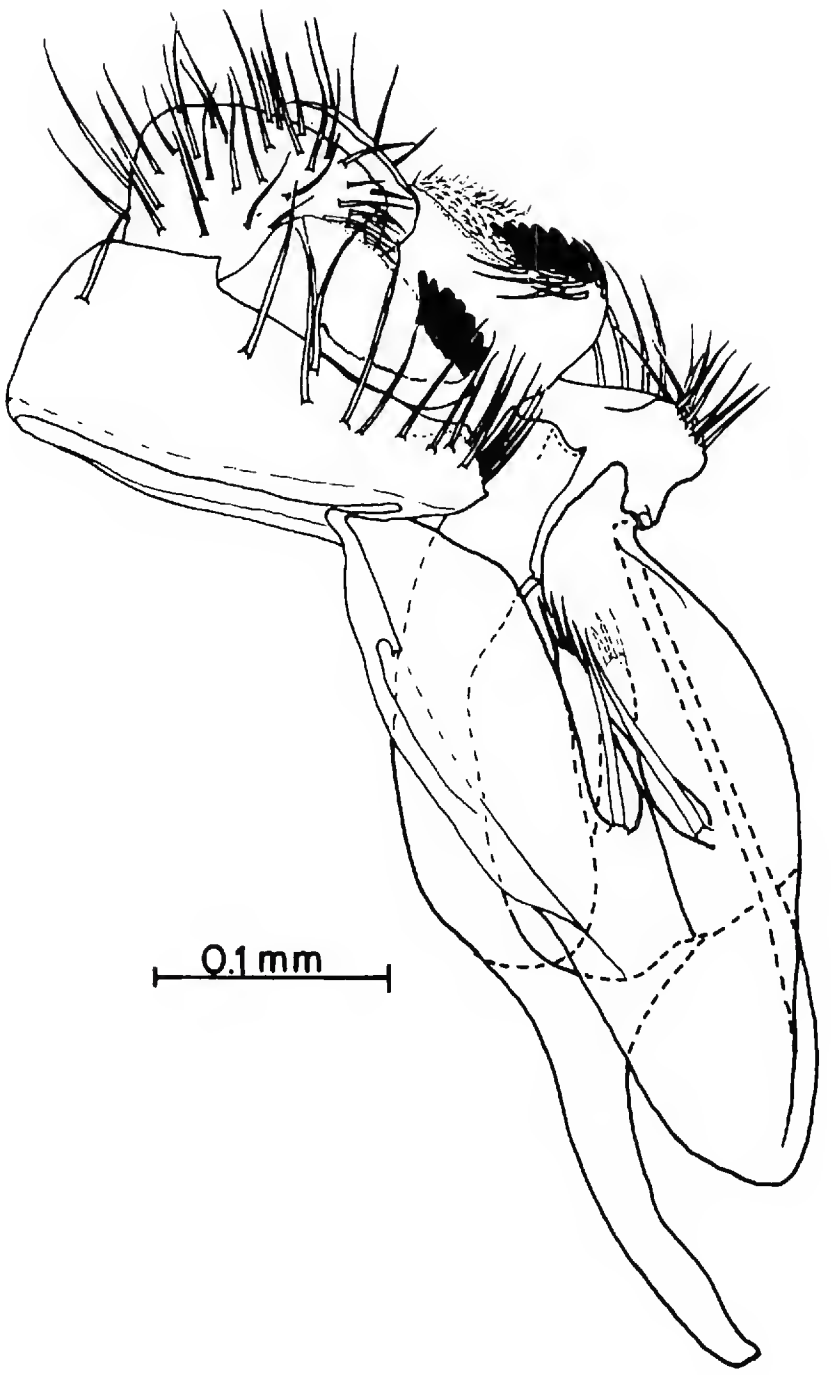

Figure 1. *Drosophila chisaca,* male genitalia.

female darker steel gray); halteres very pale gray. Anterior sternopleural bristle 2/3 length of posterior; 1 short hair between them.

Legs pale yellow except brown terminal tarsal segment. Apical and pre-apical bristles on 1st and middle tibiae; pre-apicals only on third tibiae; bristles of 1st and 3rd legs very pale and delicate; several long, pale yellow bristles on front femora.

Wings pale yellow with slightly darker veins. Costal index 3.9, 4th vein index 1.8, 4c index 0.7, 5x index 1.0. Thicker hairs continue along anterior border to basal 1/2 of 3rd section of costa.

Abdomen gray; each tergite with broad, dark gray band. Allotype female darker.

Body length, males, 2.6 mm; females, 3.0 mm. Wing length, males, 3.3 mm; females, 4.0 mm.

Genitalia of D. chisaca (Figs. 1 & 2).—Aedeagus pale tan; slightly curved. Blunt apex appears chopped off in lateral view; inverted V-shaped trough open ventrally;

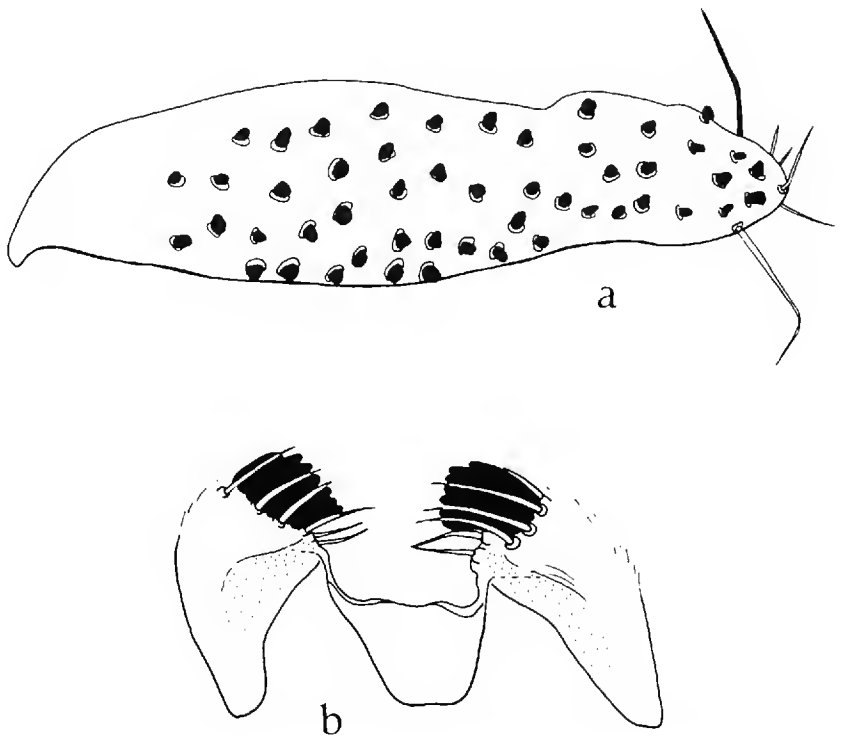

Figure 2. *Drosophila chisaca,* a. left ovipositor plate, b. male claspers, c. *Espeletia hartwegianae* in the paramo of Chisaca.

small, sharp point at both ends and apex of V; apodeme very slightly curved. Hook of genital arch articulates over pointed posterior corner of hypandrium on each side. Genital arch fused to anal plate; tuft of 8 yellow bristles on anterior, medial apex; row of 7–8 yellow bristles on posterior edge extends over clasper. Claspers with 6–7 long, thin, black primary teeth and many short, fine, yellow hairs all over outer surface; long, yellow hairs on inner surface. Claspers united by wide, dorsal bridge. Hypandrium with long, medio-ventral bristle on each side; narrow, finger-like gonapophyses with 3–4 long, yellow hairs.

Spermathecae dark brown, ovoid. Narrow ovipositor plates with 2 short, 1 medium length hairs at tip; 2 longer hairs on dorsal surface; 50–65 short, stubby, black

teeth on each ovipositor plate. Ovipositor plates extend posteriorly from last segment; internal tube extends out beyond the plates.

Other characteristics of D. chisaca.—The adult body shape is narrow like that of *Scaptomyza.* The eggs are without filaments; one female was observed extruding a larva. Eggs, larvae and pupae are found in flowers of the composite, *Espeletia hartwegiana* Cuatrecasas. *Drosophila chisaca* was found only in these plants in the paramo of Chisaca, about 50 kilometers south of Bogota on the unpaved road of El Hato. It was not found in the other species of *Espeletia,* nor in the other paramos. *Drosophila freilejoni* Hunter were also growing in the same flowers along with *D. chisaca.* Sweeping with a net, or attempts at aspiration were not successful because no flies were around the flowers or resting on them. Dry flowers containing pupae were collected and the adults emerged several days later. *Drosophila chisaca* is most closely related to the anthophilic species, *D. freilejoni, D. desbaratabaile* Hunter, *D. arboloco* Hunter, *D. bomarea* Hunter and *D. margarita* Hunter.

Holotype male emerged from flowers of *E. hartwegiana* collected in the paramo of Chisaca, 50 km south of Bogota, VIII–29–80, A. S. Hunter. Paratypes, same locality and date. Holotype #15855 and paratypes deposited in California Academy of Science.

Drosophila acuminanus, New Species

(Figs. 3 & 4)

External characters of imagines.—Arista with 2 dorsal and 1 ventral branches in addition to terminal fork; wide separation between 2 dorsal branches. Antennal segments brown with 1 medium length and 2 short bristles on 2nd segment. Frontal and ocellar triangles black. Anterior proclinate orbital bristle 2/3 length of posterior reclinate; anterior reclinate 2/3 of proclinate bristle. Face brown; carina medium height, not sulcate. Cheeks brown, narrow; 1 long oral bristle. Distance from border of eye to base of first oral bristle 1/5 of greatest diameter of eye. Eyes dark wine-red; eye index 1.1. Palpi tan with 1 long, several medium hairs.

Acrostichal hairs in 6–7 rows between dorsocentrals; anterior dorsocentral 2/3 length of posterior; no prescutellars; anterior scutellars divergent. Thorax shiny black, pleurae duller; halteres tannish yellow. Anterior sternopleural bristle 2/3 length of posterior; middle, 1/4 length of first sternopleural.

Legs with black coxae; femora mostly black except paler distally; tibiae and tarsi tannish yellow except terminal black tarsal segment. Delicate, short pre-apical bristles on first and third legs; black, strong pre-apical and apical bristles on middle legs; few long bristles on first femora.

Wings pale tan, veins tan. Costal index 3.8, 4th vein index 1.8, 4c index 0.6, 5x index 1.2. Thicker, heavier hairs continue along border to almost basal half of third section of costa.

Abdomen brown, each tergite with wide black band, complete laterally; sternites gray; abdomen relatively short, fat.

Body length, males 2.6; females, 2.8 mm. Wing length, males 3.0 mm; females, 3.2 mm.

Genitalia of D. acuminanus (Figs. 3 & 4)—Aedeagus tan, very slight dorso-ventral curve, trough-shaped shaft with serrated borders; at apex, lateral extensions form pointed tips. Penis curves asymmetrically left; apodeme long, thick, straight. Genital arch joined to anal plate dorso-posteriorly. Hypandrium articulates with genital

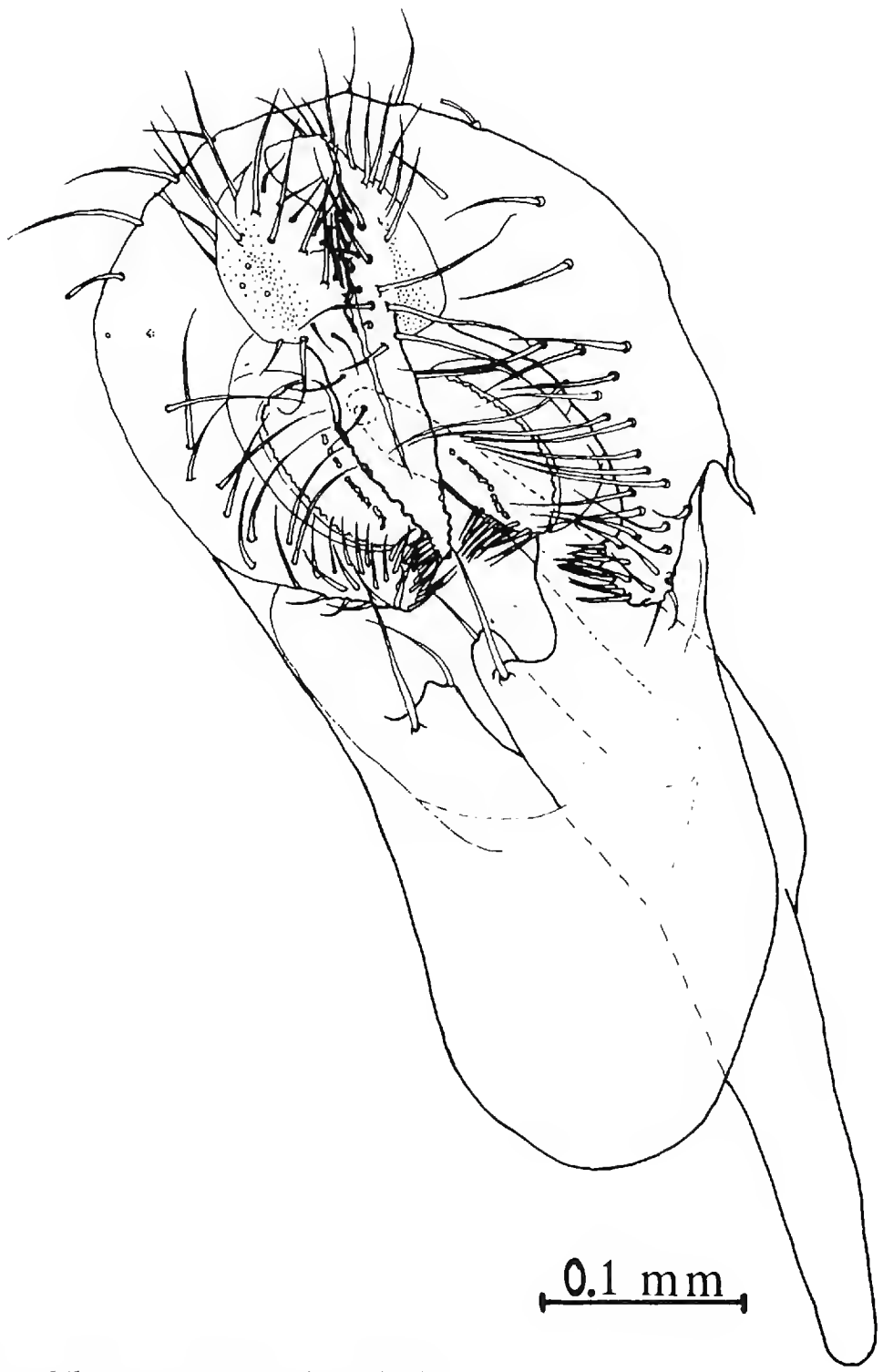

Figure 3. *Drosophila acuminanus,* male genitalia.

arch; latter with thick tuft of 10–12 medium length, black bristles on long toe; 18–20 long bristles on genital arch overlap claspers. Unusual claspers lack typical teeth; covered with fine, short, yellow hairs; cluster of long, thin yellow bristles at antero-medial apex; middle of each clasper with curved row of about 10 pegs, 3 small teeth at anterior end of row; lateral surface of each clasper with curved, elevated ridge of several irregular rows of about 50 short teeth. Claspers united by narrow bridge with median projection. Hypandrium with long, medio-ventral bristle on each side; gonapophyses broad, each with a single bristle.

Spermathecae dark brown, pear-shaped. Ovipositor plates brown, curved, with many small fine teeth all over; 15 longer teeth dorsally; 3 apical hairs project from each plate.

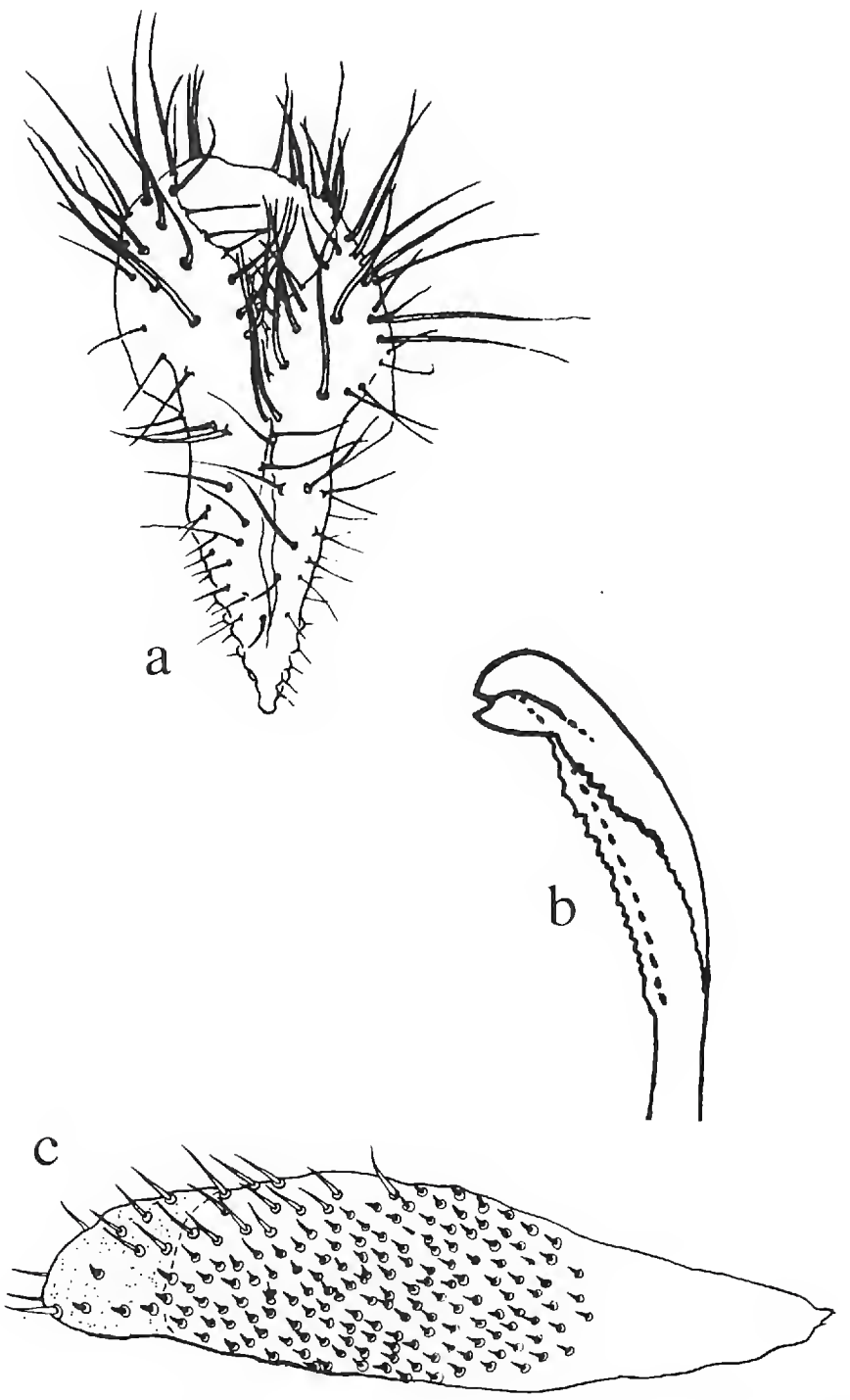

Figure 4. *Drosophila acuminanus,* a. male anal sternite, b. tip of aedeagus, c. right ovipositor plate.

Other characteristics of D. acuminanus.—The adult body looks short and fat compared to other *Drosophila.* The eggs lack filaments and are pointed anteriorly. The adults emerge from flowers of *Liabum megacephalum* Schultze, which is a yellow-flowered composite. They rest on these flowers and other related composites in the vicinity. They occur in a wooded area in the aqueduct drainage of the mountain, Monserrate. This species was not found anywhere else in extensive collections in the Bogota region.

Drosophila acuminanus is most closely related to the other anthophilic *Drosophila,* such as *D. margarita,* associated with composite flowers in the Bogota region. The presence of many teeth all over the ovipositor plates, the asymmetry of the aedeagus and lack of egg filaments are characteristic of this anthophilic group of *Drosophila* from the Bogota region. The pointed apex of the anal sternite which covers over

the external genitalia and the lack of teeth on the claspers are characteristics which distinguish this species from the other related anthophilic flies. The species is named for the unusual anal sternite.

Holotype male swept over flowers of *L. megacephalum* along the river in the aqueduct drainage of the mountain, Monserrate in Bogota, VIII–15–80, A. S. Hunter. Paratypes from same locality. Holotype #15852 and paratypes deposited in California Academy of Sciences.

Drosophila colmenares, New Species

(Figs. 5 & 6)

External characters of imagines.—Arista with 2–3 dorsal and 2 ventral branches ventral branches in addition to terminal fork. Basal antennal segments brown; 2 long bristles on 2nd segment. Frontal and ocellar triangles dark brown. Anterior proclinate orbital bristle 2/3 length of posterior reclinate; anterior reclinate 2/3 of anterior proclinate; orbital region dark brown. Face brown; carina moderately high, sloping lower ventrally; not sulcate but with a medial, pale line. Cheeks brown, average width, with 1 large oral bristle. Distance from border of eye to base of 1st oral 1/4 greatest diameter of eye. Eyes sepia with fine pile; eye index 1.2. Palpi tan with many fine hairs and 2 slightly longer hairs.

Acrostichals in 6 rows between dorsocentrals; no prescutellars; anterior scutellars divergent. Thorax, including pleurae and scutellum shiny brown; halteres tan. Anterior sternopleural bristle 2/3 length of posterior; middle sternopleural bristle very fine and 1/3 length of first.

Legs pale yellow except brown terminal tarsal segment. Apical and pre-apical bristles on 1st and middle tibiae; 1st apical bristle thin and small; fine pre-apical bristles on posterior tibiae; 5 long, dark bristles on first femora.

Wings pale grey with tan veins. Costal index 3.6, 4th vein index 1.7, 4c index 0.7, 5x index 1.2. Thicker, heavier hairs continue along border to basal 2/5 of 3rd section of costa.

Abdomen tan with dark brown bands, wider on anterior segments and in midline, thin laterally, especially on posterior segments. Allotype female with darker abdomen, more pronounced bands extending laterally.

Body length, males, 2.8 mm; females, 3.0 mm. Wing length, males, 3.0 mm; females, 3.2 mm.

Genitalia of D. colmenares (Figs. 5 & 6).—Aedeagus tan; C-shaped. Apex sharply pointed dorsally; another dorsal spike immediately anterior to tip; ventral apex much broader, paler and spoon-shaped. Apodeme slightly curved. Genital arch fused to anal plate; an irregular row of 8 long, black bristles extends from medial border of arch to overlap claspers; 5 long, black hairs on anterior medial apex. Claspers with 10 primary teeth and many short, fine, yellow hairs over external surface; 3 yellow bristles on internal surface. Claspers united by wide, dorsal bridge. Hypandrium with long, medio-ventral bristle on each side; short, wide-based gonapophyses with 3 long, yellow hairs.

Spermathecae dark brown, ovoid. Narrow ovipositor plates curved ventrally at blunt, dark end, 3 hairs at ventral, apical surface and 1 stouter hair posterior to them; 4 hairs on dorsal apical surface; 44–48 short, stubby teeth on each plate. Ovipositor plates extend out posteriorly beyond last segment; non-chitinized internal tube extends posteriorly beyond plates.

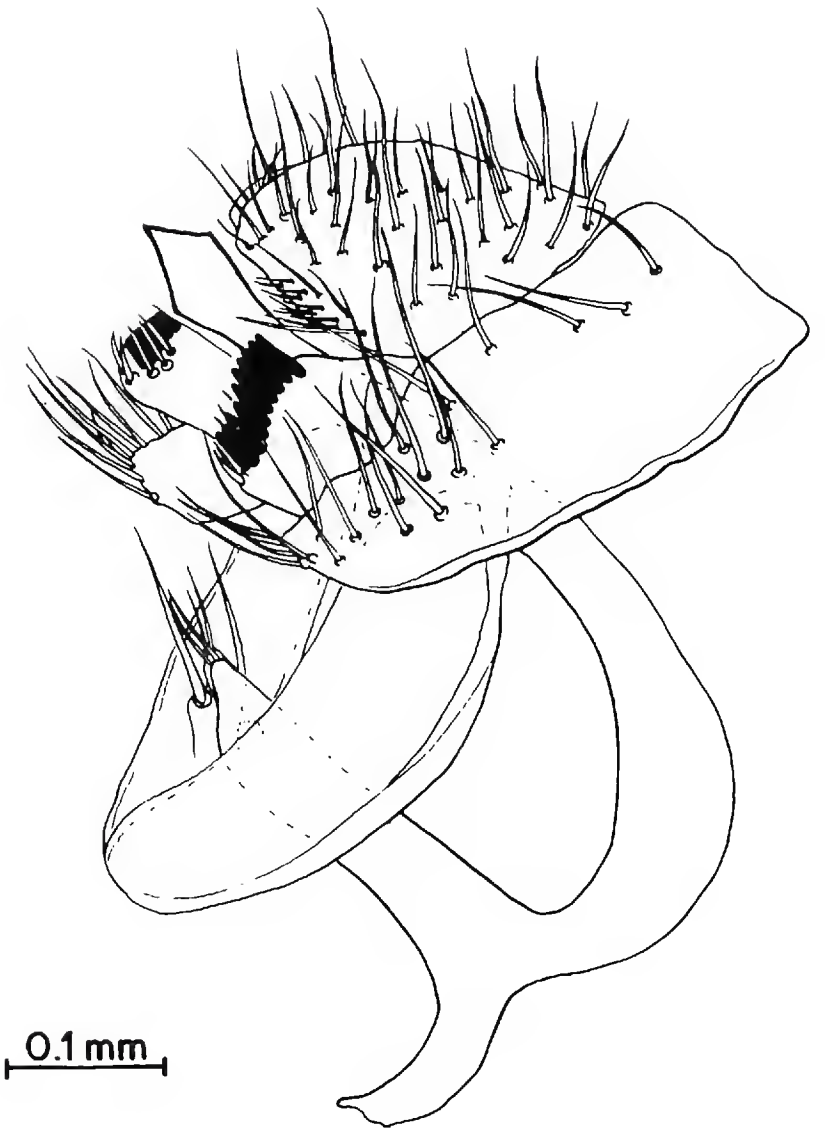

Figure 5. *Drosophila comenares,* male genitalia.

Other characteristics of D. colmenares.—The eggs are without filaments. They are laid in between the disc flowers of 2 composites in which the larvae feed and pupae are formed. The 2 species of plants were identified by Dr. Enrique Forero of the Universidad Nacional as *Liabum megacephalum* and *Bidens rubifolia* Humboldt. These plants grow in the watershed of the Bogota aqueduct between the mountains of Monserrate and Guadelupe as well as the paramo of Choachi. *Bidens rubifolia* is also found south of Bogota on the road to El Hato. These composites are hosts for other species of *Drosophila* as well as other insects. *Drosophila* can be seen flying around the flowers sometimes. *Drosophila colmenares* has the ovipositor studded with many teeth, the asymmetrical aedeagus and lack of egg filaments which are characteristic of related anthophilic species such as *D. freilejoni* and *D. arboloco.* This new species is named for Miguel Angel Colmenares who spent many hours collecting anthophilic *Drosophila.*

Holotype male swept from flowers of *L. megacephalum* in the aqueduct watershed of the mountain Monserrate in Bogota, VIII–13–80, A. S. Hunter. Paratypes from same locality. Holotype #15857 and paratypes deposited in California Academy of Sciences.

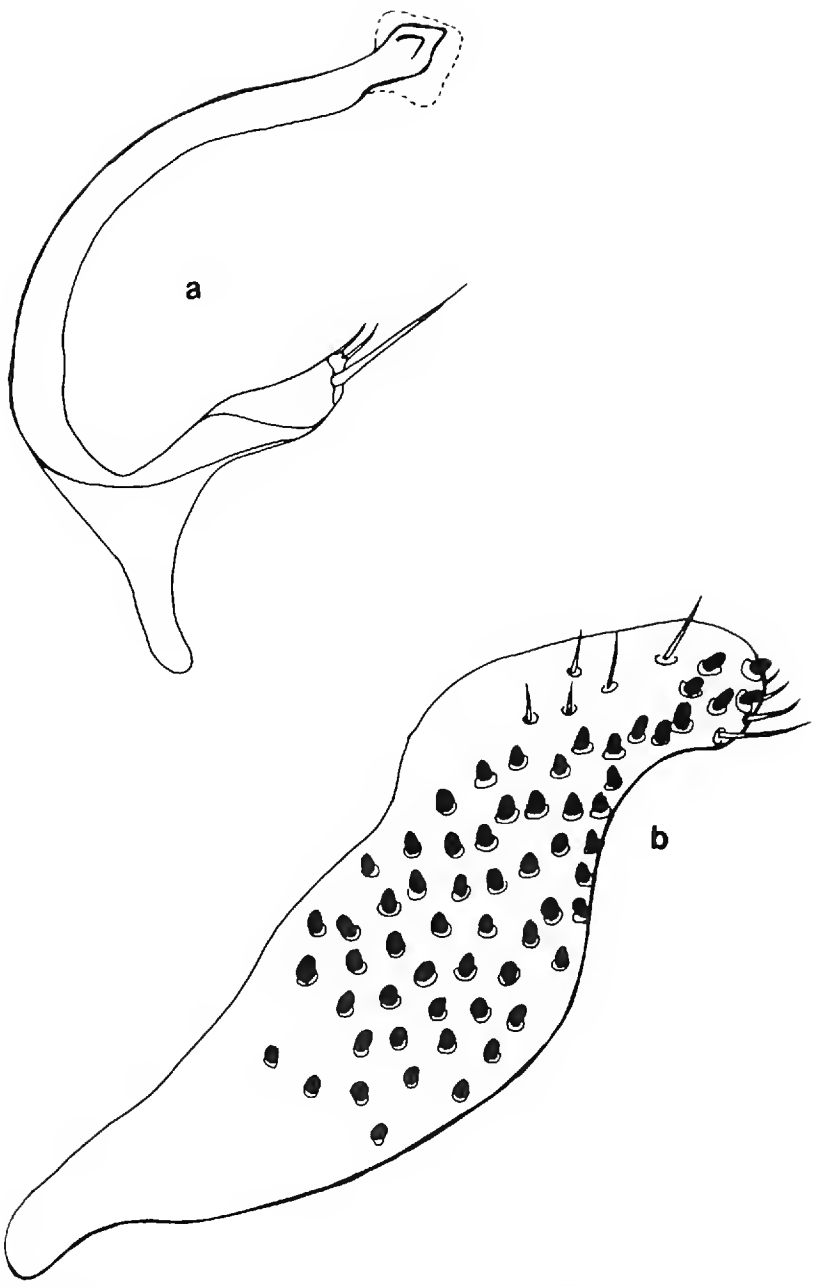

Figure 6. *Drosophila colmenares,* a. aedeagus, b. left ovipositor plate.

Drosophila franii, New Species
(Figs. 7 & 8)

External characters of imagines.—Arista with 3 dorsal and 1 ventral branches in addition to terminal fork. Basal antennal segments light brown; 3rd segment dark brown. One medium and one long hair on 2nd segment. Frontal and ocellar triangles dark brown surrounded by gray-brown. Anterior proiclinate orbital bristle 3/4 length of posterior reclinate; anterior reclinate 1/2 of posterior. Face brown; carina medium height, not sulcate. Cheeks wide, grayish brown; 1 large oral bristle. Distance from border of eye to base of 1st oral 2/5 of greatest diameter of eye. Eyes sepia; eye index 1.1. Palpi rust colored with 3 medium length hairs. Many fine hairs.

Acrostichal hairs in 7 rows between dorsocentrals; no prescutellars; anterior scutellars slightly divergent. Thorax light brown with central darker stripe; pleurae dark brown; halteres pale tan. Anterior sternopleural bristle 3/4 length of posterior; middle very small.

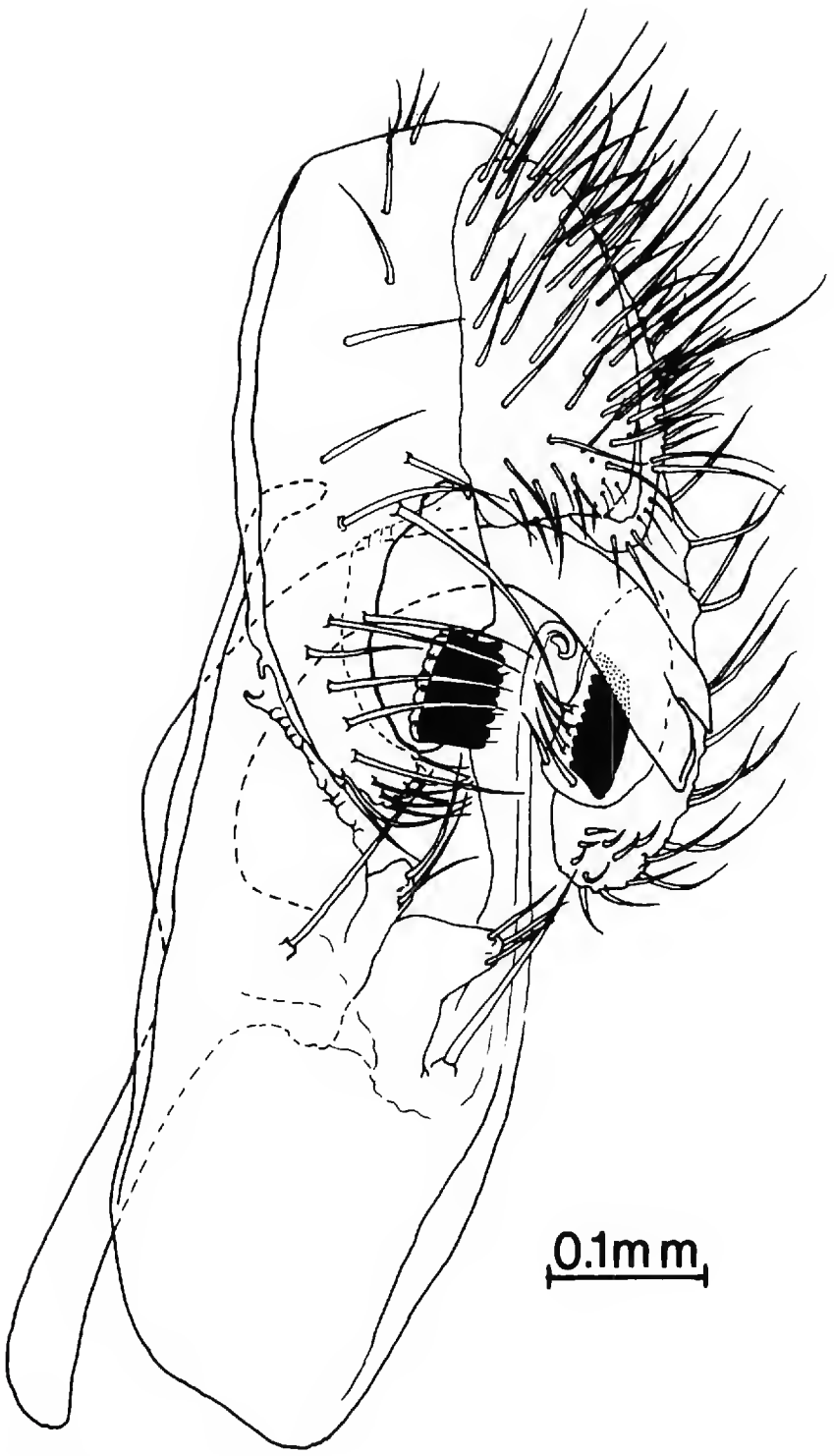

Figure 7. *Drosphila franii,* male genitalia.

Legs yellowish-orange except last, black tarsal segment. Apical and pre-apical bristles on middle legs; pre-apicals on 1st and 3rd. First femora with 6 bristles arranged medium, long, short, medium, medium, short.

Wings pale tan with darker veins. Costal index 3.1, 4th vein index 1.6, 4c index 0.8, 5x index 1.1. Thicker, heavier hairs continue along border to basal 3/8 of third section of costa.

Abdomen yellowish-orange with tan bands in posterior of each segment, wider in midline, fading out laterally, paler on last 3 segments.

Body length, males, 2.7 mm; females, 2.9 mm. Wing length, males, 3.2; females, 3.4.

Genitalia of D. franii (Figs. 7 & 8).—Aedeagus brown, bilaterally symmetrical with wide, C-shaped opening, at ventral apex. In lateral view apex bifurcated into

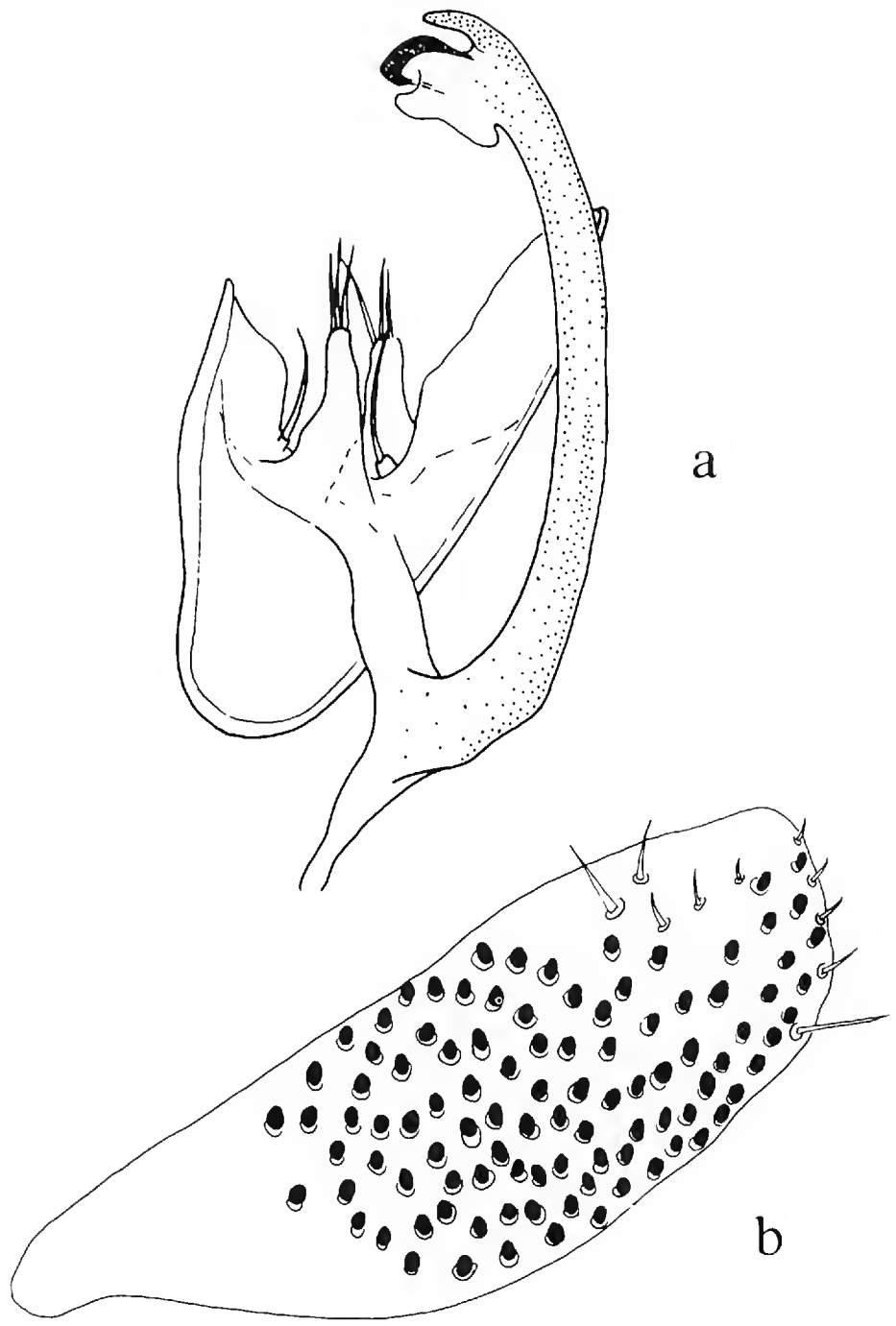

Figure 8. *Drosphila franii,* a. aedeagus; b. left ovipositor plate.

ventral spike and blunt, open, dorsal channel; latter partially enclosed by incomplete, transparent sheath. Apodeme lighter brown, straight. Genital arch fused to anal plate; toe curves medially, with 12 bristles; laterally, 5 long, black hairs, 7 widely spaced toward posterior region where fused with anal plate. Claspers with 8–9 long, closely-placed, black teeth and many, short, fine, yellow hairs all over outer surface; internally, 6 medium length, thick hairs. Claspers united by a wide, shallow bridge. Hypandrium with long, paramedian spines; short, finger-like gonapophyses, each with 3–4 yellow bristles.

Spermathecae oval to rectangular, dark brown. Ovipositor short, broad with 90–100 stubby, black teeth; dorsal apex with 1 long bristle, 4 short, yellow bristles along posterior border, 5 medium length black bristles in subapical, ventral border.

Other characteristics of *D. franii.* Eggs with anterior point, but no filaments. Adults emerge from flowers of *Bidens rubifolia* and *Liabum megacephalum* of the

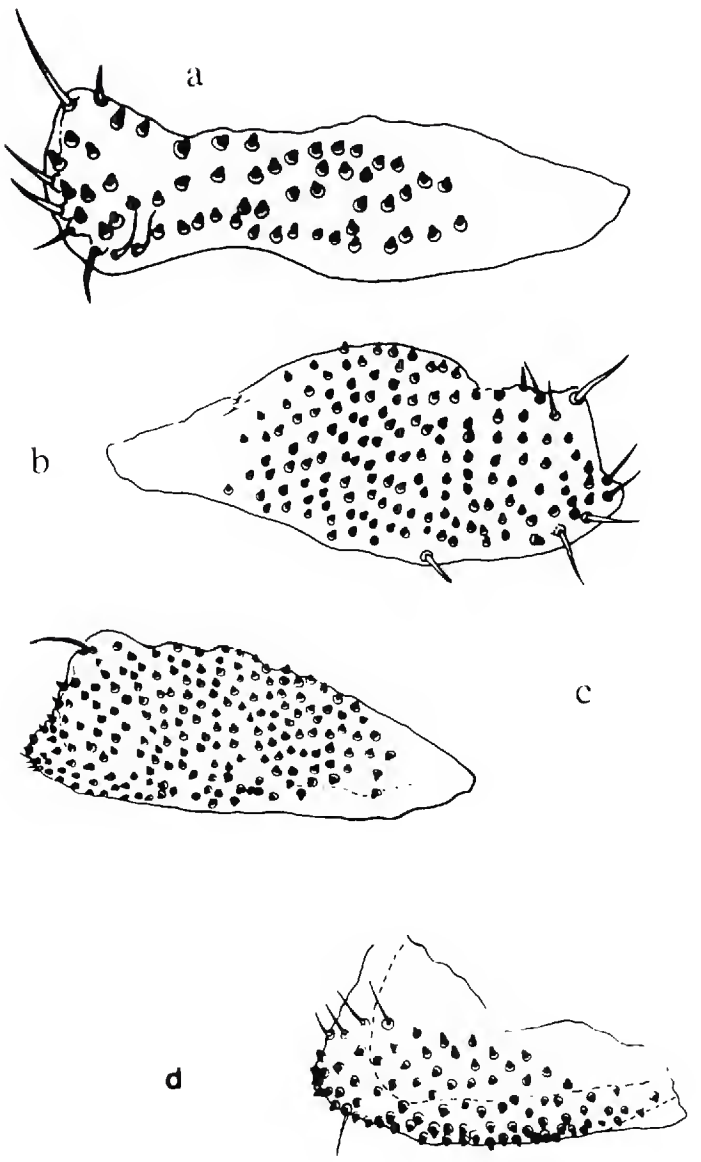

Figure 9. Flower breeding *Drosphila.* a. right ovipositor plate of *D. freilejoni,* b. left ovipositor plate of *D. arboloco,* c. right ovipositor plate of *D. desbaratabaile,* d. right ovipositor plate of *D. carablanca,* e. right ovipositor plate of *D. margarita.*

family Compositae. They can be swept or aspirated from these and other composite flowers in the paramo of Choachi and the wooded watershed of the aqueduct on the mountain, Monserrate. This species has not been found in other parts of Colombia outside of the environs of Bogota. It has the characteristic ovipositor, egg structure and male genitalia of the anthophilic group of *Drosophila* from the Bogota environs. This includes the 3 other species described in this paper and 6 previously described *Drosophila* (Hunter 1979). *Drosophila franii* is named after my late husband, Francis R. Hunter, a dedicated physiologist who also gave a lot of time to collecting *Drosophila* with me.

Holotype male aspirated from flowers of *B. rubifolia* in the aqueduct watershed on the mountain, Monserrate, in Bogota, VIII–15–80, A. S. Hunter. Paratype, same locality and date. Holotype #15858 and paratypes deposited in California Academy of Science.

Discussion

The 4 species of *Drosophila* described here are related to 6 flower-breeding species previously described from the Bogota, Colombia region (Hunter, 1979). They have several morphological and ecological characteristics in common. The ovipositors of 5 of the previously described *Drosophila* are shown in Figure 9 for comparison with those in Figures 2, 4, 6 & 8. The ovipositor plates are wide and the lateral surfaces are covered with short teeth or bristles. In Duda's 1925 paper there is an illustration of the ovipositor of *D. onychophora* Duda (from Peru and Bolivia) which is similar to those of the Bogota group. Some of the flower-breeding *Drosophila* described by Pipkin (1964) from Panama have ovipositors with lateral teeth. These, along with that of *D. paraguma* Okada and Larson from New Guinea (Okada & Carson, 1980), are similar to but not precisely the same as the ovipositors of the Bogota group. The latter are broader and have more teeth. The ovipositors of *D. paraguma* and the Panama species are more acuminate and have fewer lateral teeth or hairs.

Another distinctive feature of the 4 new species described here, as well as 6 previously described from the same region, is the lack of egg filaments. Other flower-breeding *Drosophila,* such as those of the subgenus *Phloridosa,* also lack filaments. Also, the flower-breeding group *flavopilosa* is characterized by very short egg filaments. This may be related to the nature of the substrate in which the eggs are laid. There is no problem of the egg submerging into a soft mass within the flower buds where they are deposited, so filaments have no adaptive value.

Viviparity was observed in 7 of the 10 flower-breeding species of the Bogota region. This has also been noted in some species of the *flavopilosa* group (Wheeler et al., 1962) as well as some of the Panamanian species (Pipkin et al. 1966). Another characteristic of the Bogota flower-breeding *Drosophila* is the low number of ovarioles in the females, which has also been reported for other flower-breeding drosophilids. It has been suggested that these traits are of adaptive value in the flower niche, with its limited food supply (Brncic, 1983).

Most of the flower-breeding species of *Drosophila* are found in the tropics. Perhaps flowers are available several times during the year, rather than the limited annual flowering in the temperate zone. The Bogota flower-breeding *Drosophila* live in a cool region where the temperature fluctuates around a mean of 15°C. Although Bogota is close to the equator, it is cool because it is at an altitude of 2,600 m. Flowering is affected by the rainfall which has 2 peaks in a year. Many plants flower in December-January and again in April-May. However, the flowers usually survive for a relatively long time in the cool climate. The *Drosophila* in the Bogota region have long life cycles which are correlated with the 2 rainy seasons (Hunter, 1966). It will be of interest to study the duration of the stages of the life cycle of the flower-breeding species.

These 4 new species of *Drosophila* along with those previously described from Bogota are obligate flower-breeders. My coworkers and I have collected *Drosophila* for many years in the Bogota region. A broad variety of possible breeding sites have been checked, with particular attention more recently to the flowers. None of these anthophilic species are ever attracted to yeasted baits. Seven of these *Drosophila* utilize composite flowers as the breeding site. These are not typical host flowers for *Drosophila. D. chisaca* is monophagous and has been found in only one of the several species of *Espeletia* of the Bogota environs, while *D. freilejoni* is breeding in the same flowers with *D. chisaca* and also in 3 different species of *Espeletia. D. colmenares* and

D. franii both breed in the same composite flowers of 2 different genera, *Bidens* and *Liabum*. To date, *D. acuminanus* has only been found breeding in *Liabum,* but relatively few adults (about 20) were collected emerging from these flowers over several seasons of flowering.

The 4 new species of flower-breeding *Drosophila* described here belong in the anthophilic group previously described from the Bogota region (Hunter, 1979). At present they cannot be placed in any subgenus, but are most closely related to *Phloridosa*.

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PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 313–319

Two New Species of *Paradelius* (Hymenoptera: Braconidae) from North America with Biological Notes

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INTRODUCTION

It has been known for some time that an undescribed species of braconid resembling *Paradelius ghesquierei* de Saeger (from the Belgian Congo, now Zaire), exists in western North America. This is reflected in the inclusion of *Paradelius* in the key to Nearctic genera of Braconidae by Marsh et al. (1987), despite there being no described North American species. I have recently had the opportunity to rear this species in good numbers from one of its hosts and have received reared specimens from two additional hosts. In addition, a second, morphologically quite distinct species has been collected in Texas. Below I describe both species and discuss their apparent relationships with the previously known African species.

Genus *Paradelius* de Saeger

***Paradelius* de Saeger, 1942: 313. Type-species: *Paradelius ghesquierei* de Saeger, original designation.**

De Saeger (1942) based this genus on a single species from the Belgian Congo, questionably reared from *Enarmonia* sp. (Lepidoptera: Eucosmidae). As all reliably reared species of Adeliinae have been associated with leafmining Lepidoptera, especially Nepticulidae, the host record is somewhat suspect.

Nixon (1965) remarked that in the British Museum (Natural History) there are several undescribed South African species apparently belonging to *Paradelius,* one of which differs in having a strongly sclerotized "carapace" incorporating metasomal tergites I-III, all rugose, and in having the metacarp absent. The second species described below matches this African species in the first feature. I have chosen not to recognize a new genus for these two species, as the metasomal structure seems to me to be only an extreme form of the sculpturing trends found in other *Paradelius*.

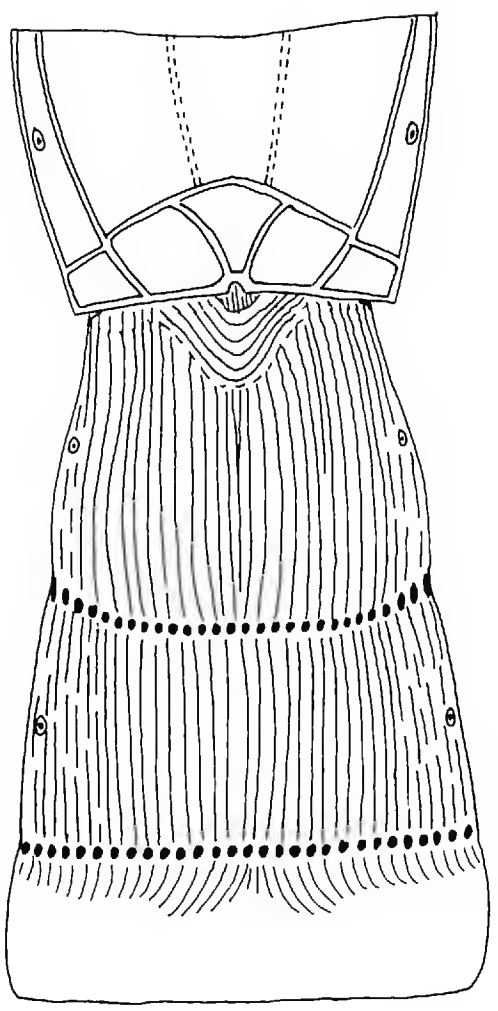
All of the species of *Paradelius* can be easily distinguished from *Adelius* Haliday (see Mason, 1985 for nomenclatural discussion of *Adelius* versus *Acaelius*) in having the first two metasomal tergites coarsely sculptured, usually with a combination of rugosity and an overlay of longitudinal ridging (especially on the second tergite). In *Adelius,* there is no macrosculpturing on the anterior tergites at all and the line separating the first two is often difficult to distinguish.

Paradelius rubra sp. n.

(Figs. 1, 3, 5, 6)

Female. Body length 1.8–2.3 mm. Fore wing length 1.6–1.9 mm.

Head entirely orange-brown, surface strongly granular. Frons 1.2–1.4x as broad as long, weakly bulging medially. Clypeus small, strongly convex. Scape as long as



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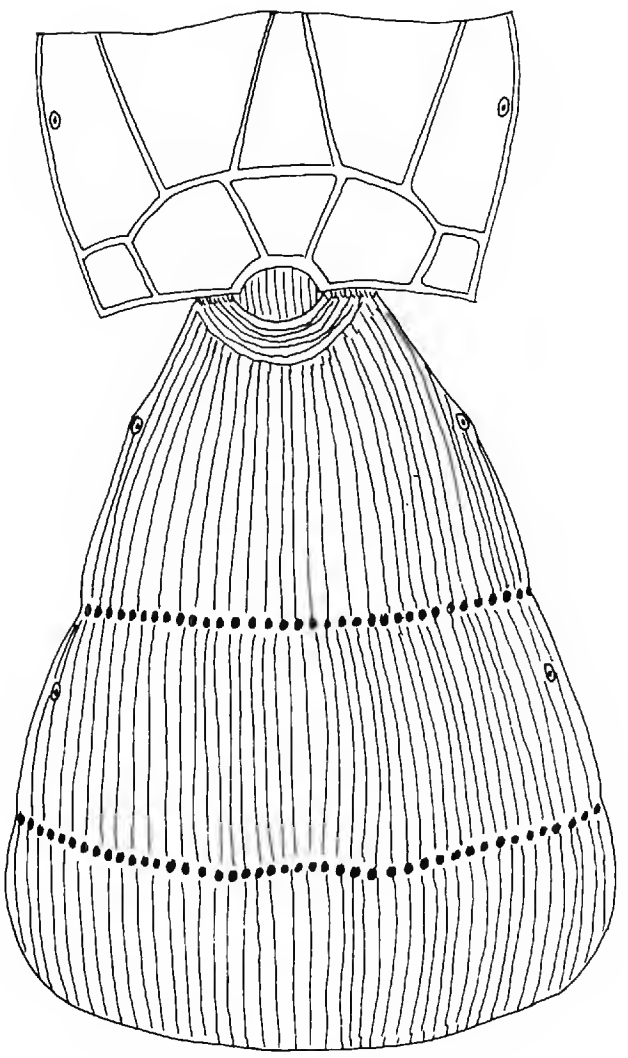

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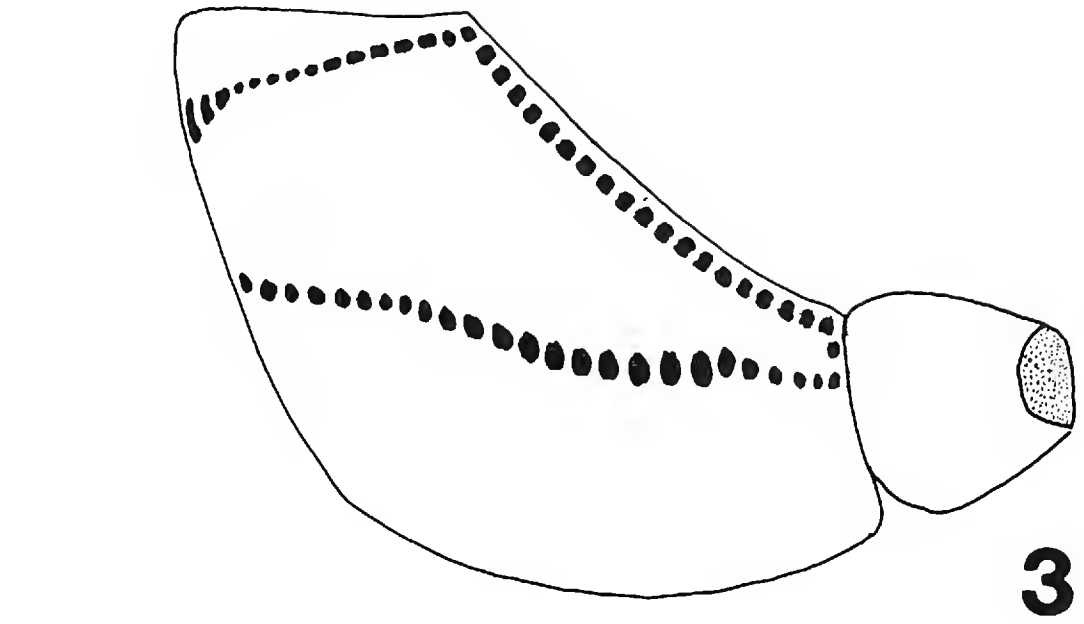
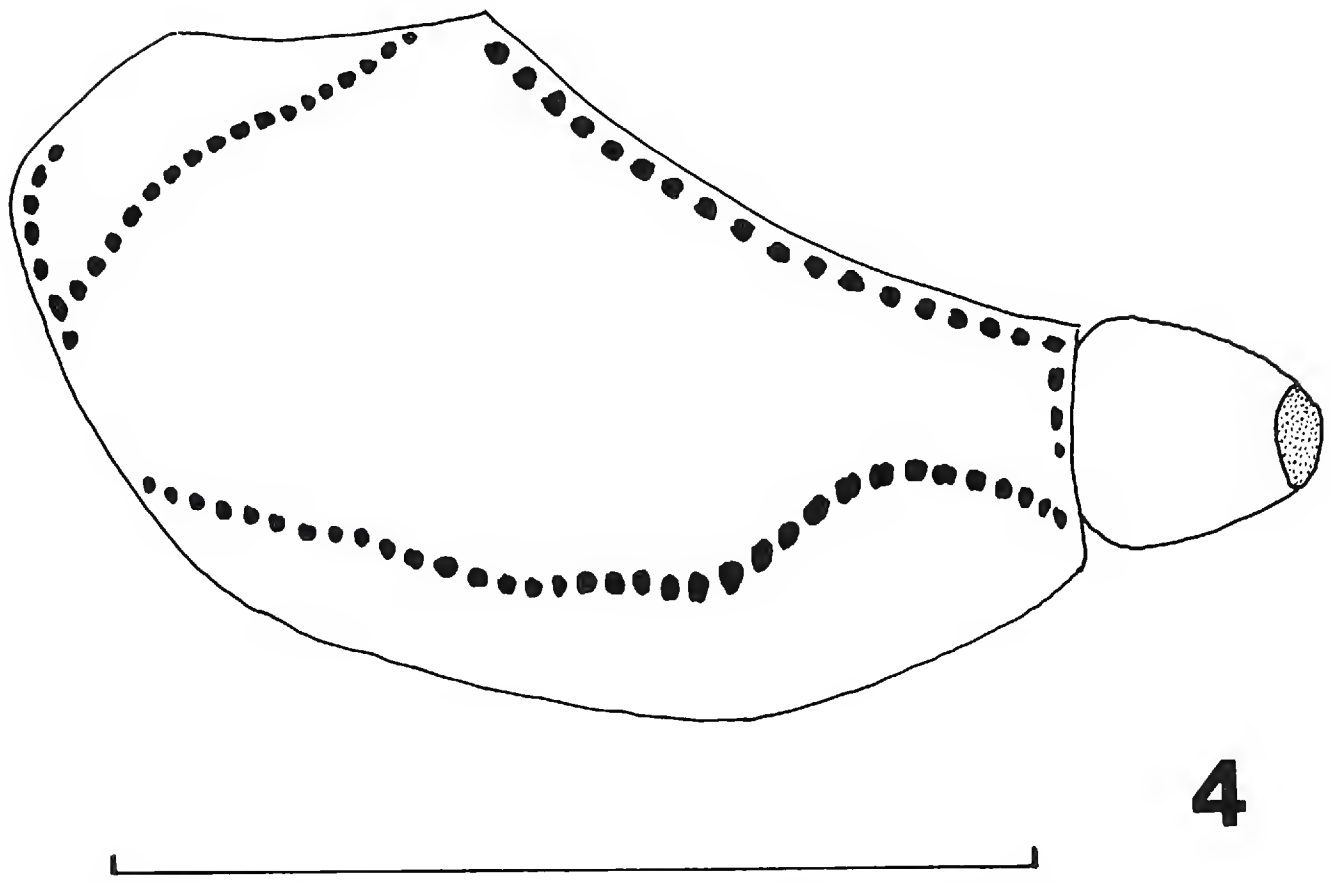
Figures 1, 2. Propodea and anterior metasomal tergites of: 1, *Paradelius rubra,* sp. n., ♀, California, ex *Stigmella variella;* 2, *P. nigra,* sp. n., ♂, Texas. Scale-line = 0.5 mm.

or longer than pedicel and first flagellomere combined. Flagellum 18-segmented, orange basally, becoming dark brown over distal 0.7–0.8. Distal flagellomeres each swollen anteriorly with denser patch of small hairs. Postgenae and occiput well-developed; head broadest just behind eyes. Occipital carina well-developed and complete. Palpi paler yellow-brown.

Mesosoma mostly orange-brown, becoming dark brown to black dorsally posterior to mid-mesoscutum and ventrally anterior to middle coxae. Pronotum with only weak ventral groove and shallow granular/longitudinally aciculate sculpturing. Mesoscutum broad, strongly granular, matte, without notauli. Scutoscutellar scrobe deeply but finely crenulate. Mesopleuron weakly granular to dorsally more aciculate, with distinct, weakly sinuate, crenulate longitudinal groove (fig. 3). Disc of scutellum strongly triangular. Propodeum rugose, with superimposed carinae as in fig. 1. Metapleura usually orange-brown and strongly contrasting with dark brown propodeum.

Legs. Prothoracic and mesothoracic legs orange-brown, with slightly darker tibiae. Inner midtibial spur large, 1.5x as long as outer. Hind legs darker brown. Hind tibiae enlarged, swollen subapically to approximate thickness of hind femora



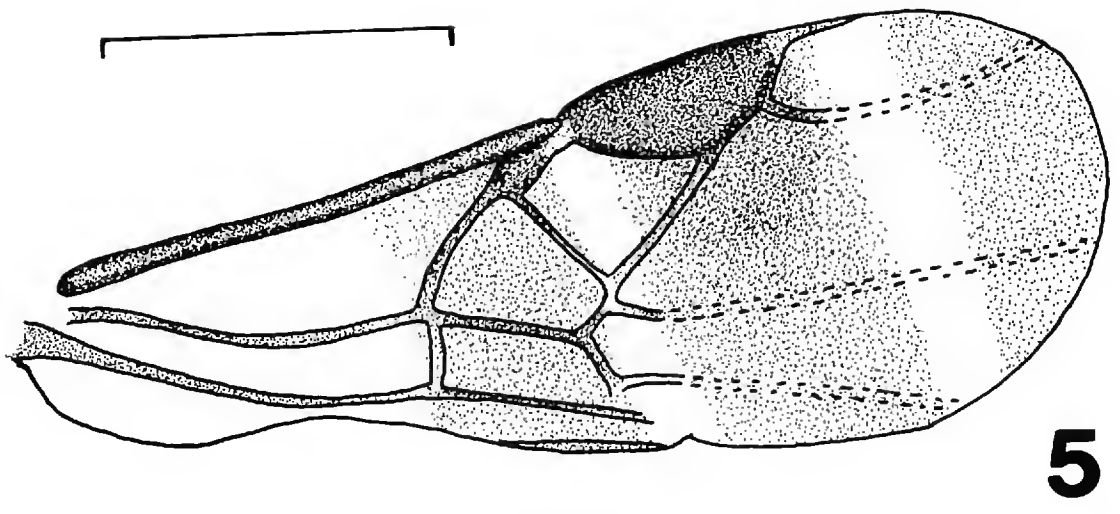


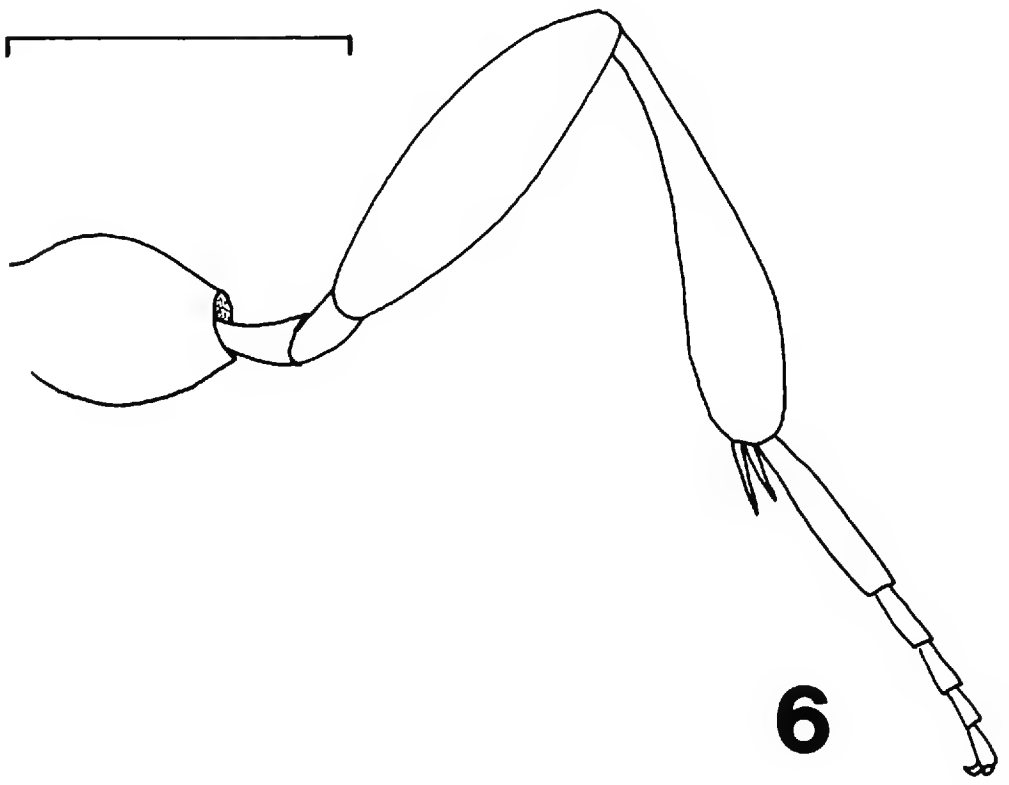
Figures 3, 4. Mesopleura of: 3, *P. rubra,* same specimen as above; 4, *P. nigra* (same specimen as above). Scale-line = 0.5 mm.

(fig. 6), rounded apically, with inner spur slightly longer than outer. Outer surface of hind tibiae armed with numerous minute, short, black spines.

Wings. Venation as in fig. 5 with three infuscate bands. Tegulae orange-brown.

Metasoma. Dorsum entirely dark brown to black, venter paler. Tergites I & II (fig. 1) broad, covering entire dorsal width of metasoma, with spiracles near lateral edges. Tergite I almost as long as apically broad; tergite II nearly twice as broad as medially long. Both tergites, as well as the anterior 0.2–0.4 of the third, longitudinally striate and separated from one another by thin crenulate grooves. Tergite III sculptured





Figures 5, 6. 5: Fore wing of *P. rubra,* ♀. Scale-line = 0.5 mm. 6: Hind leg of *P. rubra,* ♀, lateral view. Scale line = 0.5 mm.

only over anterior 0.2–0.4. Tergites IV–VI also partially visible in dorsal view, unsculptured. Hypopygium not reaching apex of metasoma. Ovipositor and sheaths short, subexserted; sheaths hairy on apical expanded portions. In most dried specimens the metasoma is strongly dorso-ventrally flattened.

Male. Body length 1.6–2.1 mm. Fore wing length 1.4–1.5 mm. Coloration and sculpturing usually very similar to female. Metasoma slightly narrower in dorsal view than in female.

Cocoons. Pupates within cocoon of host nepticulid, after emerging from host larva/prepupa.

Type material. HOLOTYPE ♀: CALIFORNIA: Alameda Co., Del Valle Lake Rec. Area, 11-II-1984, JBW no. 84B21, ex *Stigmella* on *Quercus agrifolia,* emerged 8-III-1984 (Whitfield) (USNM).

PARATYPES: 11♀, 11♂, same data as holotype except emergence dates vary from 2-18-III-1984 (USNM, CNC, TAMU, HKT); CALIFORNIA: Alameda Co., Berkeley, 2♀ 1-II-1984, JBW no. 84B1, ex *Stigmella* on *Quercus agrifolia* (Whitfield & Wagner) (USNM); 1♀, 12-III-1983, JAP no. 83C6, ex *Nepticula* on *Quercus agrifolia,* emerged 8-IV-83 (Wagner) (CNC); 1♀, 11-III-1958, J. Powell no. 58C5, ex leaf miner on *Quercus* (Powell) (CNC); Berkeley Hills, Strawberry Cyn., 1♀, 25-II-1961, J. Powell no. 61B15, ex *Nepticula variella,* emerged 20-III-61 (Powell) (CNC); Tilden Park, 1♂, 22-II-1980, no. L34II80, from *Quercus agrifolia,* emerged 1-IV-80 (Wagner) (USNM); El Dorado Co., 3mi. SW Somerset, 1♀, 14-XI-1977 (Wharton) (RAW). OREGON: Pinehurst, 1♂, 29-VI-1978 (Townes) (HKT).

Additional material examined. CALIFORNIA: Contra Costa Co., Marsh Cr. Rd. nr. Mt. Diablo, 1♂, 12-I-1983, J. Powell No. 83A11, ex *Stigmella* on *Rhamnus crocea,* emerged 30-I-83 (Wagner); Marin Co., S. P. Taylor St. Pk., 1♂, 19-III-1983, JAP no. 83C28, ex *Stigmella* on *Lithocarpus,* emerged 19-IV-83 (Wagner), Mendocino Co., Van Damme St. Pk., 1♂, 26-IV-1984, JAP no. 84D73, ex *Stigmella* on *Lithocarpus,* emerged 18-V-84 (Wagner). These last three specimens all in author's collection.

Hosts. *Stigmella variella* (Braun) on *Quercus agrifolia* Neé, *Stigmella* spp. on *Lithocarpus densiflora* (H. & A.) and *Rhamnus crocea* Nuttall. These hosts are not apparently closely related within *Stigmella* (Newton & Wilkinson, 1982), but the host plants do overlap in habitat distribution.

Biology. The series from *Stigmella variella* emerged from a very large collection of mined *Quercus* leaves, virtually all picked from sucker shoots at the bases of mature trees or stumps. The adults emerge from the *Stigmella* cocoons in all cases I have yet seen. The adult *Paradelius* run about rapidly on the oak foliage, resembling ants while in motion, a resemblance which is heightened somehow by the infuscate bands on the wings, which are held flat over the metasoma. When I aspirated six or seven of the wasps into a glass vial at one time, the wasps seemed to emit a choking, formic acid–like chemical into the air. I was unable to subsequently obtain enough wasps to have the chemical and its origin analyzed. It would be interesting if the substance were actually formic acid, as this would strongly enhance the ant mimicry.

Comments. This species differs from *P. ghesquierei* in, among other features, the more parallel-sided second metasomal tergite and the continuation of the longitudinal sculpturing onto the third tergite.

***Paradelius nigra* sp. n.**

(Figs. 2, 4)

Male. Body length 2.1 mm, fore wing length 1.8 mm.

Head. Entirely black (entire body black except all trochanters, all of prothoracic legs, and middle tarsi, which are lighter brown). Frons finely granular, weakly convex. Clypeus small, strongly convex, about 1.5x as broad as long. Scape slightly shorter than length of pedicel and first flagellar segment combined. Flagellum 18-segmented, entirely dark brown to black. Postgenae and occiput well-developed, head broadest in dorsal view at middle of eyes and just behind eyes. Occipital carina

strongly developed, complete. Palpi medium brownish but not fully visible in specimen (head attached separately to point).

Mesosoma. Pronotum with strong, crenulate, sinuate ventral groove, otherwise granular. Mesoscutum densely punctate, without notauli. Scutoscutellar scrobe narrow, crenulate. Mesopleuron punctate ventrally and anteriorly, smooth and polished posterodorsally, with narrow, crenulate, strongly sinuate longitudinal groove (fig. 4). Disc of scutellum triangular. Propodeum rugose with superimposed carinae as in figure 2.

Legs. Inner midtibial spur long, 1.5x as long as outer. Hind femora and tibiae swollen subapically but not so extremely as in *P. rubra.* Outer faces of hind tibiae with numerous minute black, short spines (difficult to see against dark legs). Inner hind tibial spurs 1.3x as long as outer.

Wings. Very similar to *P. rubra* (fig. 5), but with infuscate banding less pronounced. Infuscation strongest in large cloud under stigma. Tegulae dark brown.

Metasoma. Tergites I-III entirely longitudinally aciculorugose, with spiracles near lateral margins. Tergite I 0.8x as long as apically broad, broadening posteriorly. Tergite II 2.4x as broad as medially long. Tergite III 3.0x as broad as medially long. The three anterior tergites fused into a pseudo-carapace, separated by two crenulate grooves that arch posteriorly medially (fig. 2). Tergites IV-VI visible in dorsal view as narrow strips. Entire metasoma strongly dorsoventrally flattened.

Female. Unknown.

Cocoon. Unknown.

Type material. HOLOTYPE ♂: TEXAS: Gonzales Co., Palmetto State Park, 17-IV-1970 (Board)(USNM).

Hosts. Unknown.

Comments. The shape of the strongly sculptured tergites I-III and the striking colorational differences will easily distinguish this species from the preceding one. It appears to be closest to an undescribed South African species in the British Museum, but has at least a short metacarp, rather than none at all.

Acknowledgments

I would like to thank Jerry A. Powell (University of California, Berkeley), and David L. Wagner (University of Vermont), for helping locate the excellent site for *Stigmella variella.* Loans of specimens from the following individuals and institutions are also appreciated: W. R. M. Mason, Canadian National Collection (CNC); Henry K. Townes, American Entomological Institute (HKT); David L. Wagner; and Robert A. Wharton, Texas A&M University (TAMU, RAW). Norman F. Johnson and Sydney A. Cameron read and offered useful comments on an earlier draft of this paper. Examination of specimens at the British Museum (Natural History) was done during tenure of a fellowship awarded by the North Atlantic Treaty Organization in 1985; the assistance of Mr. Tom Huddleston at the Museum is greatly appreciated.

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PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, p. 321–344

A Revision of the *Nomada* Subgenus *Nomadita* of North America (Hymenoptera: Anthophoridae)

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Abstract.—The North American portion of the *Nomada* subgenus *Nomadita* is revised. Six species, including one new species (*Nomada timberlakei*), are recognized. *Nomada antonita* Cockerell is placed in synonymy with *Nomada snowii* Cresson. *Nomada rodecki* Mitchell is removed from the subgenus *Nomadita* and placed in the subgenus *Nomada.* The Eurasian species of *Nomadita* are discussed. A new subgenus, *Asteronomada* is described based upon *Nomada adducta* Cresson and three new species (*N. brewsterae, N. durangoae,* and *N. portalensis*) are described.

INTRODUCTION

Bees of the genus *Nomada* Scopoli (1770) are brightly colored (combinations of red, black, and yellow or white) and sparsely pubescent, with a wasp-like appearance. Over 900 names have been proposed in the genus (pers. obs.). Representatives of this genus occur on nearly every continent (Hurd, in Krombein, et al., 1979). Most species are believed to be kleptoparasites of *Andrena,* but *Halictus, Agapostemon, Nomia,* and *Exomalopsis* are also known hosts of *Nomada* sensu lato. This study was undertaken because *Nomadita* has only recently been recognized as holarctic. There is one new species in North America, and two species have been incorrectly included in the subgenus.

HISTORICAL REVIEW

The genus *Nomadita* was described by Mocsary (1894) to accommodate a single new European species, *Nomadita montana* Mocsary. Dusmet (1913) synonymized *Nomadita* with *Nomada. Nomadita* is not mentioned in the literature again until Snelling (1986) revived it as a senior synonym of *Callinomada* Rodeck (1945). Present European workers do not use subgenera within the genus *Nomada.*

Rodeck (1945) described the subgenus *Callinomada* based upon several species that had previously been included in the subgenus *Holonomada* Robertson. He designated *N. antonita* Cockerell as the type of *Callinomada* and included *N. aquilarum* Cockerell, *N. mutans* Cockerell, *N. placida* Cresson, *N. snowii* Cresson and *N. verecunda* Cresson. The subgenus *Callinomada* was revised by Rodeck (1949). No new species were described, but *N. omahaensis* Swenk was synonymized with *N. snowii,*

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and *N. dacotensis* Swenk and *N. cockerelli* Graenicher were synonymized with *N. aquilarum*. Mitchell (1962) described *Nomada* (*Callinomada*) *rodecki* for an eastern species.

Snelling (1986) revised the new world Nomadini. He revived *Nomadita* as a subgenus of *Nomada* with *Callinomada* as a junior synonym. Three European species were included in the subgenus, *N. montana, N. roberjeotiana* Panzer, and *N. rufipes* Fabricius. Tentatively assigned to the subgenus was *N. adducta* Cresson. Schwarz (1986) synonymized *N. montana* with *N. roberjeotiana* Panzer. *Nomada obtusifrons* Nylander, *N. errans* Lepeletier and *N. palmeni* Morawitz were included in the subgenus *Nomadita.* A number of names belonging in *Nomadita* have been overlooked by these authors.

Callinomada was characterized (Rodeck, 1945) as having the pronotum sharp-carinate, the antennal scape obconic in males, the hind tibiae with 3–5 short stout spines and the apex of metasomal sternum seven broad. Rodeck (1949) differentiated *Callinomada* from *Holonomada* by size, season of flight, sparse pubescence, and shape of the male genitalia. Moalif (1979) clarified the distinguishing characteristics of *Callinomada,* which included the penis valve without apical ventral hooks, the gonostylus clothed with long dense hair, and the gonocoxites separated from each other by a distance greater than the width of the gonostylus. Snelling (1986) characterized *Nomadita* by "minimum length of 1st flagellar segment equal to, or exceeding, maximum length of second, propodeum not swollen mesad of spiracle; genal margin subcarinate; male sternum 8 rather broad, margins tapering distally; female metabasitarsis broadest near base; propodeum bare or nearly so, with little or no erect hair."

The subgenus *Nomadita* is Holarctic and the type species is European. A number of names have been proposed and the correct synonymy is unclear. The old world species should be revised, but that is beyond the scope of this study. The following is a list of names known or believed to belong to the subgenus *Nomadita.*

roberjeotiana Panzer, 1799
- *panzeriana* de Walckenaer, 1802
- *neglecta* Herrich-Schaeffer, 1839
- *roberjeotiana* var. *alpina* Morawitz, 1867
- *dybovskii* Radoszkovsky, 1876
- *montana* Mocsary, 1894
- *tormentillae* Alfken, 1901

aino Tsuneki, 1973

errans Lepeletier, 1841
- *errans* var. *korleviciana* Friese, 1921
- *errans* var. *sibirica* Friese, 1921

momoglonis Tsuneki nom. nov. for *melanura* Tsuneki 1973 nec Mocsary 1883

momoglonis hakusana Tsuneki nom. nov. for *melanura hakusana* Tsuneki 1973 nec Mocsary 1883

obtusifrons Nylander, 1848

okamotonis Matsumura, 1912

okamotonis var. *kaiensis* Tsuneki, 1976

palmeni Morawitz, 1888

rufipes Fabricius, 1793

vaga Panzer, 1798
solidaginis Panzer, 1799
solidaginis var. *picta* Kirby, 1802
solidaginis var. *rufopicta* Kirby, 1802
solidaginis var. *punctulifera* Friese, 1921
solidaginis var. *minutula* Friese, 1921
sempiterna Morawitz, 1894

Cockerell (1928) described four *Nomada* species from Siberia, and stated that they were closely related to *N. roberjeotiana.* His descriptions indicate that *N. olhae* and *N. jasnitskii* probably belong in the subgenus *Nomadita. Nomada scheviakovi* might also be included. *Nomada belikovi* is probably not a species of *Nomadita* because Cockerell said the first antennal flagellar segment was shorter than the second, which is not true of *Nomadita.*

Both the Eurasian and the North American species of *Nomadita* are midsummer to fall flying bees, and are found mainly on small-flowered composites. The first flagellar antennal segment is longer than the second and the occipital margin is sharply angulate (almost carinate in some species). The shape of the male genital capsule and eighth gastric sternum provide strong evidence for the synonymy of *Nomadita* and *Callinomada.* The differences between the Eurasian species (Figs. 7–9, 17–19) and the American species (Figs. 1–6, 10–16) are minor. The shape of the eighth sternum is unusual within the genus *Nomada* in that the apex is broadly rounded (as in Figures 1–9). Eurasian species usually have a pro-coxal spine, which is rudimentary or absent in North American species. *Nomada obtusifrons, N. rufipes, N. errans* and *N. okamotonis* have pro-coxal spines. *Nomada okamotonis* and *N. obtusifrons* have a very prominent supraclypeal area, which is flattened dorsally and bordered by a thickened carina (scrobe). The supraclypeal area of *N. roberjeotiana* is quite prominent and forms a sharp angle with the frons above the antennal insertions, but it is not flattened or bordered by a carina. These differences are small compared with the overall similarity between the North America and Eurasian species of *Nomadita* and are not sufficient to warrant the maintenance of the subgenus *Callinomada.*

The first antennal flagellar segment of *Nomada rodecki* Mitchell, unlike *Nomadita,* is shorter than the second. The eighth sternum is elongated apically and not rounded, and the gonostyli of the genital capsule bear dense, long, curled hairs. This species is active in May, which is almost two months earlier than any species of *Nomadita. Nomada rodecki* belongs in the subgenus *Nomada* as defined by Snelling (1986), and is closely related to *N. beulahensis* Cockerell and *N. banksi* Cockerell.

Nomada adducta Cresson was removed from the subgenus *Pachynomada* by Snelling (1986) and tentatively placed in *Nomadita.* The swollen antennal scape of the male, the general body shape, and the form of the eighth sternum are similar to *Pachynomada.* The genital capsule (especially the lack of a ventral subapical projection on the penis valves) and the form of the hind basitarsus of *N. adducta* are similar to those of *Nomadita. Nomada adducta* differs from *Nomadita* by the following: the shape of the eighth sternum; the lack of a sharply carinate occipital margin; the dense, appressed plumose hairs on the hind coxa and propodeum; and the globose antennal scape. Because *N. adducta* does not fit with either *Pachynomada* or *Nomadita,* I removed it from *Nomadita* and designated it as the type species of a new subge-

nus, *Asteronomada*. The subgenus *Asteronomada* contains three new species in addition to the type species.

Biology

Little is known about the biology of *Nomadita*. It is found only from late summer to fall, and usually visits small-flowered composites for nectar, especially *Solidago* and *Chrysothamnus*. It has been suggested (Snelling, 1986) that the host of *Nomadita* is the *Andrena* subgenus *Cnemidandrena*. Attempts to determine the host of this subgenus have been unproductive due to the scarcity of the bee. Perkins (1919) reported the hosts of all the British *Nomadita*. *Andrena fuscipes* is the host of *N. flavipes* Illiger (*solidaginis* Panzer), *A. tarsata* for *N. tormentillae, A. coitana* for *N. obtusifrons,* and *A. denticulata* and *A. fuscipes* for *N. rufipes*.

Terminology

The morphological terminology used in this paper generally follows that of Michener (1944) or Stephen, et al. (1969). The following section explains some terms and abbreviations that may be unfamiliar.

Acetabular carina: Distinct lamella at the dorsal base of the mandible, especially prominent in male *Nomada*.

Flagellar: Referring to the antennal flagellum.

Hypospiracular band: Area along the ventral margin of the propodeum, extending upwards to the propodeal spiracle.

IOD: Interocellar distance (distance between lateral ocelli).

IPS: Interpunctural surface (areas of integument between punctures).

MLOD: Mid to lateral ocellar distance.

MOD: Middle ocellar diameter.

MOOM: Distance between mid-ocellus and occipital margin.

OOD: Ocellocular distance (distance between lateral ocellus and apex of compound eye).

Pre-lobar carina: Ridgelike continuation of the posterior margin of the pronotum, which tapers down to the anterior of the pronotal lobe.

Pre-occipital ridge: Posterior margin of the head is sharply angulate, in some cases sub-carinate.

Sternum: See tergum.

Supraspiracular ridge: Propodeal spiracle sunken, with ridge-like thickening dorsal to it. In some species it may protrude noticeably, being flat and shelf-like dorsally.

Tergum or sternum as used here refers to metasomal sclerites only.

SUBGENUS *NOMADITA*
Nomada Subgenus *Nomadita* Mocsary

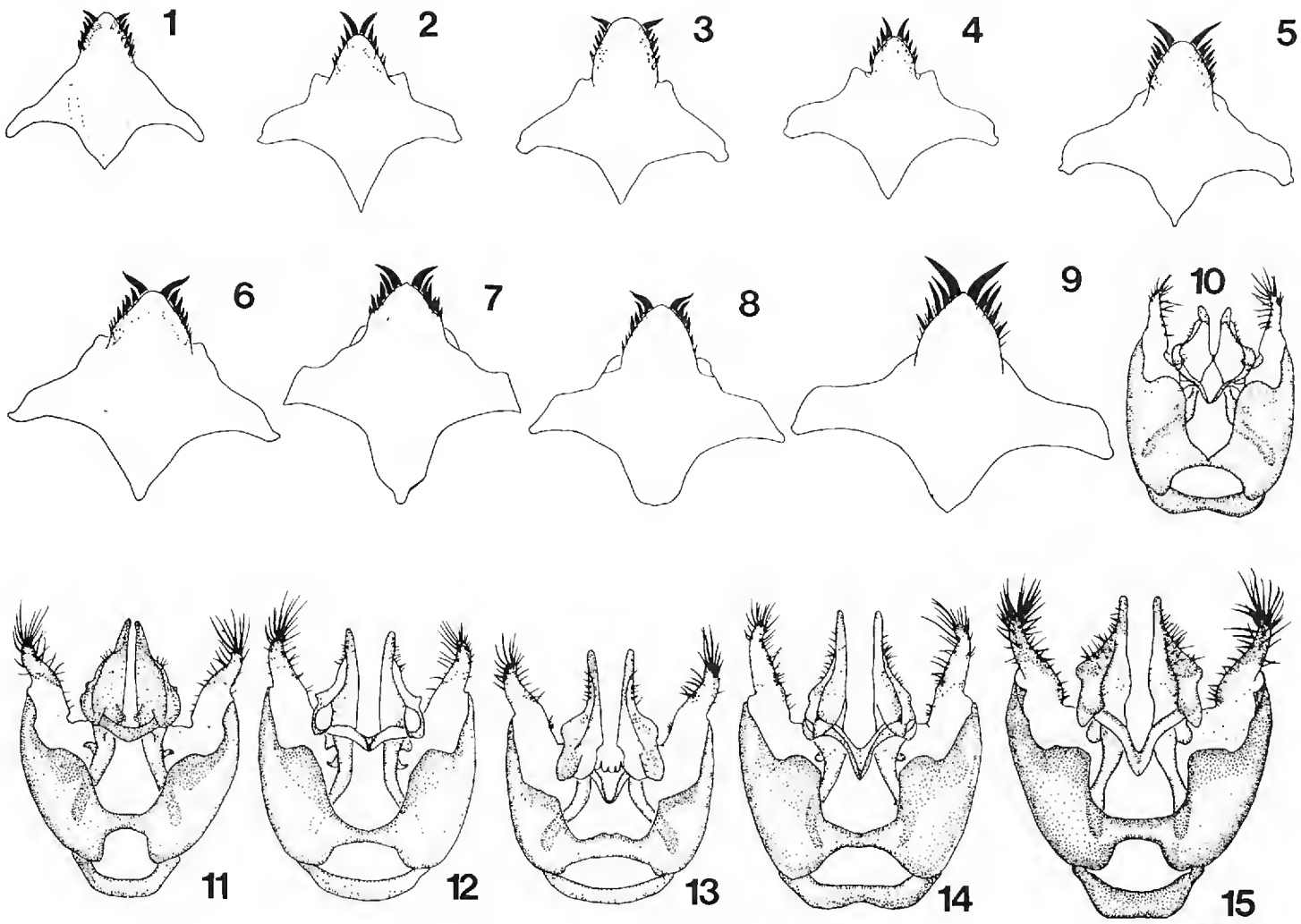
Nomadita Mocsary, 1894, Termes. Fuzetek 17:37.

Type species: *Nomadita montana* Mocsary, 1894.

Nomada (*Callinomada*) Rodeck, 1945, Entomol. News LVI:181.

Type species: *Nomada antonita* Cockerell, 1909.

Diagnosis: The short, broadly rounded apex of the male eighth sternum immediately separates *Nomadita* from all related subgenera. *Nomadita, Pachynomada,* and *Asteronomada* all differ from *Nomada* s.l. by having sparse, straight, relatively short pubescence on the gonostyli of the male genital capsule, and by having the apex of



Figs. 1–21, subgenus *Nomadita*

Figs. 1–9, male sternum 8; 1) *mutans,* 2) *placida,* 3) *timberlakei,* 4) *verecunda,* 5) *aquilarum,* 6) *snowii,* 7) *roberjeotiana,* 8) *rufipes,* 9) *okamotonis*; Figs. 10–15, genital capsule of North American species (dorsal); 10) *mutans,* 11) *placida,* 12) *timberlakei,* 13) *verecunda,* 14) *aquilarum,* 15) *snowii*; Fig. 16) *snowii* (ventral); Figs. 17–19, genital capsule of Eurasian species (dorsal); 17) *roberjeotiana,* 18) *rufipes,* 19) *okamotonis;* Fig. 20) *abdomen of* snowii, Fig. 21) abdomen of *aquilarum*

the eighth sternum **not** being narrow, elongated and parallel-sided. *Nomadita* differs from *Nomada* s.s. by having the first flagellar segment longer than the second, the apex of the mandibles simple, or lacking long, thin hind tibial apical bristles. The hind tibial apex lacks the dense cluster of fine setae present in *Holonomada* and *Laminomada.* The sharply angulate to subcarinate occipital margin and the short, broad apex of the eighth sternum which bears heavy lateral setae separates *Nomadita* from *Pachynomada, Asteronomada,* and *Phelonomada. Nomadita* also differs from

Asteronomada by the lack of dense appressed pubescence on the sides of the propodeum and dorsum of the hind coxae which obscures the integument in *Asteronomada*.

Description: Length 5.9–11.1 mm, forewing length 4.0–8.4 mm; minimum length of first flagellar segment greater than or equal to maximum length of second, antennal scape never globose, flagellum lacking prominent ridges or teeth; occipital margin sharply angulate, subcarinate in some species; supra-clypeal area distinctly prominent between antennal insertions, with prominent frontal carina; labrum with transverse subapical row of uneven denticles; mandibles simple; head densely punctate with smooth, shiny interpunctural surfaces; pronotal ridge apex sharply angulate anteriorly, abruptly depressed medially; pre-lobar carina prominent, sloping gradually to pronotal lobe; scutum contiguously punctured, not reticulate, interpunctural surface glassy, puncture rims rounded; tegulae glassy, sparsely punctate; propodeal sides densely punctate, apilose, swollen posterior to spiracle but not angulate; mesopleuron densely punctate, with rounded punctural rims, IPS smooth and shiny; procoxal spine rudiment ranging from sharp angulation to prominent spine; hind tibial apex with 4 to 10 distinct bristles arranged in one to three uneven rows; forewing with three submarginal cells; abdominal terga densely punctate, apical impunctate band width approximately two puncture diameters; male sternum 8 with short broad apex bordered by stout bristles; genital capsule (dorsally) with gonocoxites apically separated by broad emargination; gonostylus with long apical hairs (twice width of gonostylus); penis valve without ventral subapical projection.

KEY TO THE NORTH AMERICAN SPECIES OF *NOMADITA*

1) Integumental maculations lemon-yellow to orange yellow 2
— Integumental maculations white or ivory 5
2) First tergum without a complete transverse median yellow band, usually having no light maculations at all, terga 2 & 3 with bands strongly narrowed medially, usually interrupted (as in fig. 21) . . . . . *placida* Cresson
— First tergum with a complete yellow transverse median band and/or bands on remaining terga are thick, not strongly narrowed medially (never interrupted). 3
3) Legs and entire mesopleuron with bright rufo-ferruginous markings, contrasting strongly with dark areas of thorax (southern Colorado) . . . . . *snowii* Cresson
— Legs and mesopleuron brown to black, not contrasting strongly with dark areas of thorax, never more than small ferruginous mark on mesopleuron (California, Oregon, western Nevada) 4
4) Scutellum protruberant, interpunctural surface dull, apex of pronotal ridge rounded; males with entire anterior surface of antennal scape yellow, and mesopleural maculation always with a process reaching at least to pronotal lobe, usually extending to dorsal margin of pleuron; females with axillae and/or scutum always with at least a small yellow maculation . . . . . *timberlakei* n.sp.
— Scutellum flattened, sparsely punctate, interpunctural surface shiny, apex of pronotal ridge sharp, knifelike; males with anterior surface of scape with at least a basal brown patch, mesopleural maculation only rarely extending upwards behind pronotal lobe (usually only a small anterior triangle present); females with axillae and/or scutum usually without any yellow maculations . . . . . *verecunda* Cresson
5) Legs with bright rufo-ferruginous markings, contrasting sharply with dark portions of thorax; all of the following areas with at least some white marking (prono-

tal ridge and lobes, tegulae, scutellum and metanotum) ..... *snowii* Cresson
— Legs black to dark brown (sometimes light brown, but if so, then thorax also light brown); any or all of the following areas may have white marking (pronotal ridge and lobes, tegula, scutellum and metanotum) 6
6) Scutellum prominent, tergum 1 without a complete white band (usually completely black), at least one tergal band interrupted medially, supraspiracular ridge strong, shelf-like dorsally, mesopleuron black ..... *aquilarum* Cockerell
— Scutellum flattened, shiny, tergum 1 usually with a complete transverse median band, other tergal bands usually entire, supraspiracular ridge weak, mesopleuron usually with white maculations ..... *mutans* Cresson

THE NORTH AMERICAN SPECIES OF *NOMADITA*

Nomada (Nomadita) aquilarum Cockerell

Nomada aquilarum Cockerell, 1903. Ann. Mag. Nat. Hist. 12:208–209. Holotype, male: "No. 13183, 8 . 18, NM, S Fk Eagle Cr, Abt 8000 ft., Coll. Townsend, on fls *Erigeron macranthus*". Type Depository, United States National Museum.

Nomada cockerelli Graenicher, 1911. Bull. Pub. Mus. Milwaukee 1:221–249. Holotype, male: "No. 37769, Hudson, St. Croix Co., between July 6 and 12, 1910". Type Depository, Pub. Mus. Milwaukee.

Nomada dacotensis Swenk, 1913. Nebr. Univ. Studies 12:88. Holotype, female: "2803, Fargo, N. D. Aug. 17, 1911, O. A. Stevens, *Grindelia squarrosa*". Type Depository, University of Nebraska, Lincoln.

Diagnosis: Differs from *placida, timberlakei,* and *verecunda* by the presence of white instead of yellow maculations. Differs from *snowii* by the lack of ferruginous markings on the legs or thorax and broken transverse median maculations on the abdominal terga. Differs from *mutans* by the presence of a strong denticle on the pro-coxae, a prominent scutellum which is not flattened or highly polished, and the shelf-like supra-spiracular ridge. It differs from most *mutans* by having the first tergum all black and several terga with medially interrupted transverse maculations.

Male: Length 6.3–9.4 mm, forewing length 4.7–6.2 mm, hindwing length 3.8–4.9 mm; scape densely, almost contiguously punctured, IPS shiny, somewhat shagreened; IOD 0.31 mm, OOD 0.38 mm, MLOD 0.09 mm, MOD 0.17 mm, MOOM 0.39 mm; IPS within ocellar triangle roughened; labrum with broken subapical transverse carina; acetabular carina distinctly lamellate; pre-lobar carina sharp, gently sloping; pronotal ridge with abruptly angulate, deeply punctate apex; tegulae very sparsely punctate, glassy; scutellum protruberant, bilobate, coarsely punctate, scuto-scutellar suture deeply depressed, posterior interpunctural surface coarsely, transversely micro-rugose; propodeal sides with very rough IPS, supraspiracular ridge strong, forming distinct flattened shelf above spiracular opening, distinct vertical groove posterior to spiracle; metapleuron with ventral half shallowly punctate; short but stout pro-coxal spine rudiment present; hind tibial apex with 5 bristles, posterior 2 clear and quite thin; forewing with 3 submarginal cells (left wing of type with incomplete 1st intercubitus), infuscated with clear subapical crescent: COLOR: lower half of clypeus, sides of face along compound eyes halfway to antennal insertion, malar space, basal half of mandibles, labrum (in part), pronotal lobes, lateral spots on tegulae, apex of scutellar lobes, apical and basal portions of tibiae, apex of hind-femora, lateral median triangular patches on terga 2–4, complete transverse median bands on terga 5–6, apical lateral crescents on sterna 3–5, creamy-white; antennae ferruginous; remainder of body dark brown to black.

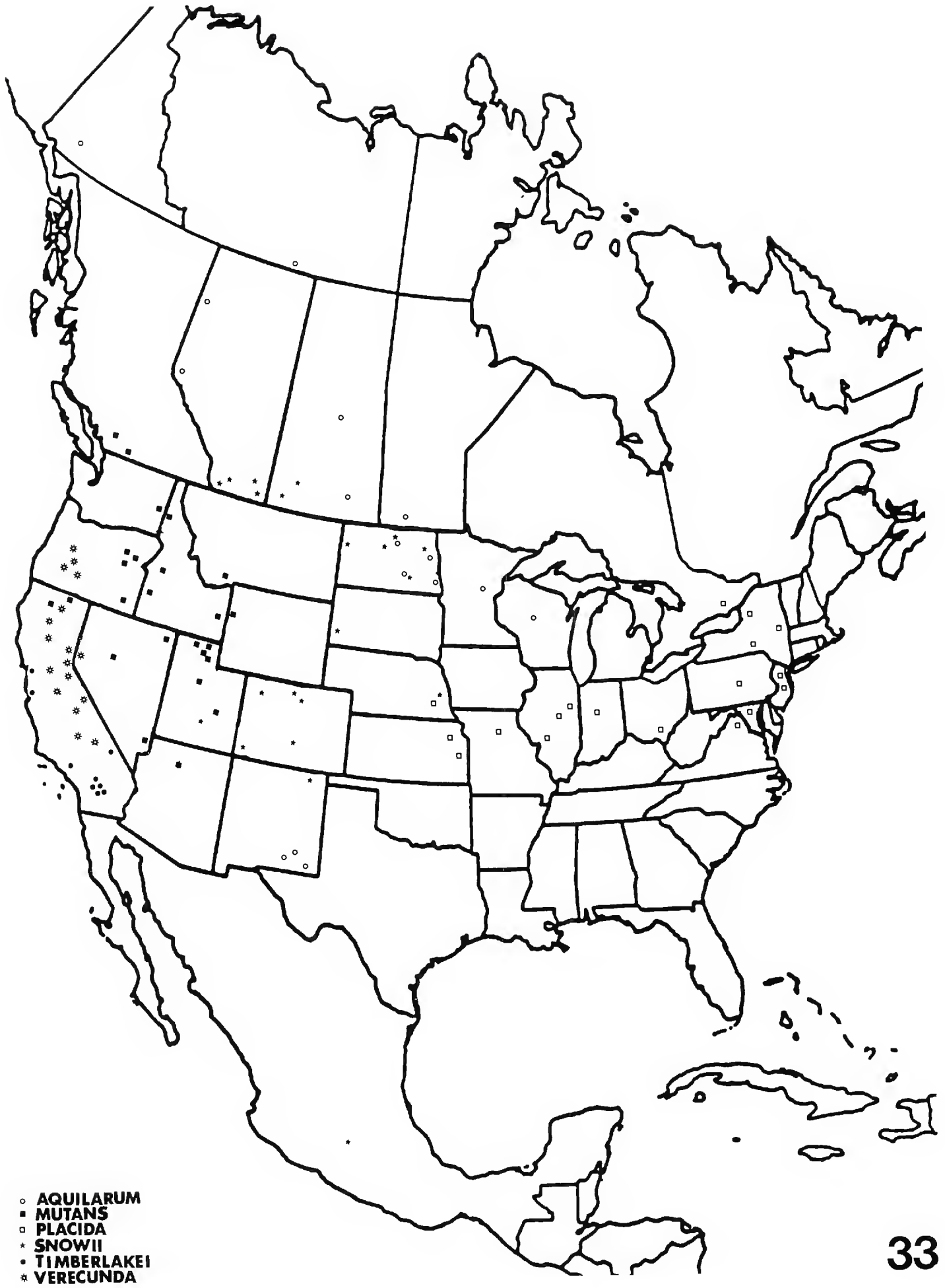


Figure 33. Distribution of the species of the subgenus *Nomadita*

Female: Length 6.2–8.1 mm, forewing length 5.1–5.6 mm, hindwing length 4.2–4.4 mm; very similar to male.

Discussion: This species is widely distributed along the Rocky Mountains. It has the most strongly developed pro-coxal spines of any of the North American species, but they are not as pronounced as those of the Eurasian species.

Material Examined: CANADA: Alberta: Aspen Beach, 1♀ 24–VIII–1944 (O. Peck) CNC; Beaverlodge, 1♂ 9–VII–1931 (O. Peck) UCM; Jasper, 1♂ 21–VII–1938 (E. H. Strickland) UCM; Manitoba: Pilot Mound, 1♂ 31–VII–1958 (A. & J. Brooks) CNC; Northwest Terr.: Fort Smith, 1♂ 31–VII–1950 (J. B. Wallis) CNC; Saskatchewan: Elbow, 1♂ 18–VII–1960 (A. R. Brooks) CNC; Prince Albert, 1♂ 23–VII–1959 (A. & J. Brooks) CNC; Rutland, 1♂ 26–VII–1940 (A. R. Brooks) CNC, 1♂ 26–VIII–1940 (A. R. Brooks) BBSL; Yukon Terr.: Whitehorse, 1♀ 20–VIII–1959 (R. Madge) CNC; U.S.A.: Minnesota: Polk Co., Maple Lake, 1♂ 18–VII–1968 *Cirsium* sp. (W. E. LaBerge) BBSL; New Mexico: Otero Co., 4.0 km (2.5 mi) E. of Cloudcroft, 2770 m (9100′), 2♂♂ , 1♀ 9–VIII–1947 (B. Valentine) AMNH; Silver Spr. Cyn. Mesc. Apa. I. Res., 3♂♂ ,4♀♀ 26–VII–1970 BBSL; North Dakota: Fargo, (O. A. Stevens), 1♂ 13–VIII-1910 *Solidago serotina* UNEB, 1♀ 17–VIII–1911 *Grindelia squarrosa* 1♀ 19–VIII–1923 *Solidago canadensis* UCM, 1♀ 20–VIII–1917 *Solidago canadensis* UCM, 1♀ 25–VIII–1917 *Solidago canadensis* UCM, 1♂ 26–VIII–1917 *Solidago canadensis* UCM; Grand Forks, 2♂♂ 19–VIII–1917 (P. W. Fattig) UCM; Granville, 1♂ 7–VIII–1915 *Grindelia squarrosa* (O. A. Stevens) UCM; Stutsman Co., Jamestown, 1♂ 7–VIII–1962 (J. G. & B. L. Rozen) BBSL; Wisconsin: Milwaukee, 1♂ 5–VII–1908 (S. Graenicher) UCM; Clark Co., Worden Township, 1♂ UCM, 1♂ AMNH 27–VII–1919; Wyoming: Yellowstone N.P., 1♂ 23–VII–1930 UCM;

Nomada (Nomadita) mutans Cockerell

Nomada (Holonomada) mutans Cockerell, 1910. Psyche 17:91–92, 98. Holotype, female: "No. 13192: W. M. Mann, Pullman, Wash., VIII:9:08". Type Depository, United States National Museum.

Diagnosis: Differs from *placida, timberlakei,* and *verecunda* by having white instead of yellow maculations. Differs from *aquilarum* by having the apex of the procoxae smoothly rounded, a flattened, sparsely punctate, shiny scutellum, and the absence of prominent supraspiracular ridges. Differs from *snowii* by the lack of rufo-ferruginous markings on the legs which contrast strongly with the thorax. If the legs of *mutans* are light brown to ferruginous, the propodeum and thorax are usually the same color.

Male: Length 6.3–7.7 mm, forewing length 4.5–5.9 mm, hindwing length 3.5–4.0 mm; very similar to female.

Female: Length 5.9–8.9 mm, forewing length 4.0–5.9 mm, hindwing length 3.0–4.7 mm; scape with dense shallow punctures, sparse posteriorly, IPS smooth, shiny; IOD 0.35 mm, OOD 0.34 mm, MLOD 0.16 mm, MOD 0.17 mm, MOOM 0.39 mm; pre-occipital ridge acutely angulate; subapical transverse ridge of labrum broken, with distinct median nipple; acetabular carina reduced to small basal; lamella; prelobar carina distinct, gradually sloping; pronotal ridge strongly angulate, depressed medially; scutal punctures with rims rounded, not angulate; tegulae sparsely punctate with highly polished IPS; metanotum not flattened medially, not laterally expanded; supraspiracular ridges not prominent; metapleuron sparsely punctate; procoxal spine rudiments lacking; metasternum ridged medially; hind tibial apex with 5 heavy, dark bristles in an overlapped double row; forewing with 3 submarginal cells: COLOR: antero-apical patch on scape, clypeus (except basal margin), labrum, basal half of mandibles, malar space, sides of face to apex of scape, ring behind compound eye to same height, pronotal ridge and lobes, tegulae in part, scutellum, metanotum, crescent behind pronotal lobe, anterior and posterior mesopleural triangles, apical

patches on meso- and meta-sternum, spot on pro-coxae, larger on mid- and hind-coxae, ventral apical stripe on pro-femora, basal and apical bands on tibiae, apical band on mid-femora, spot on hind-femora, incomplete apical and basal bands on mid- and hind-tibiae, complete transverse bands on tergum 1–5, transverse bands on sterna 2–4, white; remainder of body piceo-fuscous.

Discussion: *Nomada mutans* contains the smallest North American *Nomadita.* This species ranges from the northern coastal areas inland to Montana and Utah. The black integument is brownish in some specimens. Specimens from Utah show a reduction in the amount and extent of white maculations, including an interruption of the abdominal bands, which makes them strongly resemble *N. aquilarum.*

Material Examined: CANADA: British Columbia: H.-Steele, 1♀ 15–VIII–1921 (W. B. Anderson) CNC; Oliver, 2♂♂ 15–IX–1923 (C. B. Garrett) CNC; Nicola, 1♂ 3–VIII–1923 (E. R. Buckell) CNC; U.S.A.: Arizona: Kaibab Forest, 1♀ 9–VIII–1936 (R. H. Beamer) SMEK; California: Siskiyou Co., Gazelle, 4♂♂ 11–IX–1950 (M. F. McClay) UCD; Klamath Lake, 1♂ 21–VIII–1954 (G. Ferguson); Idaho: Moscow, 1♀ (J. M. Aldrich) BBSL; Bonneville Co., Selander Park 16.9 km (10.5 mi) SW Idaho Falls, 1♀ 17–21–VIII–1979 (J. E. Slansky) CSDA; Owyhee Co., Homedale, 3♂♂ 24–VIII–1953 (R. M. Bohart) UCD; Valley Co., Lunch Creek, 1♀ 3–VIII–1964 (R. L. Westcott) BBSL; Montana: Gallatin Co., Hebgen Lake, 1♀ 30–VII–1974 (T. Griswold); Nevada: Austin, 1♂ 12–VIII–1940 (E. E. Kenaga) SMEK; Clark Co., Kyle Canyon 2130 m (7000′), 1♂ (F. D. Parker), 1♂ (R. C. Bechtel), 11–VIII–1959 *Solidago* NDAg; Elko Co., Wild Horse 1830 m (6000′), 2♀♀ 25–VII–1962 (R & K Dreisbach); Oregon: North Powder, 6♂♂, 4♀♀ 24–VII–1938 *Solidago* (H. A. Scullen) ORSU; Powder River, 41.9 km (26 mi) E. Baker, 910 m (3000′), 1♂ 9–VIII–1937 (Bolinger-Jewett) ORSU; Queen Mine above Cornucopia, 1520 m (5000′), 1♂ 2–VIII–1937 (Bolinger-Jewett) ORSU; Baker Co., Baker, 1♀ 6–IX–1963 (J. S. Puckett) BBSL; Harney Co., Antelope Mt., 1980 m (6500′), 1♀ 14–VIII–1931 (D. K. Frewing) ORSU; Utah: Box Elder Co., Snowville, 1♂ 26–VIII–1969 *Chrysothamnus viscidiflorus* (G. F. Knowlton); Willard Basin, 1♂ 1–VIII–1961 (G. E. Bohart); Willard Pk., 1♂ 24–VIII–1964 (P. F. Torchio); Emery Co., 6.4 km (4 air mi) N. Gilson Butte 1550 m (5100′), 1♂, 1♀ 26–VIII–1985 (D. K. Broemeling), 1♂ 16/17–IX–1980 (T. Griswold); Goblin Vly. trn.off in sand dunes, 1♀ 16–IX–1979 (F. D. Parker D. Veirs); Huntington Cr. 2680 m (8800′), 1♂ 11–VIII–1973 (T. Griswold); Rich Co., Limber Pine, 2♂♂, 2♀♀ 12–VIII–1984 (D. K. Broemeling); Utah Co., Mt. Nebo Loop, 1♀ 4–VIII–1977 (G. F. Knowlton); Washington: Bay Center, 1♀ 27–VII–1937 ORSU; Pullman, (W. M. Mann), 1♀ 30–VIII–08 USNM, 2♀♀ 9–VIII–08 UCM, 1♀ 9–VIII–08 USNM; Wyoming: Jackson, 1♀ 17–VIII–1961 (J. E. R. Stainer) CNC;

Nomada (Nomadita) placida Cresson

Nomada placida Cresson, 1863. Proc. Ent. Soc. Phil. 2:291–292. Lectotype, female: "Penn., 2600". Allotype, male, "Penn., 2600". Type Depository, Academy of Natural Sciences of Philadelphia.

Diagnosis: Differs from *aquilarum, mutans* and *snowii* by having yellow maculations instead of white. Differs from *snowii* by the lack of extensive ferruginous markings on the mesopleuron and legs and by having medially interrupted transverse maculations on at least one abdominal tergum. Differs from *timberlakei* and *verecunda* by the presence of one or more medially interrupted maculations on the abdominal terga and by the absence of maculations on the first tergum.

Male: Length 7.4–7.7 mm, forewing length 5.2–5.5 mm, hindwing length 4.0–4.3 mm; does not differ significantly from female.

Female: Length 5.9–7.9 mm, forewing length 4.7–5.4 mm, hindwing length 3.7–4.1 mm; scape moderately punctate; IOD 0.33 mm, OOD 0.35 mm, MLOD 0.13 mm, MOD 0.17 mm, MOOM 0.48 mm; occipital margin sharply angulate; labrum with 5 distinct teeth in transverse subapical row; acetabular carina nearly absent; pre-lobar carina strong; pronotal ridge with sharply angulate anterior margin, depressed medially, deep, large punctures; scutal punctures often reticulate; tegulae punctate anteriorly, nearly impunctate posteriorly, IPS glassy; scutellum faintly bilobate; supraspiracular ridge angulate; hypoepimeral area not strongly protruberant; metapleuron with dense, even punctation; pro-coxae with weak spine rudiment; hind tibial apex with 5 heavy, dark bristles in a staggered row; forewing with 3 submarginal cells: COLOR: clypeus (except basally), sides of face extending upwards along compound eye to vertex, pronotal ridge and lobes, traces on tegulae, scutellum, metanotum, small anterior mesopleural triangle, tibiae dorsally, apex of hind coxa, abdomen as in illustration, yellow; supraclypeal area, antennae, base of clypeus, tegulae, legs, light brown; remainder of body black.

Discussion: This species appears to be restricted to the eastern half of the country. Its range does not overlap with any other yellow maculated species. Its closest relative would seem to be *N. verecunda,* but in structure and patterning it bears a strong resemblance to *N. aquilarum.*

Material Examined: CANADA: Ontario: Marmora, 1♂ 19–VIII–1952 (E. H. N. Smith) CNC, 1♂ 3–VIII–1952 (C. Boyle) CNC; U.S.A.: Illinois: Carlinville, (Robertson), 1♂ , 1♀ AMNH; Lincoln, 2♂♂ , 1♀ –IX– UNEB; Piatt Co., 3.2 km (2 mi) W White Heath Pres., 1♀ 22–IX–1982 (E. R. Miliczky) INHS; Vermilion Co., 8.1 km (5 mi) SE Westville Forest Glen Pres., 1♀ 30–IX–1980 (E. Miliczky) INHS; Indiana: Lafayette, 1♀ 4–IX–1930 (Geo. G. Ainslie) UCM; Kansas, Topeka: 1♂ –IX– J. (E. Taylor) ANSP; Yates Center, 1♀ 7–IX–1949 *Amphiachyris dracunculoides* (Michener-Beamer); Maryland: Glen Echo, 1♂ 21–IX–'30 *Aster ericoides* (J. C. Bridwell) USNM; Prince Geo. Co., Beltsville, 1♀ 24–IX–1964 (P. H. Arnaud, Jr.,) CAS; Missouri: Ashland, 1♂ 30–VII–1966 (Poe) CORN; Nebraska: Lincoln, 2♂♂ , 1♀ –IX– UNEB; New Jersey: Montclair, 1♀ 4–IX–1931 (M. A. Cazier) UCM; Trenton, 1♂ 2–IX–1906 (Harbeck) USNM; Union Co., Watchung Res., 2♀♀ 4–IX–1954 (G. Ferguson) BBSL; New York: Ft. Montgomery, 1♂ 9–IX–1917 (F. M. Schott) AMNH; Oswego Co., Granby Center, 1♀ 25–VIII–1950 CORN; Tompkins Co., (R. A. Morse) CORN, 1♂ 12–VIII–1960 *Solidago* sp., 1♂ , 1♀ 17–VIII–1960 *Solidago* sp., 1♀ 12–VIII–1962 *Solidago* sp., 1♂ 22–VII–1962 *Daucus carota,* 1♂ 22–VIII–1958 *Solidago* sp.; Ohio: Hocking Co., 1♂ –VIII–192? (C. H. Kennedy) LACM; Pennsylvania: 1♀ ANSP paratype 2600.4; 1♂ ANSP paratype 2600.3; Carlisle Jc., 1♂ 28–VIII–1909, (W. S. Fisher) USNM; Virginia: E. Falls Ch., 1♂ 19–IX–1920 (S. A. Rohwer) USNM; Glen Carlyn, 1♀ 20–IX–1930 (Timberlake) LACM; Minors Hill Falls Ch., 1♂ 13–IX–1912 (C. T. Greene) UCM; Fairfax Co., Scott Run, 1♀ 6–IX–1969 (A. S. Menke, D. R. Miller) LACM.

Nomada (Nomadita) snowii Cresson

Nomada snowii Cresson, 1878. American Hymenoptera 75. Lectotype, female: "Col. Snow, 2597". Type Depository, Academy of Natural Sciences of Philadelphia.

Nomada antonita Cockerell, 1909. Canadian Entomologist 41:35–36. Holotype,

male: "No. 29473, Antonito, Col., 8–5–00". Type Depository, United States National Museum. NEW SYNONYMY

Nomada (Holonomada) omahaensis Swenk, 1915. University Studies XV:17. Holotype, male: "Omaha, Nebraska, August 29, 1914, on *Solidago canadensis* L. T. Williams". Type Depository, University of Nebraska, Lincoln.

Diagnosis: Differs from the other species by the rufo-ferruginous coloring on the legs strongly contrasting with the black propodeum. Differs from *aquilarum* and *placida* by having uninterrupted medial transverse maculations on the abdominal terga (except tergum 1 which often lacks any light maculation). Differs from *placida, timberlakei* and *verecunda* by the presence of white rather than yellow maculations.

Male: Length 6.3–11.1 mm, forewing length 4.8–8.4 mm, hindwing length 3.6–6.7 mm; scape moderately punctate, interior and posterior punctation very sparse, interpunctural surface highly polished; IOD 0.48 mm, OOD 0.43 mm, MLOD 0.18 mm, MOD 0.19 mm, MOOM 0.56 mm; pre-occipital ridge thick, subcarinate; labrum with apical transverse carina, broken into distinct denticles; pre-lobar carina thickened, gently sloping to pronotal lobe; pronotal ridge apex sharply angulate; rims of scutal punctures angulate; tegulae sparsely, shallowly punctate, highly polished; scutellum slightly depressed medially, glossy; metanotum not flattened or laterally expanded medially; propodeum with thick, rounded supra-spiracular ridge, not prominent; hypo-spiracular area shiny, sparsely punctate; metapleuron with ventral half densely punctate; pro-coxal spine rudiment present, not prominent; hind tibial apex with single row of light ferruginous bristles; forewing with 3 sub-marginal cells, apex clear to somewhat clouded; pygidium entire with broadly rounded sides and flattened apex: COLOR: clypeus, sub-antennal area, ring around eye (broken dorsally), labrum, basal two-thirds of mandibles, pronotal ridge and lobes, tegulae, first axillary sclerite, scutellum, metanotum, anterior mesopleuron with posteriorly directed projection, coxal apices, ventral apical stripe on fore- and mid-femora, exterior of mid- and fore-tibiae, broad apical and basal patches on hind tibiae, transverse median band on tergum 2 broadly emarginate anteriorly, slightly narrowed transverse median bands on tergum 3–5, broad apical band on tergum 6, rectangle on sternum 1, broad transverse bands on remaining sterna, white; legs, ferruginous; remainder of body black.

Female: length 6.5–9.6 m, forewing length 4.9–6.1 mm, hindwing length 3.7–4.6 mm; similar to males except: acetabular carina virtually absent, pro-coxal spine rudiments virtually absent, hind tibial apex with 4 heavy bristles and long thin posterior bristle, supra-clypeal area and basal half of clypeus ferruginous, posterior ventral mesopleuron ferruginous, tergum 1 ferruginous with white posterolateral patch, propodeum ferruginous.

Discussion: The type of *Nomada antonita* (except for sexual differences) is virtually indistinguishable from the female lectotype of *N. snowii.* The characters used by Rodeck to distinguish *N. antonita* in his revision (1949) are all variable in *Nomada.* I am therefore placing *N. antonita* Cockerell in synonymy with *N. snowii* Cresson. Northern specimens of *N. snowii* (=*omahaensis* Swenk) usually have a complete white band on tergum 1, stronger bands on the remaining terga, and a somewhat smaller pro-coxal spine rudiment than typical specimens. Both forms have been collected at the same time and place in both Colorado and South Dakota. I feel the two forms represent a clinal variation rather than distinct taxa. There is a specimen from Arriola in Montezuma Co., Colorado which differs from typical *N. snowii* in having

light lemon yellow maculations instead of white to cream-colored markings. There are no apparent structural differences between this specimen and typical *N. snowii.* In the absence of more specimens of this form it seems unadvisable to recognize it as a separate taxon.

Material Examined: CANADA: Alberta: 4.8 km (3 mi) SE Picture Butte, 1♂ 6–VIII–1978, 3♂♂ , 2♀♀ 6–VIII–1978 *Solidago missouriensis* (C. D. Michener) SMEK; Lethbridge 2♂♂ , 1♀ 28–VII–16, (Sladen) CNC; Manyberries, 1♂ , 1♀ 11–VIII–1939, (E. H. Strickland), UCM; Medicine Hat, 1♀ 17–IX–1939 (J. L. Carr) UCM, 4♂♂ , 2♀♀ 20–VIII–16, 1♀ 23–VIII–19 (Sladen) CNC; Saskatchewan: Eastend, 2♀♀ 10–IX–1939 (A. R. Brooks) CNC, BBSL; Swiftcurrent, 1♀ 23–VIII–16, (Sladen) CNC; MEXICO: Mexico: 39.5 km (24.5 mi) NW Toluca, 1♂ 30–VII–1962, (Naumann & Marston) BBSL; U.S.A.: Colorado: 1♂ 1930, (H. G. Rodeck) UCM; Boulder, 1♀ 18–VIII–1929, (W. W. Greulich) UCM; Fremont Co., Coaldale 1980 m (6500′), 1♂ 11–VIII–1964 *Helianthus annuus* BBSL, 2♂♂ , 1♀ 11–VIII–1968 *Chrysopsis villosa* SMEK (C. D. Michener); Larimer Co., Chimney Rock 2440 m (8000′), 2♂♂ 30–VIII–1984 Ft.C, 1♀ 5–IX–1976 BBSL, 1♀ 23–VIII–1975, (H. E. Evans) Ft.C; Moffat Co., Mt. Hamilton, 16.1 km (10 mi S), 2♂♂ 11–VIII–1962, *Solidago,* (E. G. Linsley) CIS; Montezuma Co., ♀ 3 mi. W. Arriola 6000′, IX–1975, Malaise Trap, (T. Marquardt) BBSL; Nebraska: Omaha, 1♂ 29–VIII–1914, *Solidago canadensis,* (L. T. Williams) UNEB, paratype; North Dakota: Bottineau, 1♂ 19–VIII–1923, 1♂ 23–VIII–1923 (C. N. Ainslie) AMNH; Valley City, 1♀ 15–VIII–1912, BBSL; Grand Forks Co., 17.7 km (11 mi) NW Inkster, 1♀ 17–VIII–1955, *Grindelia squarrosa,* (W. E. LaBerge) SMEK; New Mexico: Colfax Co., 8.1 km (5 mi) S Eagles Nest, 1♂ 14–VIII–1971, (J. G., B. L., & K. C. Rozen) AMNH; South Dakota: Custer, 1♂ , 1♀ UNEB; Utah: Wayne Co., 27.4 km (17 mi) S. Bicknell, 1♀ 9–VIII–1950, (T. Cohn, P. Boone, M. Cazier) AMNH;

Nomada (Nomadita) timberlakei New Species

Holotype, male: "Baldwin Lake, Cal., Sept. 1. 36, Timberlake Coll.,". Allotype, female: "Valley of the Falls, Cal., Sp.7.35 nr. *Eriogonum subscaposum,* Timberlake Coll." Type Depository, University of California, Riverside.

Diagnosis: Differs from *aquilarum, mutans* and *snowii* by having bright yellow instead of white maculations. Differs from *placida* by having complete transverse maculations on all abdominal terga. Differs from *verecunda* by having a prominent, dull scutellum (as opposed to flattened, sparsely punctate and highly polished), and the apex of the pronotal ridge is rounded. A difference in reflectivity of the abdominal terga is the best (but most difficult to describe) character for differentiating *timberlakei* from *verecunda.* The abdominal terga of *timberlakei* are closely punctate, shining a bright light upon the yellow portions of the abdomen will produce a diffuse reflection, giving the tergum a dull appearance. This same light will produce a sharp, circular reflection on *verecunda. Nomada timberlakei* has much closer punctation on the terga, with a dull interpunctural surface. *Nomada verecunda* has more widely spaced punctation (1 to several puncture widths apart) and a polished interpunctural surface. The yellow abdominal maculations of *timberlakei* are usually lighter colored than *verecunda*'s.

Males: Length 6.7–10.4 mm, forewing length 5.1–6.7 mm, hindwing length 3.7–5.2 mm; scape densely punctured with smooth shiny IPS; IOD 0.45 mm, OOD 0.38 mm, MLOD 0.17 mm, MOD 0.20 mm, MOOM 0.46 mm; pre-occipital ridge

present, not sharply angulate; sub-apical transverse ridge of labrum broken into 5 teeth; acetabular carina strong, lamellate; pre-lobar carina strong, sloping gently; pronotal ridge not angulate apically, depressed medially; scutal punctures with sharply angulate rims; tegulae sparsely punctate, glassy; scutellum bilobate; metanotum somewhat laterally inflated; supraspiracular ridge not prominent; metapleuron punctate; pro-coxal spine rudiment absent; hind tibial apex with 3 short anterior bristles, one long posterior bristle, fuscous, in strong contrast to yellow tibiae; yellow bands on abdomen not highly reflective: COLOR: anterior of scape, first flagellar segment, supraclypeal area (except subantennal sutures), clypeus, sides of face up to apex of compound eyes, malar space, labrum, basal two-thirds of mandibles, submandibular area and broad band extending halfway to vertex behind eyes, pronotal ridge and lobes, tegulae, axillary sclerites in part, mesopleuron except epimeral and posterior areas, posterior medial patch on meso- and metasternum, scutellum, metanotum, coxae (except bases), trochanters in part, femora (except basal areas), fore- and mid-tibiae, hind-femora (except medial annular ring), tarsi, extensive transverse medial bands on all terga, large patch on first sternum, almost all of remaining sterna, bright lemon yellow; remainder of body dark brown to black.

Females: Length 6.7–8.9 mm, forewing length 4.7–6.1 mm, hindwing length 3.7–4.7 mm; very similar to males, except with more extensive yellow markings.

Discussion: This species is difficult to separate from *verecunda.* It has frequently been misidentified as that species. *Nomada verecunda* is found in the mountains of northern California, Nevada, and southern Oregon. *Nomada timberlakei* has only been found in central and southern California.

Paratypes: U.S.A.: California: San Bern. Co., Barton Flat, So. Fork Camp, 4♂♂ 12–IX–1944, 1♂ 21–IX–1944, 1♂ , 1♀ 24–IX–1944, 4♂♂ 3–IX–1944 (A. L. Melander) UCR; 1♂ , 1♀ E. Fk. Santa Ana River, 19–IX–1945 (A. L. Melander) UCR; Riverside, 10♂♂ , 1♀ 10–X–1931 *Baccharis emoryi,* 1♂ 10–X–1931 *Isocoma vernonioides,* 1♂ 16-X–1927 *Baccharis emoryi,* 1♂ , 2++ 17–X–1931, *Baccharis emoryi* BBSL, 4♂♂ 18–IX–1927 *Isocoma vernonioides,* 1♀ 20–X–? *Isocoma vernonioides,* 1♂ 22–IX–1949 *Isocoma vernonioides,* 1♂ 23–X–1933 *Ericameria palmeri,* 2♂♂ , 1♀ 8–X–1932 *Isocoma vernonioides*; So. Fork Camp, San Bernardino Mts., 1♂ 24–IX–1946 *Solidago californica,* 1♂ 2–IX–1946 *Solidago californica* BBSL (Timberlake); So. Fork Camp, San Bernardino Mts., 1890 m (6200′), (Timberlake) 1♂ 9–IX–1947 *Chrysothamnus,* 1♂ 2–IX–1946 *Solidago californica,* 1♂ 4–IX–1946 *Gutierrezia californica*; So. Fork Santa Ana R., S. Bern. Mts., 1890 m (6200′), (Timberlake) 1♂ 13–IX–1962 *Chrysothamnus nauseosus,* 1♂ 14–IX–1962; Valley of the Falls, *Eriogonum subscaposum,* 1♂ 29–VIII–1935, 1♀ 7–IX–1935; 1♂ 27–VIII–1935; 3.2 km (2 mi.) SW Seven Oaks, 1♂ 3–X–1967 (P. A. Rude) CIS; Upper Santa Ana River, (A. L. Melander), 1♂ 14–IX–1949, 1♂ , 1♀ 15–IX–1949, 1♀ 21–IX–1949, 1♂ 23–IX–1947, 1♂ , 1♀ 7–IX–1948, (Grace H. and John L. Sperry), 1♀ 19–IX–1946 *Chrysothamnus parryi,* 1♂ 22–IX–1946 *Chrysothamnus parryi,* 1♂ 24–VIII–1946, 3♂♂ 6–IX–1946 *Gutierrezia sarothrae,* 1♂ 6–IX–1946 *Chrysothamnus nauseosus,* 1♂ 6–IX–1946 *Senecio ionophallus,* (Paul H. Arnaud, Jr.), 5♂♂ 9–IX–1958 CAS;

Additional Material Examined: U.S.A.: California: Antioch, 1♂ 18–VIII–1974 (B. Villegas) UCD; San Pedro, 1♂ , 25–X–1909 (G. R. Pilate) CAS; Contra Costa Co., Antioch sand dunes, 1♂ 7–X–1967 (T. W. Davies) CAS; Inyo Co., CSDA; 19.3 km (12 mi) SW Little Lake, 1♂ , 1♀ 16–IX–1969 *Chrysothamnus* sp. (M. Wasbauer) CSDA; Kern Co., 3.2 km (2 mi.) W Frazier Park, 1♂ 6–X–1967 *Chrysothamnus* (P. A. Opler), CIS; Santa Clara Co., 1♂ CIS;

Nomada (Nomadita) verecunda Cresson

Nomada verecunda Cresson, 1879. American Hymenoptera 203. Lectotype, male: "Nev., 2565". Type Depository, Academy of Natural Sciences of Philadelphia.

Diagnosis: Differs from *aquilarum, mutans,* and *snowii* by having yellow rather than white maculations. Differs from *placida* by the lack of medially interrupted transverse maculations on the abdominal terga. Differs from *timberlakei* by the flattened, sparsely punctate, highly polished scutellum, sharply angulate apex of the pronotal ridge sublaterally, and the highly reflective integumental maculations of the abdominal terga.

Male: Length 6.3–8.9 mm, forewing length 4.7–5.9 mm, hindwing length 3.6–4.5 mm; scape densely punctate anteriorly, sparser interiorly; IOD 0.42 mm, OOD 0.41 mm, MLOD 0.14 mm, MOD 0.18 mm, MOOM 0.49 mm; pre-occipital ridge sharply angulate; labrum with median subapical nipple; acetabular carina strong; pre-lobar carina somewhat flattened; pronotal ridge not sharply angulate anteriorly, depressed medially; tegulae punctate, sparsely along margins, glassy; scutellum flattened, slightly depressed medially; metapleuron evenly punctate; pro-coxal spine rudiments lacking; hind tibial apex with 6 bristles in an offset double row; forewing with 3 submarginal cells: COLOR: clypeus, anterior of scape, sides of face extending to vertex, labrum, mandibles (except tips), pronotal ridge and lobes; tegulae, scutellum, anterior margin of mesopleuron and longitudinal mesopleural band, coxae, apical portions of femora, tibiae, tarsi, meso- and meta-sternal apices, transverse median bands on terga and sterna, orangeish-yellow; remainder of body dark brown to black.

Female: length 6.2–8.5 mm, forewing length 4.4–5.6 mm, hindwing length 3.6–4.4 mm; very similar to males, but with more extensive yellow markings.

Discussion: See *timberlakei.*

Material Examined: U.S.A.: California: Boca Dam 17.7 km (11 mi) E Truckee, 1♂ 24–VIII–1956 *Chrysothamnus nauseosus* ssp. *speciosus* (E. G. Linsley) CIS; Lake Tahoe, 1♂ (Thompson) CIS; Mt. Lassen N P, 1♂ 10–VIII–1940 (Richard L. Post) ORSU; Mt. Lassen Nat. Park, 2290 m (7500′), 1♂ 30–VII–1947 (R. M. Bohart) USNM, 2320 m (7600′), 1♂ 30–VII–1947 (R. M. Bohart) UCD; Nr. Lk. Eleanor Yos. Park, 1♀ 29–VII–1930 (E. C. Zimmerman) CAS; Sagehen nr. Hobart Mills, 1♂ 10–VIII–1951 *Eupatorium occidentale* (E. G. Linsley) CIS; Sonora Pass, 1♀ 30–VII–1954 (J. C. Downey) UCD; Tahoe, 1♀ –VII–1925 (F.X.W.) LACM; Alpine Co., Winnemucca Lk., 1♂ 30–VIII–1959 (P. M. Marsh) UCD; Eldorado Co., Echo Summit, 1♀ 4–VIII–19 (T. R. Haig) BBSL; Fresno Co., Huntington Lake 2130 m (7000′), 1♂ 30–VII–19 (E. P. VanDuzee) CAS; Mono Co., 32.2 km (20 mi) E Jct. Hwy. 120–395, 1♀ 9–IX–1958 (A. D. Telford) UCD; Nevada Co., Sagehen Crk, 1♀ 23–VII–1968 (C. J. Horning) UCD; Placer Co., Brockway, 1♂ –VII–1941 (G. E. Bohart) BBSL; Plumas Co., 12.9 km (8 mi) NW Chester, 1♂ 18–VIII–1958 (J. Powell) CIS; Shasta Co., Lassen Natl. Pk., 1♀ 16–VIII–1961 (R. F. Wilkey) CSDA; Old Station, 8.1 km (5 mi.) SW, 1♂ 25–VIII–1958 *Haplopappus bloomeri* ssp. *angustatus* (J. Powell) CIS; Sierra Co., Gold Lake, 1950 m (6400′), 1♂ 30–VIII–1977 (H. K. Court) CAS; nr. Gold Lake, 1♀ 13–VIII–1963 (R. L. Westcott) LACM; Weber Lake, 1♀ 4–VIII–1951 (E. I. Schlinger) BBSL; Yuba Pass, 1♂ 30–VII–1958 (A. A. Grigarick) UCD; Siskiyou Co., Castle Lake, 1♀ 29–VIII–1958 (J. Powell) CIS; Isinglass Lk T43N R11W Sec 1, 1980 m (6500′), 1♂ 12–VIII–1979 (T. Griswold) BBSL; Medicine Lake, 1♂ 5–IX–1955 (Joe Schuh) BBSL; Trinity Co., Lower Cyn

Cr Lk T36N R10W Sec21, 1♂ 29–VII–1979 (T. Griswold) BBSL; Tulare Co., Mineral King, 1♂ 7–VII–1942 (R. Bohart) BBSL; Tuolumne Co., Sonora Pass, 1♂ 4–VIII–1948 (P. D. Hurd & J. W. MacSwain) CIS; Nevada: 1♂ ANSP paratype 2565.6; 1♂ ANSP paratype 2565.7; 1♂ ANSP paratype 2565.10; 1♀ ANSP paratype 2565.5; 40♂♂ ANSP; 1♀ USNM; 2♂♂ UCM; 1♂ ANSP paratype 2565.4; 1♂ ANSP paratype 2565.9; 1♂ ANSP paratype 2565.3; 1♂ , 1♀ Fallon, 10–VI–1960 BBSL; Oregon: 8.1 km (5 mi) W. Suttle Lake, 1♀ 30–VII–1939 (Gray & Schuh) ORSU; Crater Lake Park, Pole Bridge Meadow, 1800 m (5900′), 1♂ 11–VIII–1935 (H. A. Scullen) UCM, 1♂ , 4♀♀ 11–VIII–1935 (Geo. Ferguson) ORSU, 12.9 km (8 mi.) out Medford Rd., 1680 m (5500′), 2♀♀ 10–VIII–1930 *Solidago* sp. (H. A. Scullen) ORSU, East entrance, 1680 m (5500′), 1♀ 28–VIII–1930 (H. A. Scullen) ORSU, Lost Creek, 1830 m (6000′), 1♂ 14–VIII–1930 *Solidago* sp. (H. A. Scullen) ORSU, 1♂ 14–VIII–1930 *Solidago* sp. (F. Lyle Wynd) ORSU, Sun Creek Meadow, 1980–2130 m (6500–7000′), 1♀ 26–VIII–1930 (H. A. Scullen) ORSU; Mt. Hood, 910–1830 m (3000–6000′), 2♀♀ 4–VIII–1925, 7♀♀ 5–VIII–1925, (C. L. Fox) CAS; Deschutes Nat'l. Forest, Elk Lake, 1♂, 21–VIII–1937, Sparks Lake, 1♀ 21–VIII–1937 (Bolinger Jewett) ORSU; Three Sisters, nr.Lava, 1♀ 15–VIII–1926 (H. A. Scullen) ORSU; Klamath Co., Lake of the Woods, 1♂ 6–VIII–1959 (P. F. Torchio) BBSL;

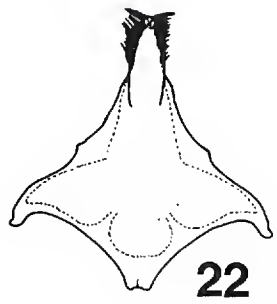
SUBGENUS *ASTERONOMADA*

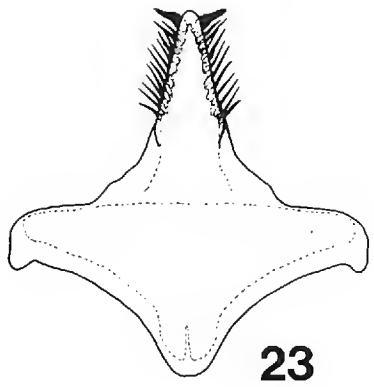
Nomada subgenus *Asteronomada* New Subgenus

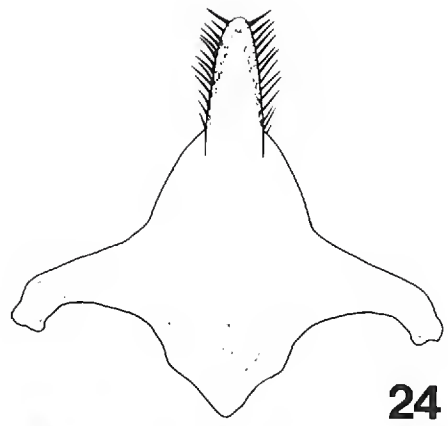
Type species *Nomada adducta* Cresson, 1878.

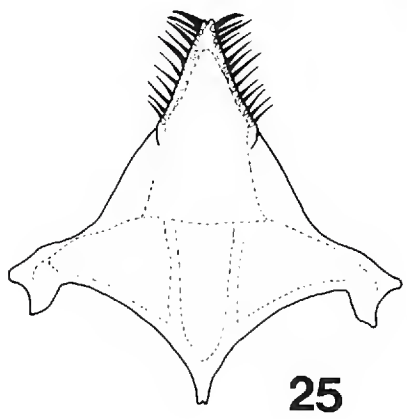
Diagnosis: Differs from *Nomada* s.s. by lack of bidentate mandibles, the first flagellar antennal segment distinctly longer than second (up to twice as long), or the rufous color found in both sexes. Differs from *Holonomada* and *Laminomada* by having the hind tibial apex with a single row of stout bristles instead of a dense cluster of pale setae. Differs from *Phelonomada* by rufous coloration and short, stout hind tibial apical bristles. Differs from *Pachynomada* and *Nomadita* by the presence of dense, appressed pubescence on the dorsum of the hind coxa and sides of the propodeum (completely hiding the underlying integument). Differs from *Pachynomada* by the lack of ventral subapical hooks on the penis valves. Differs from *Nomadita* by the elongated, narrow apex of the eighth sternum in males, and the presence of fine setae on the margins of the sternum (*Nomadita* has stout bristles on the margin).

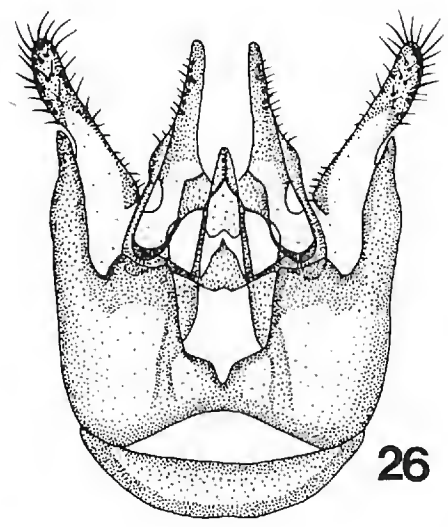
Description: Length 6.7–11.6 mm, forewing length 4.9–8.4 mm; first flagellar segment significantly longer than second; occipital margin rounded to slightly angulate; supraclypeal area distinctly protruding between antennal insertions with distinct frontal carina; labrum with a subapical transverse ridge, in some species broken into irregular denticles; acetabular carina present; mandibles simple; head densely punctate with smooth, shiny IPS: Pronotal ridge apex sharply angulate anteriorly, very narrow medially; pre-lobar carina reduced or absent; scutum distinctly higher than pronotum, curved abruptly downward to it, densely punctured, puncture rims rounded, IPS smooth, shiny; tegulae sparsely punctate, glassy; axillae rounded dorsally; sides of propodeum and hind coxae densely covered with short, appressed, silvery white, plumose hairs; mesopleuron with dense, but not contiguous punctation, hypoepimeral area not prominent; hind tibial apex with a single row of stout bristles; forewing with three submarginal cells; abdominal terga with a distinct apical depressed area which is often impunctate, this area can occupy up to one-third width of terga; male sternum 8 with long thin apex (broad basally in *adducta*) and fine lateral

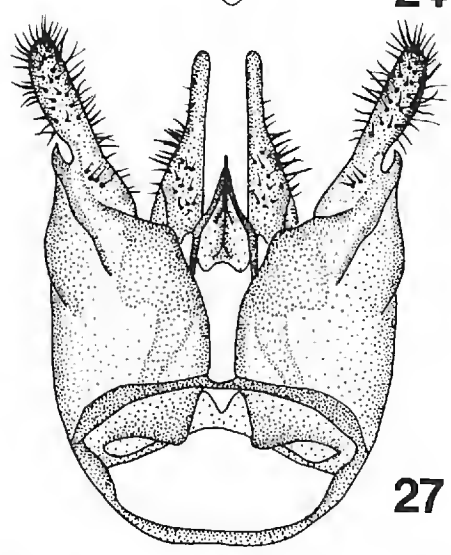


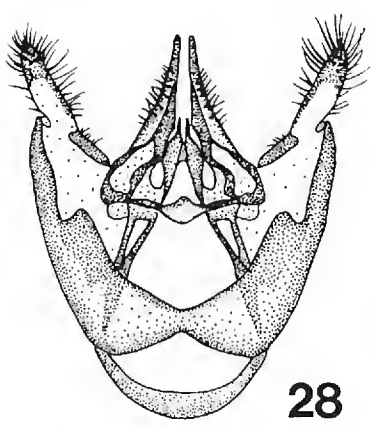


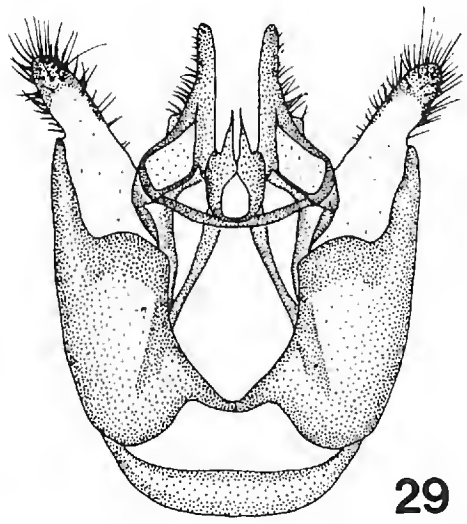


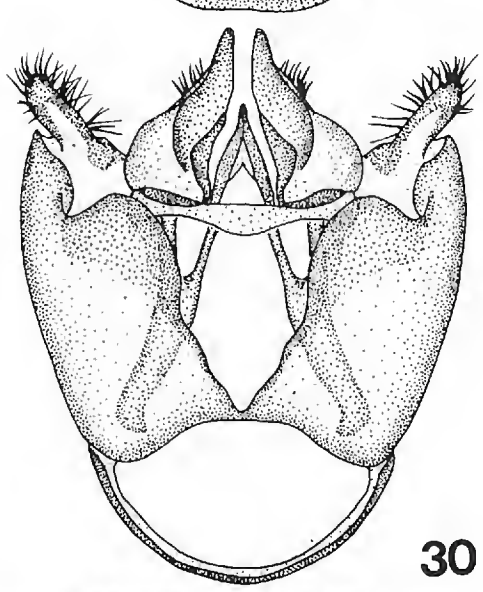


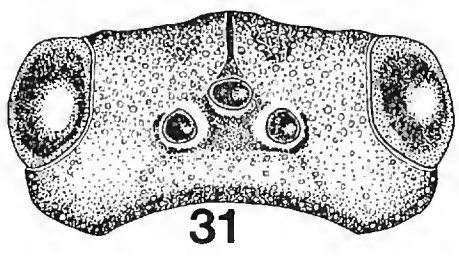


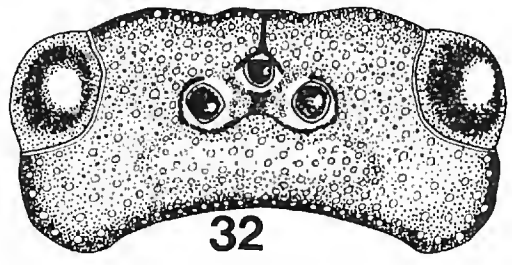












Figs. 22–22, subgenus *Asteronomada*

Figs. 22–25, male sternum 8; 22) *portalensis,* 23) *durangoae,* 24) *brewsterae,* 25) *adducta*; Figs. 26–30, genital capsule; 26) *adducta* (dorsal), 27) *adducta* (ventral), 28) *portalensis* (dorsal), 29) *durangoae* (dorsal), 30) *brewsterae* (dorsal); Fig. 31) *brewsterae* (dorsal view of vertex); 32) *durangoae* (dorsal view of vertex)

setae; genital capsule (dorsally) with gonocoxites apically separated by a broad emargination; penis valves lacking ventral subapical projection.

Discussion: This subgenus occupies a position intermediate between *Pachynomada* and *Nomadita*. *Nomada adducta* has much in common with *Pachynomada,* including the swollen male antennal scape (a feature it shares with *brewsterae,* but not with *durangoae* and *portalensis*). *Asteronomada* differs from *Pachynomada* by the lack of ventral subapical hooks on the penis valves, the hind basitarsus is flattened, not inflated medially, and is not widest at the midpoint, and *Asteronomada* species have a patch of dense appressed hair (completely hiding the integument beneath) on the sides of the propodeum. *Asteronomada* differs from *Nomadita* by the lack of a subcarinate angulation of the occipital margin, by the shape of the eighth sternum, and the appressed hairs of the propodeum which completely cover the integument beneath them. The rufo-ferruginous body color of *Asteronomada* species differs from all *Nomadita* species.

KEY TO THE SPECIES OF *ASTERONOMADA*

1) Vertex raised, forming a prominent transverse post-ocellar ridge 2
   Vertex not forming a prominent transverse post-ocellar ridge 3
2) Males without globose antennal scape, post-ocellar ridge bordered anteriorly by a shiny, impunctate groove, joining a longitudinal groove between ocelli to form a "T" . . . . . *durangoae* n.sp.
   Males with antennal scape globose, post-ocellar ridge not bordered anteriorly by a shiny, impunctate groove joined to a longitudinal groove between ocelli . . . . . *brewsterae* n.sp.
3) Males with globose antennal scape, apical impunctate band of tergum 3 narrow, (about 3 puncture diameters in width) . . . . . *adducta* Cresson
   Males without globose antennal scape, apical impunctate band of tergum 3 wide (one-third total width of tergum) . . . . . *portalensis* n.sp.

The Species of *Asteronomada*

Nomada (Asteronomada) adducta Cresson NEW COMBINATION *Nomada adducta* Cresson, 1878. American Hymenoptera 73. Holotype, male: "Col., 2591". Type Depository, Academy of Natural Sciences of Philadelphia.

Diagnosis: Differs from *portalensis* and *durangoae* by the presence of a densely punctate, globose antennal scape in males. Differs from *portalensis* by the narrow apical impunctate band of tergum 3. Differs from *durangoae* and *brewsterae* by the lack of a prominent raised, transverse ridge behind the ocellar triangle.

Male: Length 8.9–10.3 mm, forewing length 6.4–6.9 mm, hindwing length 5.0–5.2 mm; antennal scape globose, heavily punctate, smooth, shiny IPS, posterior densely micro-punctate; IOD 0.44 mm, OOD 0.46 mm, MLOD 0.17 mm, MOD 0.20 mm, MOOM 0.54 mm; occipital margin smoothly rounded; labrum with broken transverse subapical carina, and median nipple; acetabular carina strongly lamellate; prelobar carina sharp, short; pronotal ridge strongly angulate apically; scutum deeply reticulately punctured; scutellum distinctly bilobate, postero-medial region with roughened, dull IPS; metanotum flattened; hind coxae and sides of propodeum covered with short, densely appressed, plumose hairs; ventral metapleuron punctate; pro-coxal spine rudiment lacking; hind tibial apex with 4 stout, ferruginous bristles; basitarsus not medially inflated, angulate anterior margin; forewing with 3 submargi-

Figure 34. Distribution of the species of the subgenus *Asteronomada*

nal cells, apices slightly infuscated: COLOR: rufous; clypeus, sides of face, labrum, basal half of mandibles, creamy-yellow; pronotal ridge and lobes, tegulae, metanotum, scutellum, legs, ferruginous; propodeum dark ferruginous; vertex and apical tergal segments fuscous.

Female: Length 8.7–10.4 mm, forewing length 6.1–7.3 mm, hindwing length 4.6–6.1; facial markings more ferruginous than yellow. Antennal scape not globose.

Discussion: This species is widely distributed, but uncommon. This may be due in part to its late season of flight when most collectors are not active. From brief field observations, its behavior patterns seem similar to *Pachynomada* (pers. obs.), and it is often collected in the same areas.

Material Examined: U.S.A.: Arizona: Cochise Co., Apache 0.8 km (0.5) mi N, 1♂ 4–IX–1972 *Helianthus* (R. R. Snelling) LACM; Kansas: Marysville, 1♂ 12–IX–1920 *Solidago* (Edna M. Stevens) UCM; Douglas Co., 2♂♂ 25–VIII–1949 *Helianthus annuus* (Michener-Beamer) SMEK; Phillips Co., 590 m (1940′), 2♀♀ 30–VIII–1912 (F. X. Williams) UNEB; Nebraska: 20.9 km (13 mi) N. of Harrison, 2♂♂ 28–VIII–1959 BBSL; Bennet, 1♀ 21–VIII–1936 LACM; Lincoln, 1♀ –IX– UCM, 2♀♀ 17–VIII–1902 *Solidago* (M. H. Swenk) UNEB, 1♂ 27–VIII–1902 *Solidago* (M. H. Swenk) UNEB, 3♂♂ 28–VIII–1900 (J. C. Crawford) UCM, 1♀ 30–VIII–1900 *Helianthus* sp. (Crawford) UCM, 4♀♀ 30–VIII–1900 (J. C. Crawford), 1♂ ,1♀ 30–VIII–1900 (J. C. Crawford) USNM, 1♂ 30–VIII–1961 *Helianthus* (W. E. LaBerge) BBSL, 1♂ 30–VIII–1961 *Helianthus* (W. E. LaBerge); Mitchell, 1♀ 12–VIII–1916 (C. E. Mickel) UNEB; Omaha, 1♀ 25–VIII–1914 (L. T. Williams) UNEB; Sioux Co., 12.9 km (8 mi.) N Harrison, 1♂ 9–VIII–1971 (J. G., B. L., K. C. Rozen) BBSL; Utah: Garland 1♂ 1–IX–1932 (G. F. Knowlton, M. J. Janes) BBSL; Salt Lake, 1♂ 6–VIII–19?4 *Helianthus* Timberlake LACM; Salt Lake City, 1♂ 1923 (H. R. Hagan) BYU; Cache Co., Hyrum Dam, 28–VIII–1987, 1♂ (N. N. Youssef) 1♀ (D. K. Broemeling), *Grindelia*; Logan, 1♂ 27–VIII–1947 BBSL; Garfield Co., 9.7 km (6 mi.) SE Escalante, 1♂ 30–VIII–1985 *Helianthus* sp. (D. K. Broemeling) BBSL; Utah Co., 1♂ –IX–1932 (Vasco M. Tanner) BYU;

Nomada (Asteronomada) brewsterae New Species

Holotype, male: "Brewster Co., 10–8–35, TX, 6228". Type Depository, University of Colorado, Boulder.

Diagnosis: Differs from *adducta* and *portalensis* by the presence of a prominent transverse ridge behind the ocellar triangle. Differs from *adducta* by having wide apical impunctate bands on the abdominal terga (much greater than 3 puncture diameters). Differs from *durangoae* by the globose antennal scape of the males, and by the lack of a shiny impunctate groove posterior to the ocellar triangle, joined to a longitudinal groove between the ocelli.

Males: Length 11.1 mm, forewing length 8.4 mm, hindwing length 5.9 mm; antennal scape globose, very sparsely, shallowly punctate, highly polished, lacking posterior apical shelf of *Pachynomada*; IOD 0.45 mm, OOD 0.51 mm, MLOD 0.16 mm, MOD 0.24 mm, MOOM 0.55 mm; occipital margin not angulate; vertex behind ocellar triangle forming distinct ridge; area within ocellar triangle flattened, not grooved; vertex lacking micro-punctures (see *durangoae*); frontal carina flattened apically, like a *Pachynomada*; clypeus gently rounded; labrum with strong transverse subapical carina, forming medial beak; acetabular carina strongly lamellate; pre-lobar carina short, reduced; pronotal ridge sharply angulate-carinate anteriorly; scutum densely reticulately punctured, puncture rims angulate; axillae flattened dorsally, but with rounded exterior margin; scutellum bilobate, punctate, shiny; metanotum expanded medially; hind coxae and sides of propodeum covered with short, appressed, highly plumose hairs; pro-coxal spine rudiment present, not strong; hind-tibial apex with at least 5 clear bristles; basitarsus with gently curved posterior margin; tergal impunctate bands wide; forewing with 3 submarginal cells: COLOR:

rufous; lower face, clypeus, mandibles, malar space, pronotal lobes, outer area of tegulae, scutellar lobes, metanotum, yellow (discolored by cyanide in type): supra-clypeal area, post-antennal area up to vertex, expanded laterally along occipital margins, pronotum (except apex of ridge), anterior margin of mesopleuron, median longitudinal scutal band, scutal margins, propodeum and metapleuron, coxal bases, bases of terga, and bases of sterna, posterior basal mid-femora, posterior hind-femora, black.

Females: Unknown.

Discussion: Like *N. adducta,* this species resembles a *Pachynomada.* However, the penis valves lack a ventral subapical hook, and the hind basitarsus is not widest medially as in *Pachynomada.*

Material Examined: This species is known only from the type.

Nomada (Asteronomada) durangoae New Species

Holotype, male: "MEX. Durango, Bermejillo, X–5–66, GE & AS Bohart, near *Helenium*". Type Depository, United States National Museum.

Diagnosis: Differs from all other *Asteronomada* species by having a prominent transverse ridge behind the ocellar triangle which is bordered anteriorly by a polished, impunctate groove, connected to a median longitudinal groove to form a "T". Differs from *adducta* and *brewsterae* males by the lack of a swollen, globose antennal scape. Differs from *adducta* by having wide apical impunctate bands on the abdominal terga (much wider than 3 puncture diameters). The presence of tiny punctures interspersed with normal sized punctures on the vertex are unique within the subgenus.

Males: Length 11.6 mm, forewing length 8.0 mm, hindwing length 6.1 mm; antennal scape densely punctate with smooth shiny IPS, not globose; IOD 0.44 mm, OOD 0.55 mm, MLOD 0.19 mm, MOD 0.24 mm, MOOM 0.65 mm; occipital margin slightly angulate; distinct impunctate transverse groove behind lateral ocelli, joined by a median groove leading to mid-ocellus; sub-antennal area at same level as clypeus, not curving downwards; deep, large (0.04 mm) punctures on vertex interspersed with shallow micro-punctures (0.01 mm); subapical transverse carina of labrum not interrupted; mandibular bases clearly punctate; acetabular carina with thickened lamella; pre-lobar carina flattened, indistinct; pronotal ridge angulate anteriorly, very thin medially; scutum distinctly higher than pronotal ridge or lobes, with dense round punctures, rounded rims, smooth shiny IPS; tegulae densely punctate basally, postero-lateral area virtually impunctate, glassy; axillae with gently rounded dorsal surface; scutellum depressed medially, punctate, polished; hind coxae and sides of propodeum covered with short, appressed, highly plumose pubescence; scrobal and pre-episternal sutures shallow, indistinct; ventral metapleuron shiny, micro-punctate; pro-coxal spine rudiments lacking; hind tibial apex with 3 dark, thick bristles; terga deeply, sharply punctate, IPS dull, shagreened; apical impunctate bands quite wide (0.11–0.20 mm); forewing with 3 sub-marginal cells, darkened apex: COLOR: rufo-ferruginous; supra-clypeal area above termination of frontal carina, frons behind antennal insertion through vertex, median longitudinal band on scutum, entire propodeal disk, base of mid-coxae and propodeum anterior to spiracles, black; apex of clypeus, malar space, mandibular bases, somewhat yellowish.

Females: Unknown.

Discussion: This species is as large as *N. adducta* or *N. brewsterae,* but lacks the

globose antennal scape in males. It resembles *N. portalensis* but is significantly larger, in addition to the other differentiating characters given.

Material Examined: This species is known only from the type.

Nomada (Asteronomada) portalensis New Species

Holotype, male: "Kirkland Jct., Yavapai Co., Ariz., IX–15–61, *Gutierrezia microcephala,* P. D. Hurd Collector". Type Depository, University of California, Berkeley. Allotype, female: "Arizona, 4 mi E. Portal, 1 19–IX–1962 J. Willcox". Type Depository, Natural History Museum of Los Angeles County.

Diagnosis: Differs from males of *adducta* and *brewsterae* by the lack of a globose antennal scape. Differs from *brewsterae* and *durangoae* by the absence of a prominent transverse ridge posterior to the ocellar triangle. Differs from *adducta* by the wide apical impunctate bands on the abdominal terga (much greater than 3 puncture diameters).

Males: Length 6.7–9.6 mm, forewing length 4.9–5.9 mm, hindwing length 3.6–4.3 mm; antennal scape sparsely punctate, IPS shiny, smooth, not globose; IOD 0.33 mm, OOD 0.35 mm, MLOD 0.13 mm, MOD 0.18 mm, MOOM 0.48 mm; occipital margin smoothly rounded; vertex flattened within ocellar triangle, sparsely punctate, smooth but not shiny; supraclypeal area not as protruberant as *Pachynomada* or *Nomadita,* frontal carina knife-edged; subantennal area protruding and flattened, curving down slightly to clypeus; clypeus flattened; subapical transverse carina of labrum broken into flattened denticles; acetabular carina strongly lamellate; mandibular basal area virtually impunctate; pre-lobar carina fairly strong, gradually sloping; pronotal ridge with sharply angulate apex, extremely thin (dorsoventrally) medially; scutum distinctly humped above pronotal ridge and lobes; scutal punctation nearly contiguous, punctures round, IPS glassy, rims of punctures rounded; axillae smoothly rounded apically; scutellum faintly bilobate, highly polished surface; metanotum polished, punctate, protruding somewhat medially; supraspiracular ridge lacking; sides of propodeum and hind coxae densely covered with short (0.07 mm) appressed, highly plumose hairs; mesopleuron contiguously punctured, round, IPS glassy, rims of punctures rounded, hypoepimeral area not distinctly protruberant; pro-coxal spine rudiment lacking; hind tibial apex with 4 pale bristles; terga densely punctate with dull shagreened interpunctural surface, apical impunctate band on terga 3–5 very wide (0.19 mm); forewing with 3 submarginal cells: COLOR: light rufo-ferruginous; malar space, apex of clypeus, basal half of mandibles, labrum, yellowish; ocellar triangle, middle of propodeal disk, base of mid-coxae, black.

Female: same as in male.

Discussion: This is the smallest Asteronomada species, being about the size of a small *Nomadita.* The extent of fuscous to black markings is quite variable in this species.

Paratypes: U.S.A.: New Mexico: 14 km W. Animas, 1♂ 20–25/VIII–1979 (J. v.d. Vecht); Grants, 1♂ 20–VIII–1963 *Tamarix gallica*; Hidalgo Co., 11.3 km (7 mi) SE Portal AZ, 1♂ 12–IX–1985 (D. K. Broemeling); Texas: 32.2 km (20 mi) E Kent, 1♂ 28–IX–1957 (W. Nutting & F. Werner);

Acknowledgments

I extend my sincere thanks to Frank D. Parker and Terry L. Griswold of the USDA-ARS Bee Biology & Systematics Laboratory (BBSL) in Logan for their as-

sistance in this project. I am indebted to the following persons for the loan of specimens and types in their care: Roy R. Snelling, Natural History Museum of Los Angeles County (LACM); Donald Azuma, Academy of Natural Sciences of Philadelphia (ANSP); Brett C. Ratcliffe, University of Nebraska, Lincoln (UNEB); Wojiech J. Pulawski, California Academy of Science (CAS); Ronald J. McGinley, National Museum of Natural History-Smithsonian Institution (USNM); Marjorie Favreau, American Museum of Natural History (AMNH); Url N. Lanham, University of Colorado, Boulder (UCM); Charles D. Michener, Snow Entomological Museum, University of Kansas (SMEK); Howard E. Evans, Colorado State University, Fort Collins (Ft.C); Saul I. Frommer, University of California, Riverside (UCR); John A. Chemsak, University of California, Berkeley (CIS); Robert O. Schuster, University of California, Davis (CD); Louise Dumouchel, Biosystematics Research Institute, Agriculture Canada (CNC); George C. Eickwort, Cornell University (CORN); Carol S. Parron, North Carolina State University (NCSR); Robert C. Bechtel, Nevada Department of Agriculture, Reno (NDAg); and Chris O'Toole, Hope Entomological Collections, Oxford, ENGLAND.

This is a contribution from the Utah Agricultural Experiment Station, Utah State University, Logan, Utah 84322-4810, Journal Paper No. 3499, and USDA-Agricultural Research Service, Bee Biology and Systematics Laboratory, Utah State University, Logan, Utah 84322-5310.

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PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 345–351

Life History of *Trupanea imperfecta* (Coquillett) on *Bebbia juncea* (Bentham) Greene in the Colorado Desert of Southern California (Diptera: Tephritidae)

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Abstract.—*Trupanea imperfecta* is monophagous on the desert shrub, *Bebbia juncea* (Asteraceae), in southern California. Each female deposits one to three eggs singly or in a small cluster in a young capitulum. The larvae feed on the floral tubes and achenes and sometimes score the receptacle of the immature florets. The larvae pupariate towards the center of the heads individually or in clusters. Adults emerge from mature heads shedding achenes. This tephritid may be either univoltine or bivoltine; consequently, the adults may live as long as a year. Adults are thought to avoid the dry desert summers when their host plants are dormant by foraging as adults in reproductive diapause along streams and in meadows in the mountains. *Eurytoma* sp. and *E. vernonia* Bugbee (Eurytomidae), *Pteromalus purpureiventris* (Ashmead) (Pteromalidae), and *Torymus* sp. (Torymidae) are reported as primary, solitary, hymenopterous parasites of the larvae and pupae. *Horismenus* sp. (Hymenoptera: Eulophidae) is reported as a hyperparasite; whereas, *Mesopolobus* sp. (Hymenoptera: Pteromalidae) functions as a primary/hyperparasite.

As presently known, *Trupanea* is the largest and most commonly encountered genus in the subfamily Tephritinae in California (Foote and Blanc 1963, Goeden unpubl. data). But knowledge of most species of *Trupanea* is scant and restricted mainly to their taxonomy (Foote 1960, Blanc and Foote 1987), distributions (Foote 1960, Foote and Blanc 1963), and host-plant affinities (Wasbauer 1957, Goeden 1985). The biologies of only a few species have been studied, i.e., *T. actinobola* (Stegmaier 1968), *T. bisetosa* (Coquillett) (Cavender and Goeden 1982), and *T. conjuncta* (Adams) (Goeden 1987). Herein, I describe the life history of *T. imperfecta* (Coquillett).

Taxonomy.—First described as *Urellia imperfecta* by Coquillett (1902), *T. imperfecta* additionally was described and illustrated in part by Malloch (1942) (as a *Trypanea*) and by Foote (1960) and Foote and Blanc (1963) (as a *Trupanea*).

Distribution and hosts.—Foote (1960) and Foote and Blanc (1963) recorded this tephritid from Arizona, California (mainly), and Nevada. However, like its principal host plant, *Bebbia juncea* (Bentham) Greene (Asteraceae), *T. imperfecta* may range into southern New Mexico, western Texas, and adjacent parts of northern Mexico (Benson and Darrow 1981).

During a faunistic survey of *B. juncea* from 1983 to 1986, *T. imperfecta* consistently was reared from mature capitula sampled throughout the range of this plant species in the Colorado Desert of southern California (Goeden and Ricker, unpublished

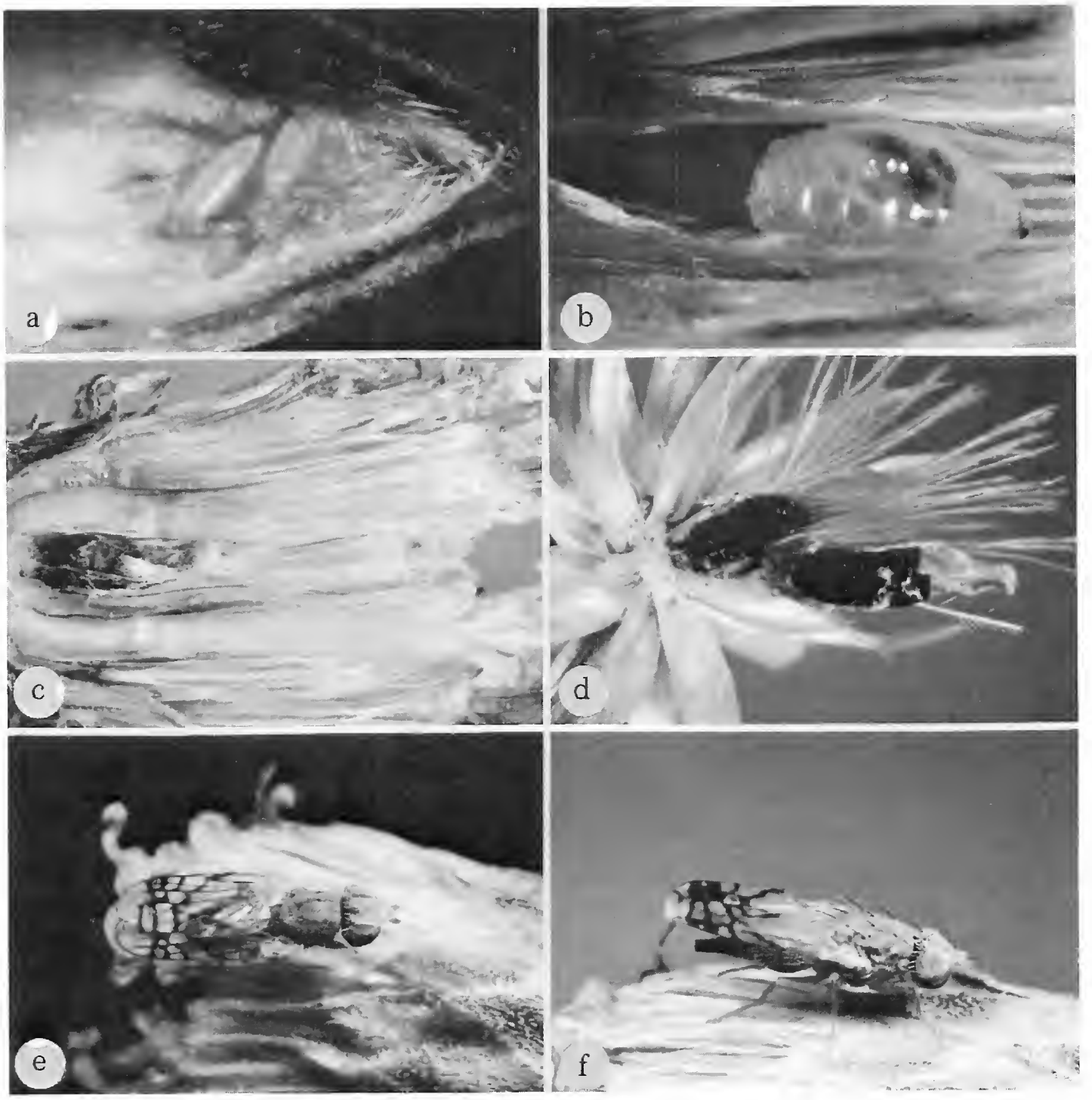

Fig. 1. Life stages of *Trupanea imperfecta*. (a) Two eggs in young capitulum, 22x. (b) Third instar, 13.5x. (c) Puparium in center of head of *Bebbia juncea,* 6x. (d) Two empty puparia attached to mature capitulum that has shed its achenes, 7x. (e) Adult male, 7x. (f) Adult female, 8x.

data and rearing records listed below). Moreover, no other tephritid was reared from these capitula, which supported the suggestion by Goeden (1985) that the record for *Trupanea pseudovicina* Hering from *B. juncea* in Wasbauer (1957) probably was erroneous, or atypical and rare.

Desert locations for *B. juncea* capitula sampled on the dates indicated, and from which *T. imperfecta* were reared, are listed chronologically and by county: Imperial Co.: Signal Mountain, 29 xi 1984; Wister, 29 xi 1984, 13 iii 1986; Painted Gorge, 12 xii 1984, 19 iii 1986; Sunrise Butte, 12 xii 1984, 30 i 1985, 20 iii 1986; Black Mountain, 7 i 1985; Indian Well, 12 iii 1986; Tumco, 13 iii 1986; Travertine Rock, 19 iii 1986; Imperial Highway, 19 iii 1986; Palm Canyon Wash, 20 iii 1986; Riverside Co.: West Bradshaw Trail, 12 i 1983, 23 iii 1983; Chino Canyon, 9 iii 1983, 13 iv 1983, 27 iv 1983, 13 v

1983, 25 v 1983, 7 vi 1983, 21 vi 1983, 7 vii 1983, 19 vii 1983, 5 viii 1983, 19 viii 1983, 19 ix 1983, 3 x 1983, 1 xi 1983, 15 xi 1983, 29 xi 1983, 13 xii 1983, 4 i 1984, 18 i 1984, 31 i 1984, 14 ii 1984, 29 ii 1984, 13 iii 1984, 29 iii 1984, 11 iv 1984, 24 iv 1984, 8 v 1984, 21 v 1984; Berdoo Canyon, 3 i 1985, 9 iii 1986; Salt Creek Wash, 28 xi 1984; Big Morongo Canyon, 9 ix 1986; Mission Creek, 9 ix 1986; Desert Center, 16 ix 1986; Painted Canyon, 16 ix 1986; San Diego Co.: Clark Dry Lake, 26 i 1983.

Goeden (1985) reported a single female of *T. imperfecta* reared from a mature capitulum of *Ambrosia ilicifolia* (Grey) Payne, although bulk samples of these heads commonly yielded only *Euaresta stigmatica* Coquillett or *Euarestoides acutangulus* (Thomson) (Goeden and Ricker 1976). Similarly, a single female of *T. imperfecta* was recorded by Goeden (1985) from *Coreopsis gigantea* (Kellogg) Hall, the capitula of which usually only contained *Dioxyna picciola* (Bigot) (Goeden and Blanc 1986). Thus, both records involved atypical hosts for *T. imperfecta.* "Mistaken" oviposition in heads of normally unattacked plant species growing closely to and stimulated by numerous capitula of a favored host species probably at least accounted for the atypical record for *A. ilicifolia,* i.e., representing what Goeden (1985) called a "spill-over effect."

Replicated rearings of bulk samples of mature capitula from 93 genera and 238 species of California Asteraceae since 1980 suggest that *T. imperfecta* essentially is monophagous on *B. juncea* (Goeden unpublished data). Foote and Blanc (1963) listed only one rearing record for *T. imperfecta* from *B. juncea* in California, but reported records for adults swept from species of *Chrysothamnus, Dicoria, Encelia, Eriogonum* (Polygonaceae), *Gnaphalium, Gutierrezia, Hyptis* (Lamiaceae), and *Lepidospartum.* Besides discounting the two non-Asteraceae as obvious non-hosts, the fact that none of the remaining genera have yet yielded a single reared specimen of *T. imperfecta* demonstrates the misleading nature of these sweep records as indicators of the larval food plants of this tephritid. This limitation of sweep records also was discussed by Goeden et al. (1987) relative to hosts of *Neotephritis finalis* (Loew) and to tephritids swept from *Hymenoclea salsola* Torrey and Gray by Goeden and Ricker (1986).

Biology

The biology of *T. imperfecta* was studied largely in the field, or in the laboratory with field-collected material, during the faunistic survey of *B. juncea* noted above. Additional field observations were made in conjunction with my study of *T. conjuncta* (Goeden 1987) in Chino Canyon, 1 km NW of Palm Springs, Riverside Co., during 1983–1986.

Egg.—Newly laid eggs (Fig. 1a) are smooth, shiny, white and elongate-ellipsoidal, with a reduced, button-like, anterior pedicel, like those of *T. bisetosa* and *T. conjuncta* (Cavender and Goeden 1982, Goeden 1987). Fifty-one field-collected eggs averaged 0.68 ± 0.005 (± SE) mm in length and 0.19 ± 0.001 mm in greatest width. The pedicels averaged 0.02 ± 0.000 mm in length. Thus, the eggs and pedicels are slightly shorter, but about as wide as those of *T. bisetosa* and *T. conjuncta.*

Most eggs were oviposited into immature heads of *B. juncea* that measured about 3 mm wide and 3 to 5 mm externally from base to apex, where the tips of the outer phyllaries converged. Eggs were laid loosely, and singly or in laterally touching groups of two to five (Fig. 1a). The orientation of their long axes ranged from perpendicular to parallel with the receptacle surfaces, and at various angles in between, but

mostly nearest the former plane, with their pedicels directed away from the receptacles (Fig. 1a). Some eggs were inserted between and parallel to the outer ranks of phyllaries, some alongside and parallel to the receptacle bracts, some pierced these bracts, and still others were oviposited within the open space above the layer of tiny buttonlike, unelongated floral tubes beneath the overlapping phyllaries.

Seventeen field-collected immature heads collected at Travertine Rock, Imperial Co., on 26 i 1983, contained an average of 5 (range, 2 to 9) eggs of *T. imperfecta.* Forty-six immature heads collected at Chino Canyon on 26 ii 1985 also contained an average of 5 (range, 1 to 14) eggs. These eggs were laid individually or in small clusters at slightly different angles (Fig. 1). In some cases, the eggs showed obvious differences in embryony between clusters in the same heads, indicating that they probably were oviposited by different females.

Larva.—Dissections of field-collected heads indicated that a newly hatched first instar usually entered a floral tube initially and fed on its contents. If the larva already was located centrally in the head and alone there, it continued to excavate this floret, and by the second or early third instar, entered the achene and completed its larval development there or in an adjacent achene (Fig. 1b). If the larva hatched on the periphery of a head, it tended to tunnel through a succession of floral tubes and bracts inward toward the center of the head where it passed the third instar feeding on a centrally located achene. When several larvae infested the same head, instead of feeding gregariously clustered in a single, central chamber like *T. conjuncta* (Goeden 1987), they remained separated but centralized while feeding.

The mature heads of *B. juncea* are small, i.e., 1–2 cm in dia. (Benson and Darrow 1981). Twenty-three capitula collected from Fossil Canyon, Imperial Co., on 11 i 1987 contained an average of 17 (range, 9 to 27) achenes. However, usually at least some achenes in a head, even one infested by several larvae, remained unattacked. Some receptacles were shallowly scarred by larval feeding, a phenomenon noted and currently being assessed quantitatively with *Paracantha gentilis* Hering in capitula of *Cirsium californicum* Gray (D. H. Headrick and R. D. Goeden, unpublished data). As with other *Trupanea* studied (Cavender and Goeden 1982, Goeden 1987), larvae of *imperfecta* usually oriented with their heads directed outward away from the receptacles after they stopped feeding before pupariating (Fig. 1b and 1c).

Pupa.—The puparium (Fig. 1c and 1d) is black, ellipsoidal, smoothly rounded at both ends, superficially smooth, but distinctly segmented, much like *T. conjuncta* (Goeden 1987). Thirty-one, field-collected puparia measured 2.6 ± 0.04 (range, 2.1–3.3) mm in length by 1.2 ± 0.02 (range, 0.9–1.3) mm in greatest width. Thus, the puparia of *T. imperfecta* are shorter and narrower than those of both *T. bisetosa* and *T. conjuncta* (Cavender and Goeden, 1982, Goeden 1987).

Puparia from which adults emerged remain attached for months to the dried, open heads that have shed their achenes (Fig. 1d), thus forming units readily sampled and counted to determine infestation rates. Accordingly, a total of 555 infested heads, collected from three locations, contained an average of 2 (range, 1 to 9) puparia. Most puparia were borne centrally, < 1 mm above and perpendicular to the receptacle surface, frequently with their posterior ends tightly appressed within the concave basal remains of one or two achenes (Fig. 1c). In heads that bore more than one puparium, these cases usually were glued together lengthwise and staggered (Fig. 1d), or were affixed to opposite sides of centrally located, receptacle bracts. Although most puparia were located centrally, a few were formed on the peripheries of multi-infested heads.

Adult.—Adults of *T. imperfecta* are readily recognized by their sexually dimorphic wing patterns. This pattern is considerably reduced in the male (Figs. 1e, 1f).

Males and females, newly emerged from mature heads, are sexually immature and apparently do not mate, much like *T. conjuncta* (Goeden 1987). From analysis of rearing records for 555 males and 509 females from 33 samples of capitula collected at Chino Canyon during 1983–84, the sex ratio appears to be slightly male biased, as reported for *T. conjuncta* (Goeden 1987), although statistically not significant [$\hat{p}$ = 0.478% ♀♀, SE ($\hat{p}$) = 0.015, 95% c.l. = 0.508–0.448]. Males emerged along with females throughout their emergence periods, as determined from daily records of adults reared from the 33 samples, and as also reported for *T. conjuncta* by Goeden (1987).

Normally, flowering by *B. juncea* terminates and the plants go dormant in the low-elevation Colorado Desert in late spring (June). At this time, the newly emerged adults migrate to higher elevations, many following drying water courses upward into surrounding mountains. There, these long-lived adults pass the summer foraging along streams and in meadows, as they apparently remain in reproductive diapause. On three different years, both sexes were swept in low numbers from damp, grassy meadows at ca. 3000 m on San Gorgonio Mountain in mid-summer (July and August), at locations well removed from *B. juncea* inhabiting canyons and washes on the southern and eastern, basal slopes of this mountain.

During autumn, perhaps in response to shorter daylengths or lower temperatures in the mountains, the flies migrate downward and congregate on and near *B. juncea,* which by December and January already is responding to winter rainfall and resuming vegetative growth and flower bud production. Presumably mating occurs at this time, although this behavior was not observed in the field or in insectary cagings.

Oviposition was observed in the field on several occasions. The female usually initiated oviposition and obtained purchase on a young capitulum by placing the tip of her oviscape downward in the notch formed by two overlapping outer phyllaries. Repeated thrusts of the ovipositor brought its tip to one of the sites within the head previously described, where from one to three eggs were laid at a single insertion. Ovipositions by nine different females lasted an average of 45 (range, 28 to 93) sec. These females remained motionless with their wings held tightly overlapped, horizontal, and backward over their dorsa during oviposition. Oviposition was observed in the field during the warmest parts of winter days (between 10:00 and 14:00 in February and March, 1985 and 1986). After ovipositing, the females characteristically rubbed their oviscapes and partly exserted ovipositors with their hind tarsi. During this post-ovipositional grooming, one female repeatedly touched the tip of her ovipositor to the apex of the bud in which she had just oviposited. This behavior may have involved deposition of a short term oviposition deterrent, as recently observed with *P. gentilis* (Headrick and Goeden, unpublished data), and needs to be addressed experimentally.

Seasonal history.—As documented above by the sample dates for Chino Canyon, more than one generation may be produced per year. In 1983, flowering by *B. juncea* as well as reproduction by *T. imperfecta* continued locally all year on plants growing close to a continuously flowing stream. However, more typically, and as had occurred with plants growing above and away from the stream in 1983, reproduction by *T. imperfecta* and its host plants dwindled then ceased in June along with the waterflow following a winter with less rainfall in 1984. This demonstrated that reproduction by *T. imperfecta* is facultative and closely associated with and stimulated by the

presence of its flowering host plant. Facultative voltinism was reported for other stenophagous, desert-inhabiting Tephritiade, i.e., a gall-forming *Procecidochares* sp. (Silverman and Goeden 1980) and *T. conjuncta* (Goeden 1987).

Mortality factors.—As reported for *T. conjuncta* (Goeden 1987), jumping spiders (Araneida: Salticidae) and crab spiders (Araneida: Thomisidae) appeared to be the most common predators of adults observed on the preblossom and flowering host plants. Several species of parasitic Hymenoptera were reared from capitula of *B. juncea* infested by *T. imperfecta.* Species positively identified as parasites of *T. imperfecta* include: *Horismenus* sp. (Eulophidae), a solitary, hyperparasite; *Eurytoma* sp. and *E. vernonia* Bugbee (Eurytomidae), solitary, primary, larval or larval-pupal endoparasites; *Pteromalus (Habrocytus) purpureiventris* (Ashmead) (Pteromalidae), a solitary, primary, larval ectoparasite; *Mesopolobus* sp. (Pteromalidae), a solitary, facultative primary/hyperparasite; and *Torymus* sp. (Torymidae), a rare, solitary, larval ectoparasite. *Eurytoma* sp., *E. vernonia,* and *P. purpureiventris* also parasitized *T. conjuncta* in heads of *Trixus californica* (Adams) at desert locations where both plant species were found (Goeden 1987).

Acknowledgments

My thanks to D. W. Ricker for technical assistance, including the insect photography involved in Fig. 1. Thanks also to F.L. Blanc, R. H. Foote, G. Gordh, and E. R. Oatman for their helpful comments on early drafts of the manuscript. The parasites were identified by John LaSalle, Division of Biological Control, Department of Entomology, University of California, Riverside, and E. E. Grissell, Systematic Entomology Laboratory, BBII, USDA, ARS, Beltsville, Maryland.

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Fig. 1. Life stages of *Trupanea imperfecta.* (a) Two eggs in young capitulum, 22x. (b) Third instar, 13.5x. (c) Puparium in center of head of *Bebbia juncea,* 6x. (d) Two empty puparia attached to mature capitulum that has shed its achenes, 7x. (e) Adult male, 7x. (f) Adult female, 8x.

PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 353–357

The Nymph of *Utacapnia trava* (Nebeker and Gaufin) (Plecoptera: Capniidae)

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Abstract.—The mature nymph of *Utacapnia trava* (Nebeker and Gaufin) is described from specimens collected in Alberta, Canada. Habitus, mouthparts, setal profile and supraanal lobe of the male nymph are illustrated. Underwater thermoregulation by adults is reported.

Species of the winter stonefly genus *Utacapnia* occur primarily in small streams of western North America. The nymphs of four of 10 species have been described in this genus (Nebeker and Gaufin 1965; Harper and Hynes 1971). *Utacapnia trava,* originally described by Nebeker and Gaufin (1965), ranges from Alberta and Saskatchewan to Idaho and Montana (Stark *et al.* 1986). This first nymphal description is based on a collection of 110 nymphs from Battle Creek near Reesor Lake in Cypress Hills, Alberta from which 23 males and 20 females were reared to the adult stage in laboratory aquaria. Specimens have been deposited in the Canadian National Collection, Ottawa and in the authors' personal collections.

Description of Nymph: Total length of mature nymph: 7.2–9.0 mm (excluding antennae and cerci). General colour light to medium brown, venter and appendages lighter. Conspicuous color pattern in very mature nymphs which is an underlying pre-adult pattern (Fig. 1): head with 2 dark spots near posterior ocelli which extend from each ocellus along the ecdysial line nearly to antennae; two dark dots bracket anterior ocellus. Anterior margin of head with 3 dark dots near base of each antenna. Pronotum nearly uniformly dark above, or with darker areas interspersed in a reticulate pattern, but with a darker median line extending laterad at anterior and posterior ends. Meso- and metanota with dark, basal, V-shaped markings. Anterior margins of abdominal segments 1–8 in males with dark medial markings which become wider (approximately 1/4 the mid-dorsal tergum length) laterally. Subtriangular dark spots below lateral markings; submedian dark dots on abdominal segments 1–7. Male ninth and tenth abdominal terga with no lateral markings; male supraanal lobe as in Fig. 6. Mature females without dark line across anterior margins of abdominal terga; segments 1–7 with subrectangular dark markings on anterolateral segmental

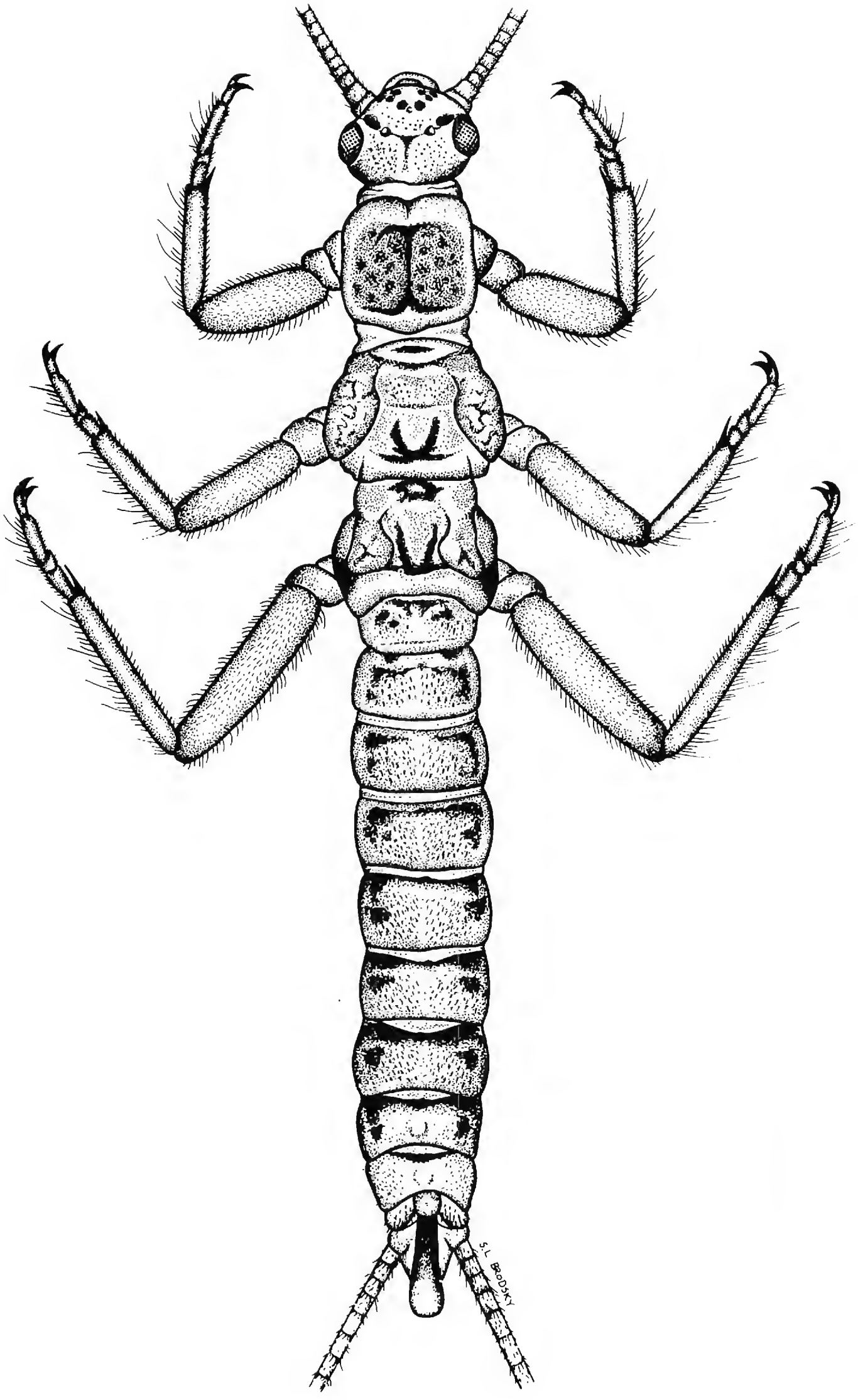
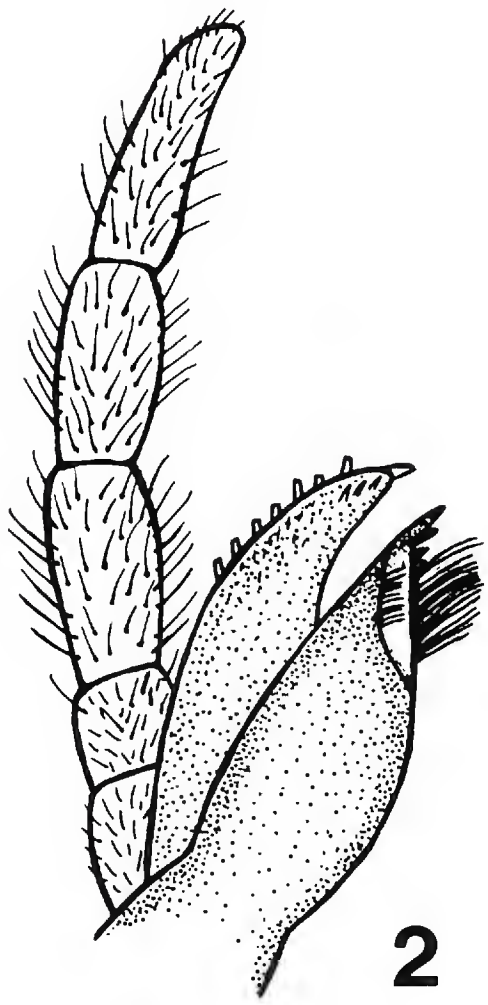


Fig. 1. *Utacapnia trava* mature male nymph, habitus.



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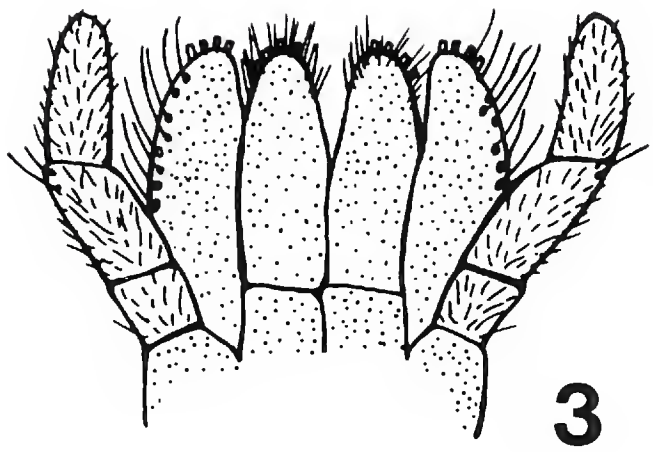

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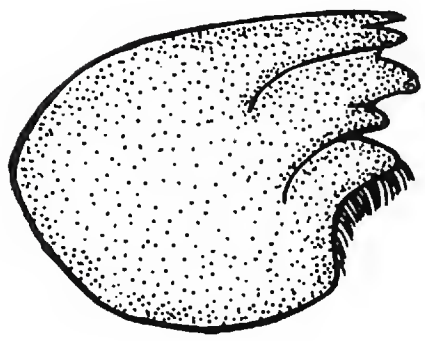

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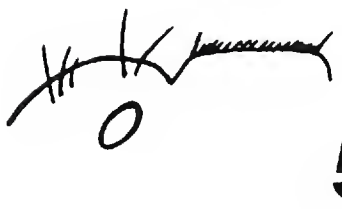

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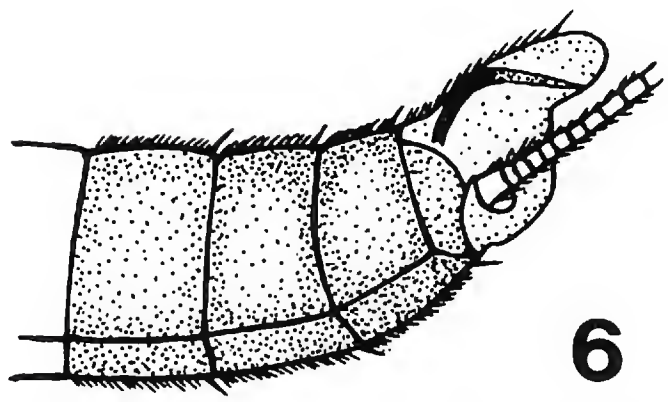

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Figs. 2–6. Mouthparts, male supraanal lobe and setae of *Utacapnia trava* nymph. 2, maxilla; 3, labium; 4, mandible; 5, setae seen in profile on the top of the head and pronotum; 6, male supraanal lobe and abdominal setae in profile.

margins and a large (about 1/2 the mid-dorsal length of the tergum) and small (about 1/6 the mid-dorsal tergum length) subcircular spot beneath each subrectangular marking. Abdominal segments 8–9 with subcircular dark markings only; segment 10 without markings.

Body clothed with short, sparse hairs. Head with longer hairs near eyes and at anterior angle of frons (Fig. 5). Margins of pronotum and posterior margins of tergites with a few short, erect bristles: on abdomen bristles are about 1/4 the mid-dorsal tergum length (Fig. 6). Legs covered with short bristles; longer hairs on tibiae and tarsi (Fig. 1).

Maxilla (Fig. 2) with slender lacinia and 4 teeth at apex. Twelve to 15 bristles on inner apical margin and 8–10 shorter bristles along a parallel apical ridge. Galea equal in length to lacinia with a single apical spine and 2–3 smaller spines below. Seven peg-like projections along lateral margin of galea. Palpi with last segment longer than penultimate segment. Labium (Fig. 3) with glossae and paraglossae equal in length. Glossae with an apical fringe of short hairs; paraglossae with 8 long hairs along outer lateral margins. Four peg-like projections at tips of glossae and paraglossae. Palpi short with apical and penultimate segments equal in length; apical segment tapering to a blunt point. Mandible (Fig. 4) with 2 sharp outer cusps and one blunt inner cusp. Inner cusp with a fringe of short bristles.

Remarks

It is presently inadvisable to try to identify generic characteristics because few species have been described, and descriptions by Nebeker and Gaufin (1965) have not included patterns of setation. Potential diagnostic characters to distinguish species may include setal pattern, number of apical teeth on the lacinia of the maxilla and number and arrangement of peg-like projections on the maxilla and labium. Nymphs of *U. trava* differ from descriptions of *Utacapnia columbiana* (Claassen), *Utacapnia lemoniana* (Nebeker and Gaufin) and *Utacapnia poda* (Nebeker and Gaufin) in Nebeker and Gaufin (1965) by the presence of four, rather than three, apical teeth on the lacinia. Nymphs of *Utacapnia labradora* (Ricker), tentatively described by Harper and Hynes (1971), have abdominal bristles nearly as long as the mid-dorsal length of the tergum. In *U. trava* nymphs, these bristles extend only one-quarter the mid-dorsal length.

On the date nymphs were collected (4 March 1986), all ice had disappeared from the stream and water temperature was 2°C. Adults were also present, although not abundant. Due to an unusually early spring, this adult record is considerably earlier than emergence dates reported previously for this species at the same site (Dosdall and Lehmkuhl 1979). It is noteworthy that four adult males were collected in stream benthic samples taken with a standard sweep net at an approximate water depth of 25 cm. Furthermore, both males and females were occasionally observed to crawl beneath the water surface of laboratory rearing aquaria (5 ± 1 °C; 12h light : 12h dark) for periods of up to 50 minutes. Tozer (1979) observed similar behavior by adults of *Zapada cinctipes* (Banks) (Nemouridae) and considered it to be a means of thermoregulation during severe temperatures. Adults of *U. trava* appear to employ the same adaptive strategy to prevent freezing in an environment where air temperatures at emergence time can drop far below freezing (for example, night temperatures of -15° C are common at this time of year), but where water temperatures remain relatively constant and above freezing.

The gut contents of 10 nymphs were examined and found to contain filamentous algae and coarse particles of plant material. This corresponds to general descriptions of members of Capniidae as detrivorous shredders (Harper and Stewart 1984).

Acknowledgments

We thank Shirley Brodsky for drawing the nymph and Dr. P. P. Harper for critical review of the manuscript. D. W. Parker and B. J. Jarvis provided assistance in the field. The research was supported by the Natural Sciences and Engineering Research Council of Canada.

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PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 359–363

Pronotal Stripes and Wing Length in *Gerris incurvatus* Drake and Hottes (Hemiptera: Gerridae)[1]

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Abstract.—The discovery of what appeared to be brachypterous female *Gerris incurvatus* with an atypical pronotal stripe led to a study to determine if the presence or absence of this stripe was linked to season, sex, and/or brachyptery, and if the brachypterous striped individuals might be a hybrid between *G. incurvatus* and *G. buenoi.* Results show that the striped brachypterous form of *G. incurvatus* is a seasonal form of the species found only in mid-summer and not later in the season. However, linkage of the pronotal stripe with either sex or brachyptery is not complete. Electrophoretic comparisons show that brachypterous striped and macropterous unstriped female *G. incurvatus* are conspecific and clearly distinct from *G. buenoi,* not a hybrid.

Insects of the family Gerridae, often referred to as water striders, water skippers, pond skaters, or wherrymen, are found on the surfaces of most bodies of fresh water throughout the world with the exception of the polar regions. Gerrids have considerable intraspecific variation in wing length, ranging from apterous, brachypterous to macropterous. Most members of the subfamily Gerrinae are either bivoltine or have short development times that suggest that two generations per year are possible (Calabrese 1978). Some populations exhibit differences in wing length between generations.

Previous studies have suggested that environmental factors such as day length, temperature, and habitat stability affect wing length (Brinkhurst, 1959; Vepsäläinen, 1971a, 1971b). For this reason, wing length has not been widely used as a taxonomic character in the Gerrinae. However, the apparent relationship between certain body markings and wing length has posed a problem in identification of *G. incurvatus* Drake and Hottes and *G. comatus* Drake and Hottes. In recent keys (Polhemus and Chapman, 1979; Stonedahl and Lattin, 1982), *G. incurvatus* is primarily distinguished from the sympatric species *G. buenoi* Kirkaldy by its lack of a silvery or rufous stripe on the anterolateral margins of the pronotum. However, brachypterous females of *G. incurvatus* with a pronotal stripe have been discovered and their identity confirmed in collections from northern Idaho.

A similar problem was encountered by Drake and Hottes (1925) who described *mickeli* as a variety of *G. comatus* from five brachypterous females with a russet-brown anterolateral pronotal stripe. Typical *G. comatus* lack this stripe. The variety was later recorded from Minnesota, Oregon, and Colorado; all specimens were bra-

[1]Published as Idaho Agricultural Experiment Station research paper no. 87764.

Table 1. Number and percentage of adult forms of *Gerris incurvatus* Drake and Hottes collected on five dates at Morton Slough, Bonner County, Idaho. M = macropterous, B = brachypterous

Date	FEMALES			MALES		
	M	B	B w/stripe	M	B	B w/stripe
7/18/84	3 (30%)	7 (70%)	7 (100%)	3 (37%)	5 (63%)	0
8/25/84	7 (100%)	0	0	11 (100%)	0	0
7/20/85	11 (12%)	84 (88%)	67 (80%)	17 (30%)	40 (70%)	0
7/18/87	5[1](8%)	55 (92%)	53 (96%)	3 (6%)	49 (94%)	6 (12%)
8/25/87	0	0	0	2 (100%)	0	0

[1]Includes one macropterous female with an anterolateral stripe on the pronotum.

chypterous females (Drake and Harris 1928). These authors suggested that males of this variety, when found, might prove it to be a distinct species. However, to date, no males have been discovered. Drake and Harris (1934) later suggested that *mickeli* be retained as a variety of *comatus,* not a distinct species, but they did not allow for the variety in their key.

The questions addressed by this study were: 1) To what degree is the presence or absence of a pronotal stripe linked to season, sex and/or brachyptery in *G. incurvatus*?; 2) Is what appears to be striped brachypterous *G. incurvatus* actually a hybrid between *G. incurvatus* and *G. buenoi* or simply a seasonal form of *G. incurvatus*?; and 3) What inferences can be made about the taxonomic status of *G. comatus* var. *mickeli*? To help answer these questions we used starch gel electrophoresis, a technique that has proven value as an adjunct to more traditional taxonomic methods for elucidating relationships among closely related and/or morphologically ambiguous or indistinguishable groups.

Methods and Results

Insects for this study were collected with an aquatic D-net on Morton Slough on the Pend Oreille River in Bonner County, Idaho, during summer 1984, 1985, 1987 (Table 1). Species were identified using keys in Drake and Harris (1934) and Stonedahl and Lattin (1982). On July 18, 1984, 18 *G. incurvatus* (8 males and 10 females) were collected (along with specimens of the gerrids *G. buenoi* and *Limnoporus notabilis* Drake and Hottes). Seven (70%) of the females were brachypterous and could not be correctly identified using established keys; all possessed an anterolateral stripe not found on the three macropterous females or on the males. A subsequent collection on August 25, 1984, yielded 18 more *G. incurvatus* (11 males and 7 females). All females were macropterous and lacked the pronotal stripe as did the males. No brachypterous females were found. A collection the following year on July 20, 1985, yielded 152 specimens of *G. incurvatus* (57 males and 95 females). Of the 95 females, 84 (88%) were brachypterous. Of these 67 (80%) had the pronotal stripe. Only 17 (20%) lacked the pronotal stripe and fit the standard species description. Additional *G. incurvatus* were collected from the site on July 18, 1987. Of the 60 females collected, 55 (92%) were brachypterous. Of these, 53 (96%) had a pronotal stripe. Only 2 (4%) lacked the pronotal stripe.

G. buenoi collected with *G. incurvatus* showed similar changes in wing length with season. July collections of *G. buenoi* contained both micropterous and macropterous forms, while specimens collected in August were all macropterous.

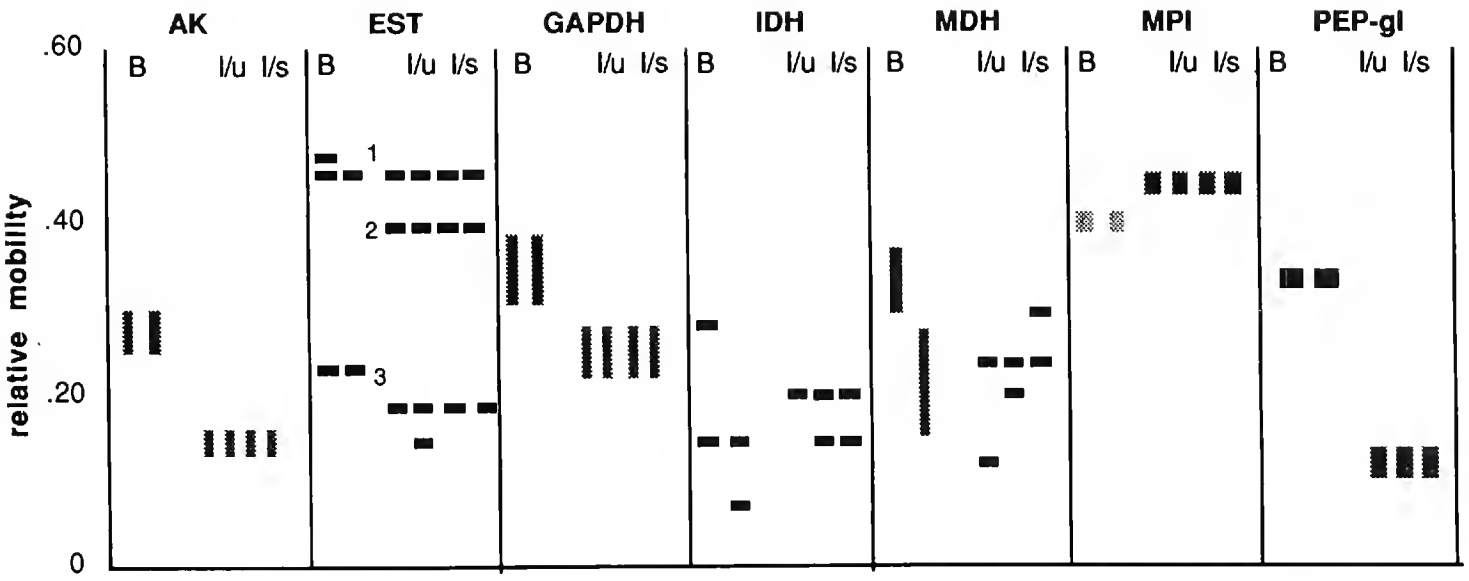

Figure 1. Representative enzyme variations assayed in *G. buenoi* (B), macropterous unstriped *G. incurvatus* (I/u), and brachypterous striped *G. incurvatus* (I/s).

Living specimens from the July 20, 1985, collection were returned alive to the laboratory in an ice chest and then frozen for electrophoretic analysis. Five female specimens of *G. buenoi,* 10 macropterous, stripeless female *G. incurvatus*, and five brachypterous, striped female *G. incurvatus* were subjected to electrophoretic analysis following procedures described by Higby and Stock (1982) and Bentz and Stock (1986). Seven enzyme types were assayed. Of these, assays for esterase (EST), isocitrate dehydrogenase (IDH), malate dehydrogenase (MDH), peptidase (PEP-gl), and phosphomannose isomerase (PMI) followed methods described in the literature cited above. Assays for adenylate kinase (AK) and glyceraldehyde-3-phosphate-dehydrogenase (GAPDH) are those we are currently using for taxonomic studies of *Ips* bark beetles:

AK: Aminopropyl morpholine/citric acid buffer system (Clayton and Tretiak 1972), 100 mg ADP, 10 mg NADP (nicotinamide adenine dinucleotide phosphate), 200 mg glucose, 100 units hexokinase, stain mixture (10 mg each nitroblue tetrazolium and MTT tetrazolium, 3 mg phenazine methosulfate, and 1 ml 0.1 M MgCl2 solution), in 30 ml Ridgway gel buffer (Ridgway et al. 1970).

GAPDH: Ridgway buffer system (Ridgway et al. 1970), 10 mg NADP, 35 mg mannose-6-phosphate, 100 units glucose-6-phosphate dehydrogenase, 60 units glucose phosphate isomerase, stain mixture (see AK above), in 35 ml Ridgway gel buffer.

The esterase assays revealed two loci in *G. buenoi* and three loci in *G. incurvatus*. This is not surprising because esterase is highly polymorphic in virtually all insect species that have been tested to date. The six other assays revealed only one locus per gerrid species. At all loci, allozyme banding patterns of brachypterous striped and macropterous stripeless *G. incurvatus* were identical, and banding patterns for insects identified as *G. buenoi* were very different (Fig. 1). No overlap was seen in banding patterns for AK, EST (second and third loci for *G. incurvatus*), GAPDH, MPI, and PEP-gl. Some overlap in banding patterns was seen in IDH and MDH.

Discussion

The striped, brachypterous form of *G. incurvatus* appears to be a seasonal form of this species. It is found only in mid-summer (July) and is totally replaced by the unstriped, macropterous form by late August. However, not all brachypterous females have the stripe, and even a few brachypterous males and one macropterous female have been observed with the stripe. Thus, although stripes and short wings are more characteristic of females, these features are not invariably linked nor completely sex-linked. The electrophoretic comparisons show that brachypterous striped and macropterous unstriped female *G. incurvatus* are conspecific and clearly distinct from *G. buenoi,* not a hybrid. The totally different electrophoretic patterns seen in these two species at five of the seven loci are clearly diagnostic of complete species separation.

Although a comparative electrophoretic study of *G. comatus* and *G. comatus mickeli* has not yet been performed, it is possible that the brachypterous striped variety of *G. comatus mickeli* is also a conspecific seasonal variant of *G. comatus*. Keys to species of Gerridae should have a qualifying statement added to any couplet using pronotal stripes as the sole distinguishing characteristic for variable taxa such as *G. incurvatus* and *G. comatus*. In addition, features of the male genitalia will usually distinguish taxa that are confused because of intraspecific variation in color patterns and wing length. We also suggest that, when collecting gerrids, a moderate to large series be obtained in the event there is more than one variant form of a species present in the area.

Acknowledgments

We thank Dr. Merlyn A. Brusven and Paul E. Blom for help with collections and Sandra J. Gast for help with the electrophoretic analyses. Dr. Gary Stonedahl, American Museum of Natural History, New York, confirmed the identity of the *Gerris* species collected in July 1987. Drs. Gary Stonedahl, Diane Calabrese, William Turner, Merlyn Brusven, and James Johnson provided helpful reviews of the manuscript.

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PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 365–370

Cornelius Becker Philip
(1900–1987)

Cornelius ("Neil") Becker Philip, distinguished medical entomologist and world authority on Tabanidae, died at his home at Parkmerced, San Francisco, California, on the afternoon of January 8, 1987, at the age of 86, after an illness of several months duration.

Cornelius Philip, the first of four sons of Smith Durie Philip (1874–1970) and Mattie Newcomb Philip (née Shoemaker, 1876–1931), was born in Fort Lupton, Colorado, on June 12, 1900, on the family farm that his paternal grandfather, George Gilfillan Philip, had homesteaded upon his emigration from Scotland in the early 1870's. Attending public schools in Colorado, Idaho, and California, Philip was registered for his Sophomore to Senior years at Long Beach Polytechnic High School, in southern California, where he was also active on the basketball team. He was encouraged to study insects and natural history by his biology teacher. After graduation in 1918, Philip enlisted in the Student's Army Training Corps at the University of Nebraska. His first stay in the military lasted less than two months with his honorable discharge on December 15 as a Private, U.S. Army.

After receiving his Bachelor of Science degree from the University of Nebraska in 1923 (studying with Professors Ralph W. Dawson and Clarence E. Mickel), Philip commenced graduate studies at the University of Minnesota (studying with Professors William A. Riley and R. N. Chapman). In order to recoup finances, Philip moved to Bozeman, Montana in 1926, for a year's employment as Assistant Entomologist in the Experiment Station, Montana State College. Employment in the summer of 1927 with the Montana State Board of Health in mosquito control projects provided background experience with mosquitoes for his later assignment in Nigeria. Philip's first scientific publication "Diurnal Fluctuations in the Hydrogen Ion Activity of a Minnesota Lake" was published in *Ecology* in 1927, and it alerted readers to the fact that ecological classifications of "acid lakes" could depend on the time of day that readings were taken.

Prior to the completion of his doctorate, and beginning in March, 1928, Philip accepted a temporary appointment with the Rockefeller West African Yellow Fever Commission in Lagos, Nigeria, which was a hazardous assignment. Dr. Hideyo Noguchi died from yellow fever shortly after Philip's arrival, and a total of four of the 20 Americans assigned to Lagos died within 20 months from the disease or other causes. Before his departure from Lagos Dr. Ralph R. Parker cabled Philip to offer him a position as Medical Entomologist in the newly organized Spotted Fever Laboratory in Hamilton, Montana, to which Philip promptly accepted. He received his doctorate in 1930 and published his thesis "The Tabanidae (Horseflies) of Minnesota with Special Reference to Their Biologies and Taxonomy" in 1931.

Philip's original mission at the Laboratory was to study the mysterious differences in virulence of spotted fever rickettsiae on the west versus the east side of the Bitterroot Valley. In 1933, Philip was sent on special assignment to St. Louis to help in the fight to stem the ravages of encephalitis. In 1937, he undertook a parasitological reconnaissance to south-central Alaska and southwest Yukon Territory (Lake Bennett), and the suspected presence of *Francisella tularense* in Alaska was confirmed. In 1941, the first demonstration of the epizootic SLE virus in horses was published by

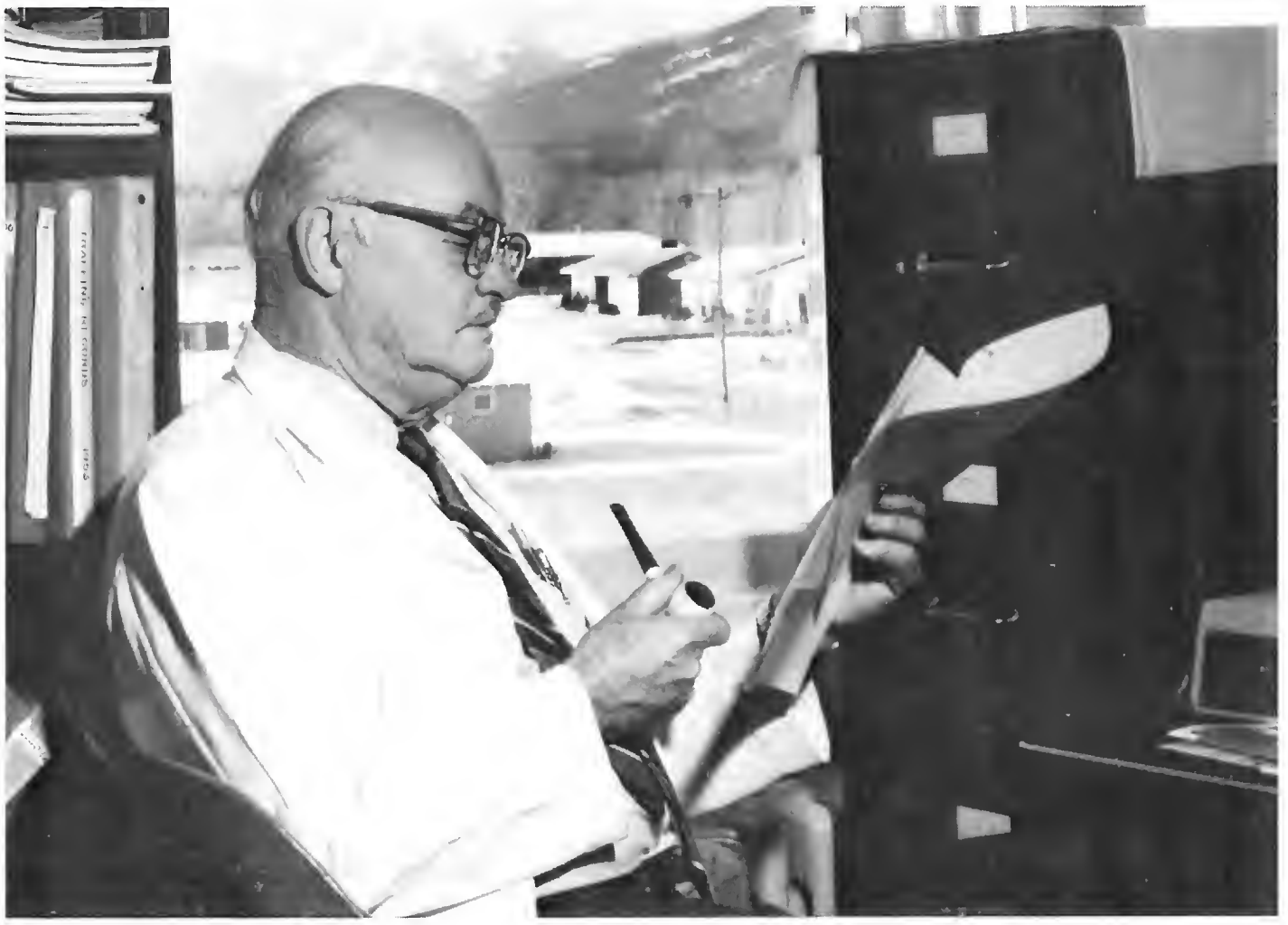

Fig. 1. Dr. Cornelius B. Philip at office window, Rocky Mountain Laboratory, Hamilton, Montana, March, 1970, looking south-southwest with the Como Peaks of the Bitterroot Mountains in the background.

C. B. Philip, H. R. Cox, and J. H. Fountain and also the experimental susceptibility of horses to this virus was published by H. R. Cox, C. B. Philip, and J. W. Kilpatrick.

With the entry of the United States into World War II, Philip joined the Sanitary Corps, U.S. Army, as a Major, and served from July, 1942, through September, 1946, with assignments in the American, European, and Southwest Pacific Theaters. After first participating in the training of medical officers at the Walter Reed Medical Center, Washington, D.C., Philip was assigned to the Jamaican Typhus Commission, which reported the first occurrence of murine typhus in Jamaica. In 1943, when assigned to the U.S. Army Neurotropic Virus Commission, headquartered in Cairo, with Major A. B. Sabin and Dr. J. R. Paul, Philip studied *Phlebotomus papatasi* (Scopoli), a local vector of sand fly fever. Also as part of this assignment *Phlebotomus* spp. were also studied in the Calcutta area of India and in northern Burma (at Myitkyina on the Lido Road). Transferring to the U.S.A. Typhus Commission in Italy in early December, 1943, Philip participated in the operation of the successful program of dusting the civilian population of Naples with the new insecticide DDT, dispensed with both power and hand dusters, and thus for the first time a potential typhus epidemic in civilian as well as military personnel was aborted under combat conditions.

Philip was then transferred to the Southwest Pacific Theater where he served in Australia, New Guinea, Owi Island, Admiralty Islands, Philippine Islands, and Japan. His assignment to a U.S.A. Typhus Commission team helped demonstrate several new foci of mite-borne typhus in parts of New Guinea, Owi Island, the Philip-

pines, and even beyond the classic areas within Japan. In August, 1945, Lieutenant Colonel Philip was presented the U.S.A. Typhus Commission Medal at a ceremony in Manila.

After the end of the war, Philip returned to the Rocky Mountain Laboratory to continue his studies of rickettsial diseases. In the following years he participated as a member or chairman of many national and international committees and congresses, presented lectures, and served as officer of various societies, including:

From 1946 through 1955, Associate Member of the Commission on Virus and Rickettsial Diseases, Army Service Forces, Army Epidemiological Board of the U.S. Army. In 1947, Secretary to both the International Northwestern Conference on Diseases in Nature Communicable to Man and the International Conference of Great Plains Entomologists. In 1948, presented the Theobald Smith Lecture at the New York Academy of Tropical Medicine. Also reactivated as Colonel to serve as member of the Scrub Typhus Unit, U.S. Army, in Malaya headed by Dr. Joseph E. Smadel, where in a short time the efficacy of chloromycetin® (Chloramphenicol) was demonstrated in the treatment of scrub typhus.

In 1950, presented the Invitational Public Address entitled "Tick Talk" to the 45th Entomological Society of America joint meeting with the American Association of Economic Entomologists, at Denver, Colorado. From 1950–1962, Assistant Director of the Rocky Mountain Laboratory, U.S. Public Health Service, Hamilton, Montana. From 1951–1961, Consultant to the Chemical Corps Biological Warfare Laboratory, Fort Detrick, Maryland. In 1952, President of the International Northwestern Conference on Diseases in Nature Communicable to Man. From 1952 to 1956, Consultant to the Air Forces Arctic Aeromedical Laboratory, Fairbanks, Alaska. In 1953, President of the American Society of Parasitologists. In 1955, Secretary to Section D, Medical and Veterinary Entomology, Entomological Society of America. From 1955 to 1970, Consultant to the U.S. Naval Medical Research Unit No. 3, in Cairo; researched under their auspices in Kenya in 1953 and in Ethiopia in 1963. From 1955 through 1970, Research Associate in the Department of Insects and Spiders, American Museum of Natural History, New York. In 1956, Chairman to Section D, Medical and Veterinary Entomology, Entomological Society of America. From 1958 to 1966, Member of the International Committee of Bacteriological Nomenclature. From 1959 to 1962, Member of the Board of Governors, Entomological Society of America. From 1959 to 1963, Member of the Interagency Advisory Committee, Dugway Proving Grounds, Utah. From 1959 to 1970, Member of the Expert Panel on Tickborne Diseases, Food and Agricultural Organization of the United Nations.

In 1960, Member and Delegate of the Entomological Society of America, XIth International Congress of Entomology, Vienna. From 1960 to 1969, Consultant to the Biological and Chemical Defense, Department of Defense. From 1962 to 1964, Director of the Rocky Mountain Laboratory, U.S. Public Health Service. In 1963, Co-chairman of the World Health Organization Conference on Rickettsioses, Geneva, July 8–13. From 1963 to 1966, Member of the Judicial Commission, International Committee of Bacteriological Nomenclature. In 1964, Member of the First International Congress of Parasitology, Rome, September 21–26. In 1964 and 1965, field work in Ecuador, Chile, and Argentinian-Bolivian border for Pan American Health Organization, two separate trips. In 1966, Chairman of the Third Expert Panel on Tick-borne Diseases of Livestock, Hamilton, Montana, August 8–15, and

Chairman of the Tsutsugamushi Disease Symposium, Eleventh Pacific Science Congress, Niigata, September 5.

Philip retired at age 70, on June 30, 1970, from the United States Public Health Service, Rocky Mountain Laboratory, after forty and one-half years of service. The Philips moved to San Francisco, California, and he began his second career, primarily dedicated to the study of the Tabanidae, with emphasis on the Mexican and Neotropical faunas, as a Research Associate in the Department of Entomology, California Academy of Sciences. In August Philip delivered the R. R. Parker Memorial Lecture at the 25th Annual Meeting of the International Northwestern Conference on Diseases in Nature Communicable to Man, at Pullman, Washington.

In 1971 Philip began the donation of his personal collection of Tabanidae to the California Academy of Sciences. The collection contained over 17,000 specimens including 124 holotypes, 87 allotypes and neallotypes, 976 paratypes, and 25 syntypes. More than 35 papers, mostly on Neotropical Tabanidae, were published during his retirement, and systematic studies were discontinued only when serious eye problems prevented his use of a binocular microscope. In spite of his diminishing eyesight Philip continued to type his own letters and drafts of manuscripts.

In 1974, Philip served as President of the Pacific Coast Entomological Society. He faithfully attended all meetings of this society during his residency in San Francisco and was always an active participant in the discussion period that followed the talks of the evening. Elected a Fellow of the California Academy of Sciences in 1972, he was always in attendance at the annual meetings and dinners of that fellowship.

In 1980 Philip was elected an Honorary Member of the American Society of Rickettsiologists and Rickettsial Diseases in recognition of his contributions to rickettsiology. Throughout the years he received many other honors that included: Fellow of the Entomological Society of America, in 1951; Honorary Doctor of Sciences degree from the University of Nebraska, in 1951; Outstanding Alumnus Achievement Award, from the Regents of the University of Minnesota, conferred June 4, 1960; Superior Service Award, Department of Health, Education, and Welfare, received May 28, 1966; and Honorary Life Member, International Northwestern Conference on Diseases in Nature Communicable to Man, in 1970.

Dr. Philip was also active in civic and fraternal organizations, especially in the years when he resided in Hamilton, Montana. These included the Elks (serving as Scholarship Chairman), the Lions Club, the American Legion (serving as Post Commander), Western Montana Association of Federal Business Men (President in 1957), and the Boy Scouts of America. He was fond of fishing and hunting and especially enjoyed the trout fishing along Girds Creek on the property of the Bitterroot Stock Farm founded by Marcus Daly. Philip also enjoyed elk and antelope hunting on a ranch in the central portion of Montana when permits could be obtained. A favorite retreat was Blue Nose Peak, at an elevation of 8,000 feet, on the Montana-Idaho divide about 80 miles south of Hamilton, where he held title to the use, for some years, to a deactivated Forest Service lookout cabin. This area that Philip looked forward to visiting with family and colleagues, which was especially productive for the collection of mountain topping Diptera such as male Tabanidae, *Cuterebra,* and the illusive *Cephenemyia,* he chose to be his final resting place.

During his career that spanned 60 years, Philip published 350 scientific articles with 3,595 pages of text and illustrations in parasitology and the biosystematics of Tabanidae, including the descriptions of 574 taxa (12 rickettsiae, 8 Acari, 2 Culi-

cidae, 2 Pelecorhynchidae, and 550 Tabanidae). He and coauthors proposed 18 genus-group names and 532 species-group names in the Tabanidae which constitute approximately 15% of the tabanid species recognized worldwide. Philip was generous in naming new taxa after his colleagues. One hundred twenty-seven individuals are included in the 156 patronymical names proposed.

Dr. Philip's many achievements have been documented by Jellison and Kohls (1973, Exp. Parasitol. 33:407–423), Collins (1976, J. Parasitol. 62:504–509), and in a Festschrift coedited by Arnaud and Lane (1985, Myia 3:1–714). In the Festschrift Lane and Arnaud provided bibliographies of Philip's parasitological and tabanidological publications, respectively, and the following five titles will complete Philip's bibliography:

1985

[From our Readers.] [Giardiasis.] Alaska Magazine 51(11):52.

[Abstract.] Tests in the field in western Montana of mechanical transmission of tularemia by biting flies between immobilized laboratory animals. Proc. Pac. Div., Amer. Assoc. Advanc. Sci. 4(1):38. [By Philip and W. L. Jellison.]

Tularemia and other problems in livestock induced by wood ticks in Montana. Bull. Soc. Vector Ecol. 10:45–47. [By Philip and S. C. Williams.]

1986

A collection of four species of tabanid flies taken from an anaconda snake in Peru in May 1984. Pan-Pac. Entomol. 62:63.

Field tests in western Montana of mechanical transmission of tularemia by biting flies (Diptera) between immobilized laboratory animals. Bull. Soc. Vector Ecol. 11:197–198. [By Philip and W. L. Jellison.]

Dr. Philip's extensive library of books and reprints on Tabanidae were donated to the Department of Entomology, California Academy of Sciences, by his family, while a bound set of seven volumes of Philip's publications was donated to the Academy by his son, Dr. Gordon W. Philip. The Philip correspondence files, pictures, and related materials are deposited in the California Academy of Sciences' Archives.

In 1922 Philip married Gladys Helen Hill who steadfastly supported his scientific endeavors for the next 64 years. He is survived by his wife Gladys, two daughters—Bonnie Dee Hasselbeck of Troy, Ohio, and Jo Joyce Dratz of Missoula, Montana, two sons—Dr. Robert N. Philip of Hamilton, Montana, and Dr. Gordon W. Philip of Silverdale, Washington, his brother George C. Philip of Denver, Colorado, 15 grandchildren, and six great-grandchildren. As quoted from a recent obituary written by Dr. Robert S. Lane: "He also leaves behind many colleagues and friends who benefited immeasurably from his constant encouragement and his generosity in sharing with them his time and broad knowledge. Moreover, Neil's keen sense of humor and his sage counsel will be missed sorely by all of us who were privileged to have known him." Dr. Philip requested that there be no funeral or memorial services.

Some taxa named in honor of Cornelius Becker Philip:

Arachnida: Acari: Ixodidae:

Amblyomma philipi Cooley and Kohls, 1939 (USA: Texas; Mexico).

Ixodes philipi Keirans and Kohls, 1970 (Japan).

Arachnida: Araneae: Salticidae:

Pellenes philipi Gertsch and Jellison, 1939 (USA: Montana).
Insecta: Diptera: Culicidae:
Culex (*Culex*) *philipi* Edwards, 1929 (Nigeria).
Insecta: Diptera: Tabanidae:
Philipomyia Olsufjev, 1964 (Palearctic).
Philipotabanus Fairchild, 1943 (Neotropical).
Anerythrops philipi Barretto, 1948 (Brazil).
Apatolestes philipi Pechuman, 1985 (USA: Texas).
Bolbodimyia philipi Stone, 1954 (Guatemala).
Chrysops philipi Burger, 1985 (Sarawak).
Cydistomyia philipi Burger, 1981 (Sri Lanka).
Haematopota philipi Chvála, 1969 (Nepal).
Hybomitra philipi (Stone, 1939, as *Tabanus*) (USA: Washington).
Leucotabanus cornelianus Fairchild, 1985 (Ecuador).
Lissimas philipi Mackerras, 1964 (New Guinea).
Silvius (*Zeuximyia*) *philipi* Pechuman, 1938 (USA: Oregon).

—Paul H. Arnaud, Jr., Department of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118.

PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 371–380

New *Barrojuba* with a revised key to species (Coleoptera: Pselaphidae)[1]

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Abstract.—Eight new species of the Neotropical genus *Barrojuba* are described: *simplicinota* n. sp. from Colombia; *pedunculata* n. sp. from Trinidad; and *lenticornis* n. sp., *simpliciventris* n. sp., *afoveata* n. sp., *plaumanni* n. sp., *prolongicornis* n. sp., and *campbelli* n. sp. from Brazil. Five of these new species have females associated with males, while females are not known for any of the previously described species. Characteristics of the genus are noted, and a key to the fourteen species now included in the genus is presented. New records for *albertae* Park, *tuberosa* Chandler, and *varia* Chandler are included. Members of the genus have now been collected from southern Mexico to southern Brazil.

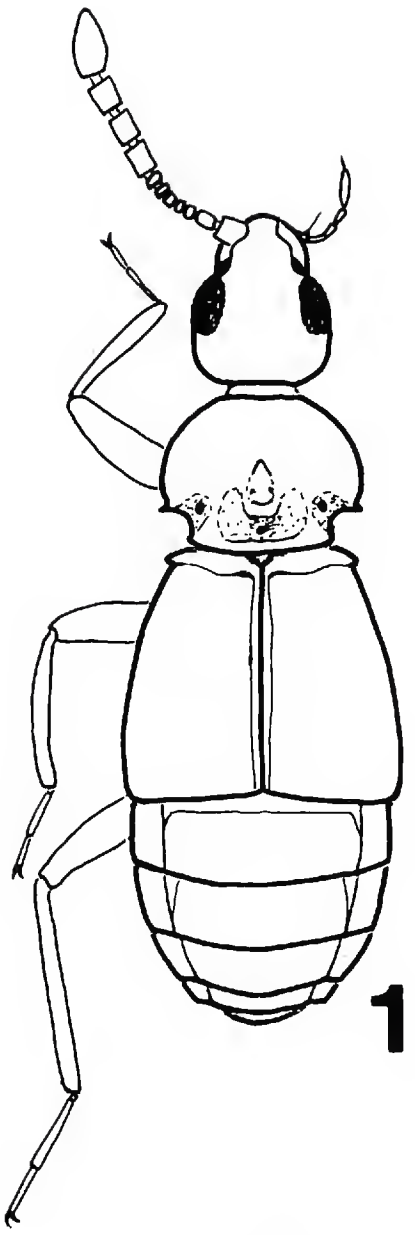
Subsequent to my revision of *Barrojuba* (Chandler 1983), I had the opportunity to sort the large pselaphid collections of three North American institutions and discovered eight undescribed species belonging to this genus. Five of these have females associated with them, while females were unknown for the six species covered in my earlier paper. Previously the genus was known only from Panama, with the new species and records in this paper extending the range from southern Mexico to southern Brazil. The new species are described, a revised key to the species of the genus is presented, and new records for three other species are included.

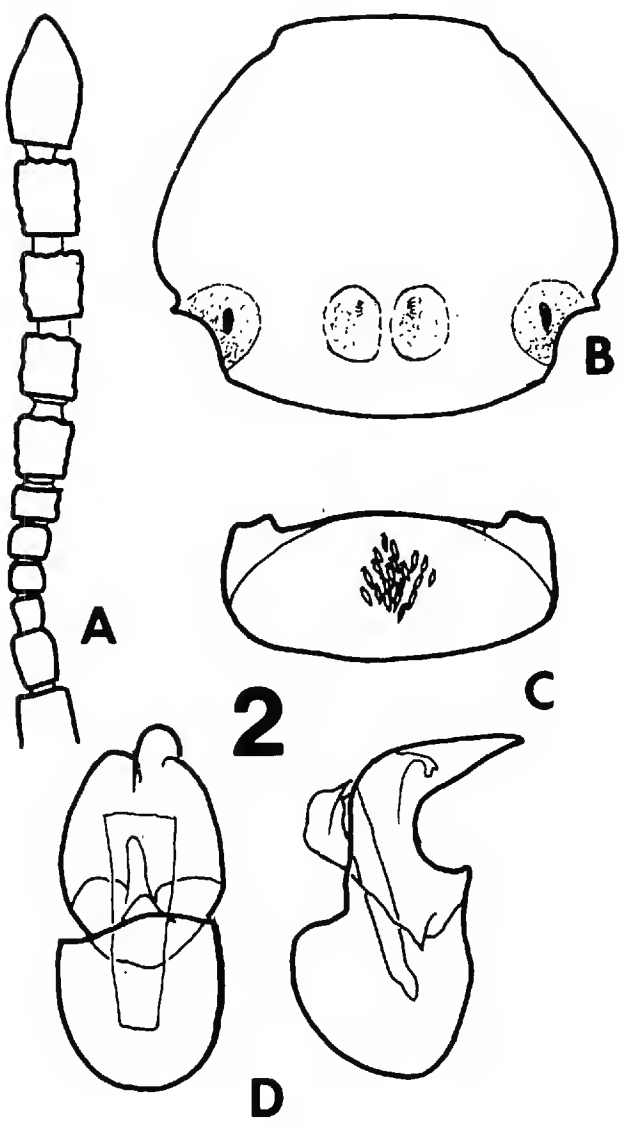
Members of *Barrojuba* are readily recognized among the Jubini by the lack of vertexal foveae and sulci, and the incomplete transverse antebasal sulcus of the pronotum. Members of the genus are further distinguished by the baso-medial pair of foveae on tergites II–IV and sternites II–V. I have not seen these particular foveae present in members of any other genus in the tribe. These foveae are only readily visible on cleared specimens mounted on slides. Males have large eyes of 35–60 facets, an elongate antennal club of 4–5 flagellomeres, and the antebasal area of the pronotum is impressed and often tuberculate. Females have 5–10 facets forming the eyes, a comparatively much shorter 3–4 segmented antennal club (one segment less than that of their respective males, except possibly in *pedunculata* n. sp.), and the antebasal area of the pronotum has only a feeble medial remnant of the transverse sulcus present. At this time only males may be identified to species.

All measurements are in millimeters. Descriptions are compiled from cleared, disarticulated specimens on slides, and from specimens on points. Holotypes are cleared, disarticulated, and mounted on slides in Canada balsam. Deposition of specimens are indicated by the following acronyms:

CNCI. Canadian National Collection of Insects, Ottawa, Canada.
DSC. Private collection of author, Durham, NH.

[1]Scientific contribution Number 1539 of the New Hampshire Agricultural Experiment Station.





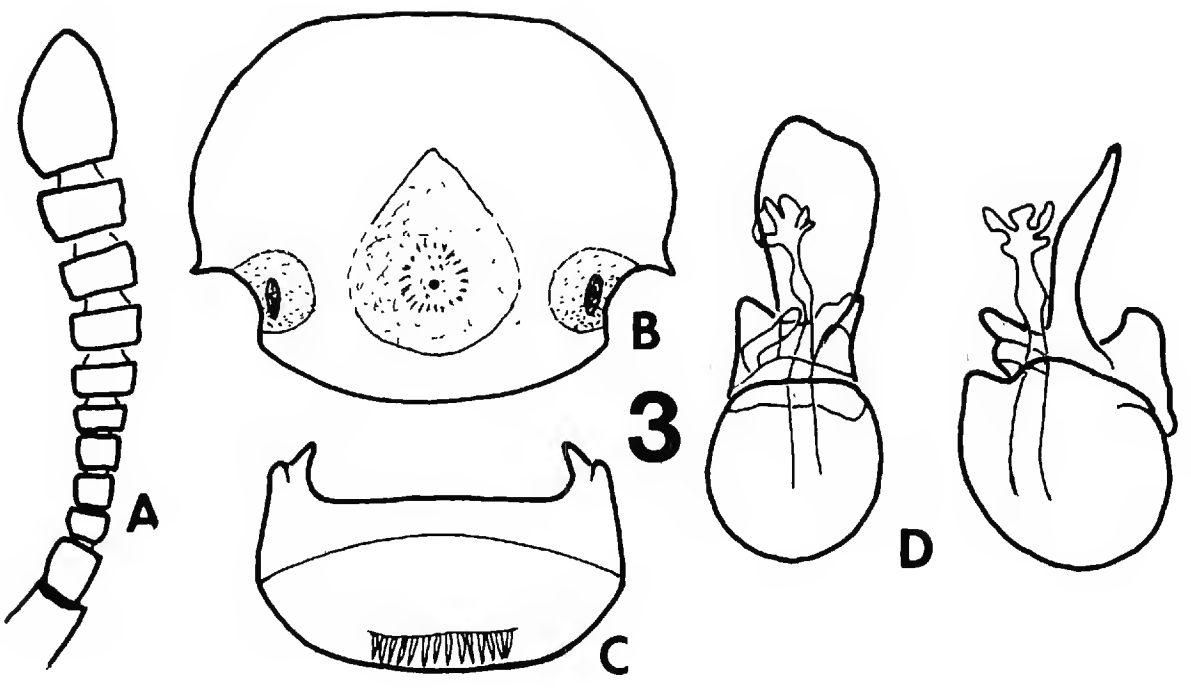


Fig. 1. Dorsal view *Barrojuba albertae*. Figs. 2–3. A dorsal view antenna; B, dorsal view pronotum; C, ventral view sternite VI; D, dorsal and left lateral view aedeagus; 2. *B. simplicinota;* 3. *B. lenticornis*

FMNH. Field Museum of Natural History, Chicago, IL.
MCZC. Museum of Comparative Zoology, Cambridge, MA.

Key to males of *Barrojuba*

Males may be recognized by the large eyes (35–60 facets), depression and/or tubercle in the antebasal region of the pronotum, and the impression of sternite VI. In females the eyes are small (5–10 facets), the antebasal region of the pronotum bears only a slight medial remnant of the antebasal sulcus, and all sternites are convex.

1. Antennal club formed by apical five flagellomeres, flagellomere V at least half again as long as IV (Fig. 2A) 2
   Antennal club formed by apical four flagellomeres, V and IV subequal in length (Fig. 6A) 5
2. (1) Tubercle in antebasal impression with tuft of setae at apex, tubercle visible in lateral view (Fig. 1, Chandler 1983) 3
   Tubercle barely developed in antebasal impression and lacking apical tuft of setae, or tubercle absent, tubercle not visible in lateral view 4
3. (2) Flagellomere V longer than wide; pronotal tubercle barely visible in lateral view (Fig. 1, Chandler 1983); Panama ..... *uliginosa* Chandler
   Flagellomere V transverse; prontoal tubercle easily visible in lateral view (Fig. 2, Chandler 1983); Mexico to Panama ..... *tuberosa* Chandler
4. (2) Flagellomeres V–VIII elongate (Fig. 2A); pronotum with paired weak antebasal impressions (Fig. 2B); Colombia ..... *simplicinota* n. sp.
   Flagellomeres V–VIII transverse (Fig. 3A); pronotum with distinct circular antebasal impression (Fig. 3B); Brazil ..... *lenticornis* n. sp.
5. (1) Flagellomere VI with widest portion as long as wide or longer (Fig. 5A) 6
   Flagellomere VI with widest portion clearly transverse (Fig. 7A) ... 10
6. (5) Pronotum with prominent acute tubercle on anterior margin of antebasal impression (Fig. 5B); Brazil ..... *simpliciventris* n. sp.
   Pronotum with tubercle on posterior margin of antebasal impression, or inconspicuous 7
7. (6) Sternites III–V narrowly flattened medially; pronotum with vague bituberculate rhomboidal raised area on anterior margin of antebasal impression, setate tubercle near posterior margin of impression and inconspicuous, bearing a single seta; flagellomere VI only slightly longer than wide (Fig. 1); Panama ..... *albertae* Park
   Sternites III–V widely flattened or impressed; pronotal modifications of antebasal impression absent or different, tubercle easily visible, bearing tuft of setae at apex; flagellomere VI twice as long as wide (Fig. 6, Chandler 1983) 8
8. (7) Pronotum with antero-medial margin of antebasal impression slightly gibbous, longest setae on disc originating from this area (Fig. 6, Chandler 1983); Panama ..... *gibbosa* Chandler
   Pronotum lacking any development of anterior margin of antebasal impression, longest setae over basal half of pronotum 9

9. (8) Sternite VI with preapical row of pointed setae (Fig. 5, Chandler 1983); Panama ..... *woldai* Chandler
Sternite VI with preapical row of rectangular setae (Fig. 4, Chandler 1983) ..... *varia* Chandler

10. (5) Pronotum with stout pedunculate tubercle near middle of circular impression, tubercle lacking apical tuft of setae (Fig. 4B); Trinidad ..... *pedunculata* n. sp.
Pronotum with tubercle on anterior margin of vague U or Y-shaped antebasal impression (Figs. 6B, 7B), tubercle with apical tuft of setae ... 11

11. (10) Pronotum with broad prominent tubercle, posterior face granulate (Fig. 6B); Brazil ..... *afoveata* n. sp.
Pronotum with conical tubercle, posterior face not granulate (Fig. 7B) 12

12. (11) Pronotum with conspicuous punctures, separation of punctures about equal to puncture diameter; body length greater than 2.1 mm; Brazil ..... *plaumanni* n. sp.
Pronotum with punctures closer and indistinct; body length less than 1.9 mm 13

13. (12) Sternite VI with two preapical rows of short flattened setae interrupted at middle (Fig. 9C); Brazil ..... *campbelli* n. sp.
Sternite VI with uninterrupted medial row of long flattened setae (Fig. 8C); Brazil ..... *prolongicornis* n. sp.

Barrojuba simplicinota n. sp.
(Fig. 2)

Length 2.55. Males with head densely and coarsely punctate, pronotum less densely punctate; eyes with about 60 facets, antennal club 4-segmented, flagellomere V twice as long as IV; pronotum with two shallow antebasal impressions, lacking medial tubercle; sternites II–V convex, VI with transverse impression, cluster of large flattened seate at center of impression.

Females unknown.

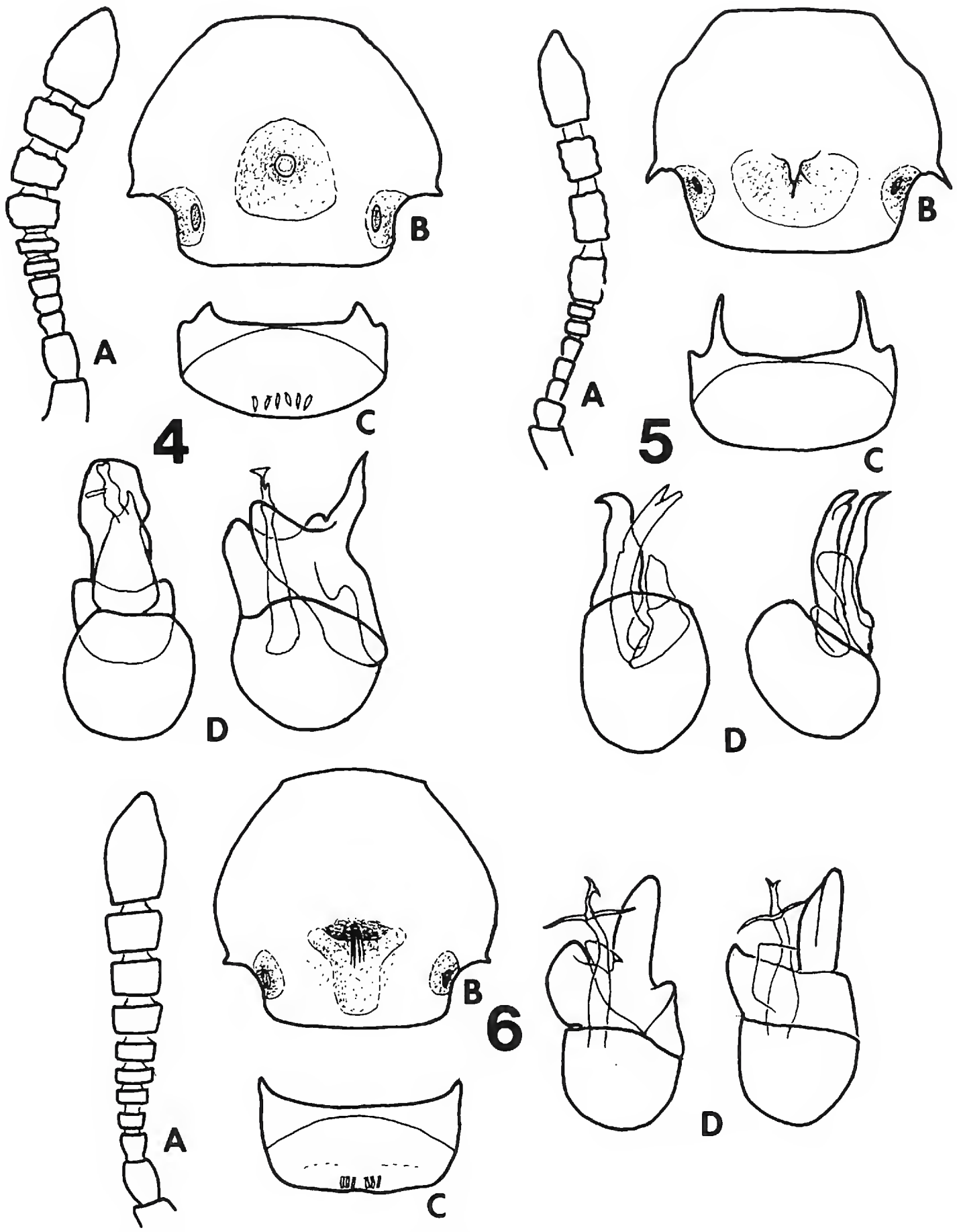
Male holotype: head 0.48 long, flagellomere IV 0.05 long, 0.05 wide, V 0.09 long, 0.06 wide; pronotum 0.46 long, 0.53 at widest point; elytra 0.78 long; aedeagus 0.21 long.

Specimen examined: HOLOTYPE male, COLOMBIA, Cundinamarca, Tequendama, 7600', VII–6–1970, J. M. Campbell (CNCI). The name is derived from the relatively simple pronotal modifications.

Comments: *Simplicinota* is similar to *uliginosa* and *tuberosa* in the antennal club of five elongate flagellomeres, but is readily separated by the lack of a pronotal tubercle, the loosely clumped flattened setae of sternite VI, and the simple rather than lobed penis apex.

Barrojuba lenticornis n. sp.
(Fig. 3)

Length 1.80. Males with head and pronotum densely and smoothly punctate; eyes with about 50 facts, antennal club 5-segmented, flagellomere IV two-thirds as long as V; pronotum with rounded rhomboidal impression, small tubercle at center of im-



Figs. 4–6. A, dorsal view antenna; B, dorsal view pronotum; C, ventral view sternite VI; D, dorsal and left lateral view aedeagus; 4. *B. pedunculata;* 5. *B. simpliciventris;* 6. *B. afoveata.*

pression lacking apical setae; sternite III medially flattened, IV–V medially impressed, VI with deep transverse impression, with preapical row of flattened pointed setae.

Females with sculpture of head and pronotum similar, eyes with 5 facets, antennal club 4-segmented, flagellomere VI twice as long as V; sternites convex.

Male holotype: head 0.32 long, flagellomere V 0.03 long, 0.05 wide, VI 0.05 long, 0.06 wide; pronotum 0.35 long, 0.44 at widest point; elytra 0.60 long; aedeagus 0.22 long.

Specimens examined, 2: HOLOTYPE male, BRAZIL, Amazonas, Floresta de Tijuca, Guanabara, II–1960, C. A. Campos Seabra (FMNH). PARATYPE: 1 female, eutopotypical (FMNH). The name is derived from the form of the apical flagellomeres.

Comments: Distinct among the species with an antennal club of five flagellomeres, by the small size, transverse apical flagellomeres, and the short asetate pronotal tubercle. *B. uliginosa* is perhaps most similar by the short setate pronotal tubercle, sternite VI with a transverse row of flattened setae, and the penis apex with a series of small lobes.

Barrojuba pedunculata n. sp.

(Fig. 4)

Length 1.35–1.57. Head densely punctate, rugosely sculptured, pronotum less densely punctured; eyes with about 45 facets, antennal club apparently 4-segmented, flagellomere VI twice as long as V; pronotum with distinct circular antebasal impression, with short pedunculate tubercle near middle; sternites II–V convex, VI transversely impressed, with a few large pointed setae in preapical transverse row.

Females with antennal club 4-segmented, flagellomere V less than half length of VI, eyes with 5–6 facets; pronotal disc smoothly convex, lacking antebasal modifications, weak transverse antebasal sulcus present only medially; all sternites convex.

Male holotype: head 0.27 long, flagellomere V 0.03 long, 0.05 wide, VI 0.05 long, 0.06 wide; pronotum 0.31 long, 0.39 at widest point; elytra 0.48 long; aedeagus 0.12 long.

Specimens examined, 7: HOLOTYPE male, TRINIDAD, Curepe, XI–28/29–1937, W. R. M. Mason (CNCI). PARATYPES: all from Trinidad, 2 males, 2 females, St. Augustine, VII–17–1935, VIII–3–1935 (2), IX–24–1935, N. A. Weber (DSC, MCZC); 1 female, Narriva Swamp, XII–5–1935, N. A. Weber, rainforest (MCZC); 1 female, Rocks off Galera Point, V–19–1935, N. A. Weber (MCZC). The name is derived from the form of the pronotal tubercle.

Comments: This species is best placed in the group with five flagellomeres in the male antennal club, since the female has a 4-segmented club. Male flagellomere V is definitely wider than IV, but only half the length of VI, which gives a 4-segmented appearance with flagellomere V wide enough but not long enough to be included. *Pedunculata* shares with *lenticornis* the asetate tubercle centered in the pronotal impression, transverse flagellomeres forming the antennal club, transverse row of pointed setae on sternite VI, and the apical lobes of the penis. The larger, pedunculate pronotal tubercle and shorter flagellomere V serve to separate this species from any others.

Barrojuba simpliciventris n. sp.
(Fig. 5)

Length 1.59. Males with head densely and coarsely punctate, pronotum less densely and coarsely punctate; eyes with about 60 facets, antennal club 4-segmented, V one-third length of VI, vertexal foveae indented between antennal bases and eyes, forming basally constricted antennal rostrum; pronotum with broad U-shaped antebasal impression, sharp tubercle on anterior margin bearing spine at apex; sternites II–V convex, VI transversely impressed, lacking modified setae.

Females unknown.

Male holotype: head 0.27 long, flagellomere V 0.03 long, 0.04 wide, VI 0.09 long, 0.05 wide; pronotum 0.29 long, 0.36 at widest point; elytra 0.48 long; aedeagus 0.22 long.

Specimen examined: HOLOTYPE male, BRAZIL, Para, Belem, IPEAN, III–23–1970, J. M. & B. A. Campbell (CNCI). The name is derived from the simple last sternite.

Comments: *Simpliciventris* shares with *campbelli* the pronotal tubercle on the anterior margin of the impression, and the general form of the simple aedeagus. It is readily separated from *campbelli* by the elongate flagellomeres of the antennal club, and the lack of any modified setae on sternite VI.

Barrojuba afoveata n. sp.
(Fig. 6)

Length 1.98–2.22. Males with head coarsely and closely punctate, rugulose, pronotum smoothly rugulose; eyes with 35–45 facets, antennal club 4-segmented, flagellomere VI twice as long as V; pronotum with quadrate tubercle on anterior margin of weakly defined Y-shaped antebasal impression, posterior face of tubercle granulate, bearing subapical tuft of setae angled posteriorly; sternites III–V lightly flattened at middle, VI transversely impressed, with preapical row of large rectangular setae interrupted at middle.

Females with antennal club 3-segmented, flagellomeres VII–VIII each twice as long as VI, eyes with about 8 facets; pronotal disc smoothly convex, lacking antebasal modifications, weak transverse antebasal sulcus present only medially; all sternites convex.

Male holotype: head 0.42 long, flagellomere V 0.04 long, 0.06 wide, VI 0.06 long, 0.07 wide; pronotum 0.40 long, 0.49 at widest point; elytra 0.63 long; aedeagus 0.16 long.

Specimens examined, 61: HOLOTYPE male, BRAZIL, Santa Catarina, Nova Teutonia, VII–1957, F. Plaumann (FMNH). PARATYPES: 22 males, 31 females, same data except dates from VIII–1953 to X–1957 (DSC, FMNH); 1 male, 1 female, Iramy, VII–1958, F. Plaumann (FMNH); 4 females, Seara, VIII–1958, F. Plaumann (FMNH). One female specimen bears an additional label, "ex: berlese leafmold." The name is derived from the manuscript name of Orlando Park for this species.

Comments: *Afoveata* is placed near the group of species with the 4-segmented antennal club formed by transverse flagellomeres, and the setate tubercle on the anterior margin of the pronotal impression. However, it is readily distinguished by the broad rather than conical pronotal tubercle, the medially divided row of setae on sternite VI, and the apical lobes of the penis.

Barrojuba plaumanni n. sp.
(Fig. 7)

Length 2.13–2.37. Males with head coarsely and densely punctate, pronotum with moderately dense umbilicate punctures; eyes with about 45 facets, antennal club 4-segmented, VI over twice as long as V; pronotum with shallow U-shaped antebasal impression, with stout tubercle on anterior margin bearing tuft of setae at apex; sternites II–V convex, VI transversely impressed, with medial transverse row of acute large flattened setae.

Females with sculpture of head and pronotum similar to males; antennal club 3-segmented, eyes with 6 facets; pronotum with indistinct transverse impression at middle near base; sternites convex.

Male holotype: head 0.39 long, flagellomere V 0.04 long, 0.06 wide, VI 0.08 long, 0.07 wide; pronotum 0.44 long, 0.51 at widest point; elytra 0.66 long; aedeagus 0.25 long.

Specimens examined, 2: HOLOTYPE male, BRAZIL, Santa Catarina, Nova Teutonia, 27°11′, 52°23′, 770 m, I–1977, F. Plaumann (MCZC). PARATYPE: 1 female, eutopotypical (MCZC). The name is proposed in honor of the collector of the type series.

Comments: Placed near *campbelli* and *prolongicornis* by the transverse flagellomeres of the 4-segmented and antennal club, and the setate tubercle on the anterior margin of the pronotal impression. *Plaumanni* is perhaps closest to *campbelli* by sharing the medial row of pointed setae on sternite VI, and is distinguished by the larger body size and form of the aedeagus.

Barrojuba prolongicornis n. sp.
(Fig. 8)

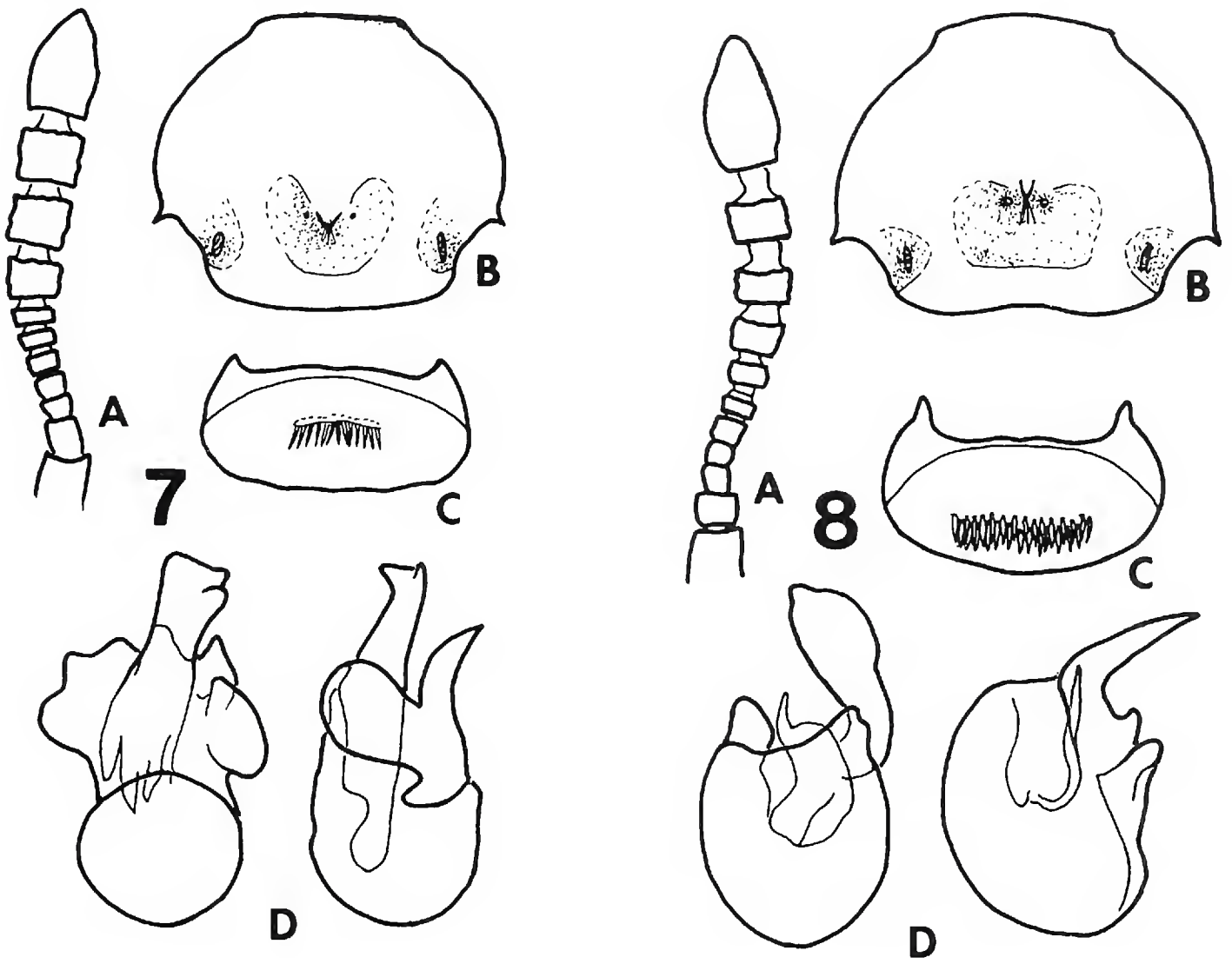
Length 1.62–1.83. Males with head closely and coarsely punctate, pronotum feebly and sparsely punctate; eyes with about 60 facets, antennal club 4-segmented, flagellomere VI twice as long as V; pronotum with short tubercle projecting posteriorly on anterior margin of deep transverse impression, tubercle with short tuft of setae at apex; sternites III–V smoothly convex, VI transversely impressed, with irregular row of large pointed setae near apex.

Female with similar sculpture of head and pronotum; eyes with five facets, antennal club 3-segmented, flagellomere VII twice as long as VI; pronotum with antebasal sulcus restricted to weak medial V-shaped impression; sternites convex.

Male holotype: head 0.27 long, flagellomere V 0.02 long, 0.04 wide, VI 0.05 long, 0.05 wide; pronotum 0.26 long, 0.34 at widest point; elytra 0.44 long; aedeagus 0.18 long.

Specimens examined, 3: HOLOTYPE male, BRAZIL, D. F. (now Rio de Janeiro), Corcovado, Rio de J(aneiro), VIII–18–1946 (FMNH). PARATYPES: 1 male, 1 female, Sao Paulo, Caraguatatuba, I–29/30–1970, J. M. & B. A. Campbell (CNCI). The name is derived from the apically produced terminal flagellomeres.

Comments: *Prolongicornis* shares with *plaumanni* and *campbelli* the transverse flagellomeres of the 4-segmented antennal club, and the acute setate tubercle on the anterior margin of the pronotal impression. It is closest in size to *campbelli,* but is most similar to the larger species, *plaumanni,* by the medial row of long acute setae on sternite VI.



Figs. 7–9. A, dorsal view antenna; B, dorsal view pronotum; C, ventral view sternite VI; D, dorsal and left lateral view aedeagus; 7, *B. plaumanni;* 8, *B. prolongicornis;* 9, *B. campbelli.*

***Barrojuba campbelli* n. sp.**
(Fig. 9)

Length 1.74. Males with head smoothly and rugosely punctate, pronotum with less dense and weak puncation; eyes with 40 facets, antennal club 4-segmented, VI almost twice as long as V; pronotum with shallow U-shaped antebasal impression, with short blunt tubercle on anterior margin bearing apical tuft of setae; sternite V lightly

flattened at middle, VI transversely impressed, with subapical row of short flattened setae briefly interrupted medially.

Females unknown.

Male holotype: head 0.31 long, flagellomere V 0.03 long, 0.05 wide, VI 0.05 long, 0.06 wide; pronotum 0.33 long, 0.41 at widest point; elytra 0.51 long; aedeagus 0.21 long.

Specimen examined: HOLOTYPE male, BRAZIL, Parana, Alexandra, 20 km W Paranagua, 80 m, II–13–1970, J. M. & B. A. Campbell (CNCI). The name is proposed in honor of the collector of the holotype.

Comments: Near *plaumanni* and *prolongicornis* by sharing the features discussed under those two species. Closest in body size to *prolongicornis,* but separated from both species by the two preapical rows of short setae on sternite VI.

New Records

Barrojuba albertae Park

PANAMA: *Bocas del Toro,* Almirante, III–27–1959, H. S. Dybas, berlese conc. floor litter (FMNH).

Barrojuba tuberosa Chandler

PANAMA: *Chiriqui,* 24 km NNE San Felix, 81°50′, 8°50′, 1300 m, VI–24–1980, J. A. Wagner, berlese floor litter & root mat (FMNH). MEXICO: *Chiapas,* Finca Esperanza, 710 m, IV–12–1938, R. Nettel, at light (FMNH). *Veracruz,* 2 mi S Acayucan, Rd. 185, VII–10–1962, J. M. Campbell (CNCI).

Barrojuba varia Chandler

PANAMA: *Chiriqui,* Boquete, X–2–1975, D. S. Chandler, sift coffee tree litter (DSC).

Acknowledgments

I would like to thank the following individuals for the loan of specimens in their care: J. M. Campbell, Agriculture Canada, Ottawa, Ontario, Canada; L. E. Watrous, Field of Museum of Natural History, Chicago, IL; and S. R. Shaw, Museum of Comparative Zoology, Harvard University, Cambridge, MA. I would also like to thank J. F. Burger and R. M. Reeves, University of New Hampshire, Durham, NH, for reading the manuscript.

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PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 381–390

Taeniopteryx of Western North America (Plecoptera: Taeniopterygidae)

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Abstract.—Of the 11 valid North American species of *Taeniopteryx,* 3 have distributions including western North America: *T. burksi* Ricker and Ross, *T. nivalis* (Pictet), and *T. parvula* (Banks). *Taeniopteryx pecos* Baumann and Jacobi is considered conspecific with *T. parvula.* Keys to the adults and nymphs are presented for the above species.

There are presently twelve species of *Taeniopteryx* recognized from North America (Stark et al., 1986); of these, only four have been recorded from western North America: *T. burksi* Ricker and Ross, *T. nivalis* (Fitch), *T. parvula* Banks, and *T. pecos* Baumann and Jacobi. Additionally, Canton et al., (1981) reported on several populations of an unidentified species of *Taeniopteryx* occurring in northcentral Colorado. Adults of these and others from the North Platte River drainage in Wyoming were successfully reared by us. In order to identify these specimens a study of the *Taeniopteryx* species that occur west of the Mississippi River was necessary. Previously, only *T. nivalis* was recognized from the Rocky Mountains by Baumann, et al., (1977).

The following institutions or individuals made specimens available for study: S. P. Canton, Littletown, Colorado; J. F. Flannagan, Freshwater Institute, Winnipeg, Manitoba; O. S. Flint, Jr., Smithsonian Institution, Washington, D.C.; G. R. Fiala, Gresham, Oregon; D. Funk, Avondale Pennsylvania; W. J. Hanson, Utah State University; P. P. Harper, University of Montreal, Montreal, Quebec; S. G. Jewett. Jr., West Linn, Oregon; R. F. Kirchner, Huntington, West Virginia; J. Z. Jacobi, New Mexico Highlands University; A. V. Nebeker, Corvallis, Oregon; N. D. Penny, California Academy of Sciences; S. D. Smith and R. N. Vinyard, Central Washington State University; G. B. Wiggins, Royal Ontario Museum, Toronto; B. Wisseman, Oregon State University; and R. S. Zack and W. L. Turner, Washington State University.

Taeniopteryx burksi Ricker and Ross

Taeniopteryx burksi Ricker and Ross 1968: 1425 (description of adults).
Taeniopteryx burksi, Harper and Hynes 1971: 943; Fullington and Stewart 1980: 244 (description of nymph).

The male of this species is very similar to the eastern *T. maura* (Pictet) and the transcontinental *T. nivalis,* all three species having straight, bluntly pointed paraprocts (Fig. 3), and a vesicle. Males of *T. burksi* may be distinguished from its western relative, *T. nivalis* most reliably by the vesicle being 3–5 times as long as wide and by the distinctive extruded aedeagus having both dorso- and ventrolateral lobes long (Fig. 5). Females as similar to *T. parvula,* bu the V-shaped notch of the 8th sternum is usually uniformily sclerotized in older individuals.

Taeniopteryx burksi is a common and widely distributed species east of the Rocky Mountains (Ricker and Ross, 1968; Kondratieff and Ward, 1987). The presence of this species in a few streams of the Great Plains of eastern Colorado is no doubt the result of western dispersal from the East during glacial periods (Stewart et. al., 1974).

Western records examined: COLORADO: Yuma Co., Chief Cr., 31 I 1986, B. C. Kondratieff & J. V. Ward, 15♂, 11♀, 1 N; N Fork Republican R., Wray, 31 I 1986, B. C. Kondratieff and J. V. Ward 18♂, 17♀, 20 N; Kit Carson Co., S Fork Republican R., Rt. 385, 31 I 1986, B. C. Kondratieff & J. V. Ward, 2 N.

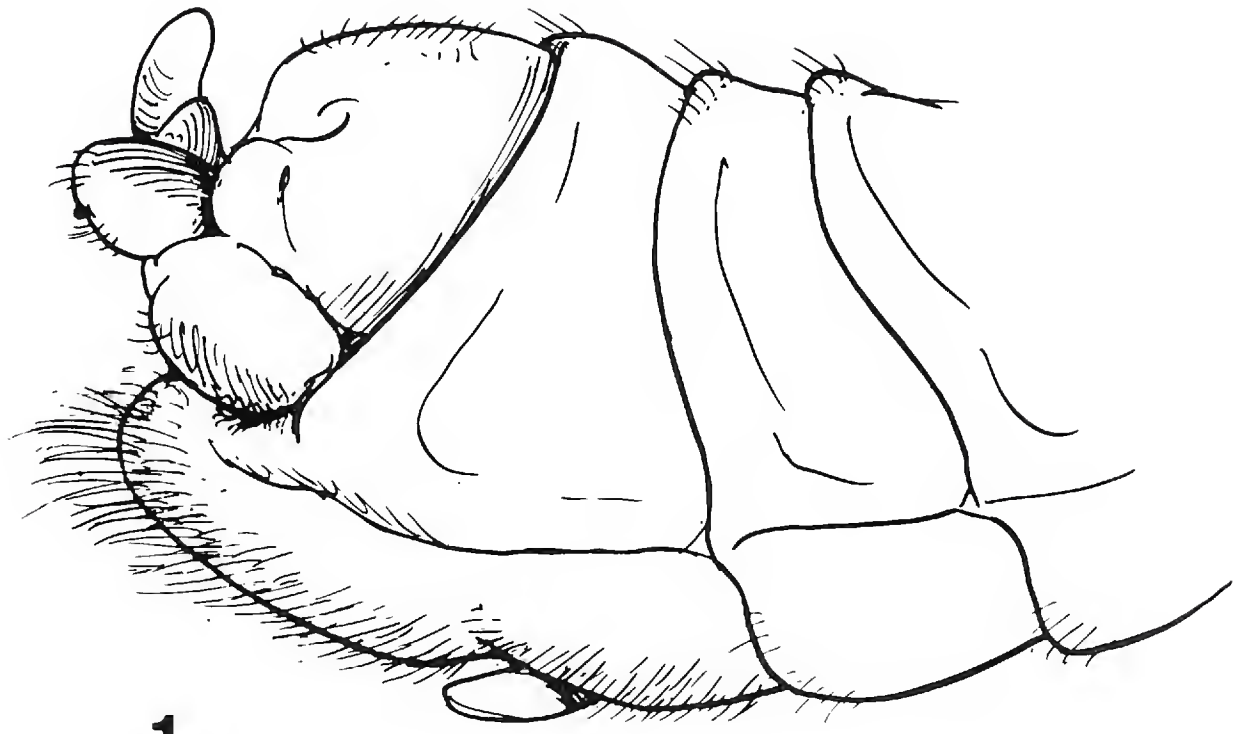
Taeniopteryx nivalis (Fitch)

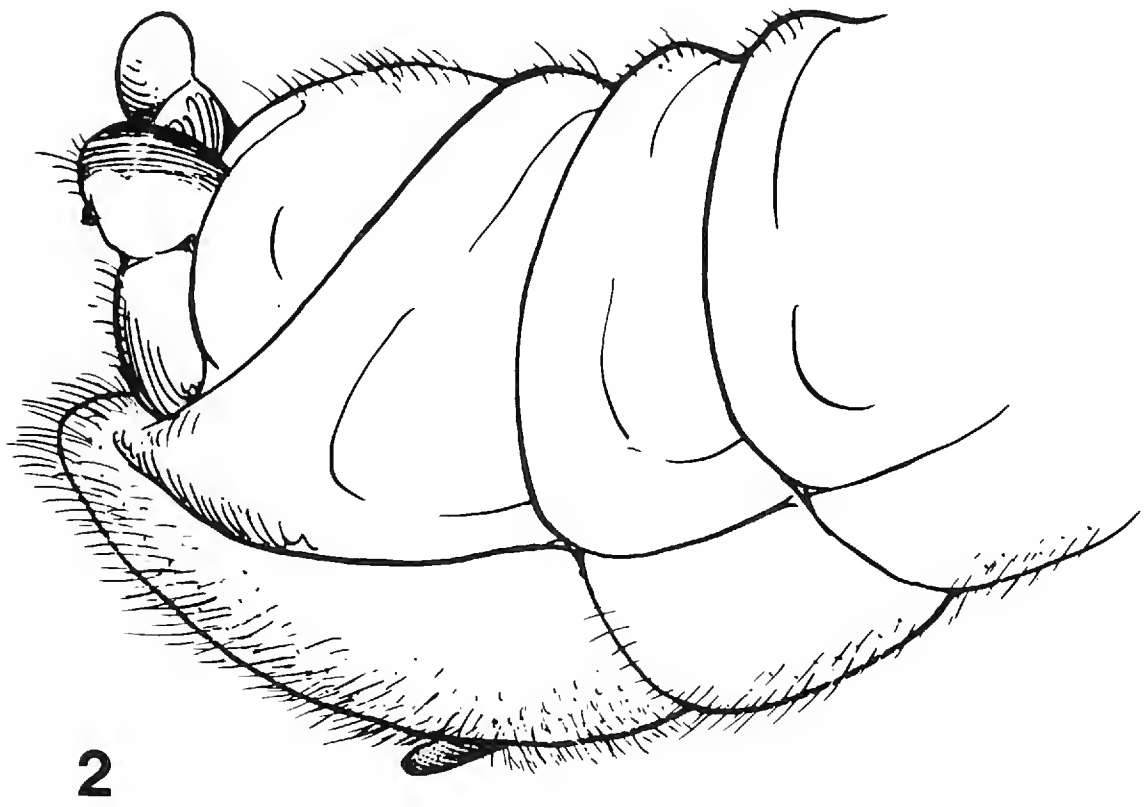
Nemoura nivalis Fitch 1847: 279.
Taeniopteryx nivalis, Ricker and Ross, 1968: 1434; Dosdall and Lehmkuhl, 1979:22 (description of adults).
Taeniopteryx nivalis, Harper and Hynes 1971: 945; Fullington and Stewart 1980: 253 (description of nymph).

The male of *T. nivalis* can only be confused with *T. burksi* in the West. The short vesicle (Fig. 2) (2–3 times as long as wide) and the extruded aedeagus with only short ventrolateral lobes easily distinguishes this species (Fig. 6). Previously, in other existing keys to the North American species (Ricker and Ross, 1968; Hitchcock, 1974), the character "hairs of the hind margin of the 9th sternite pointing downward and forward, usually much shorter than those situated more anteriorly on the sternite" is used to separate *T. nivalis* from *T. burksi* (and *T. maura*). However, for many western specimens of *T. nivalis,* this character is difficult to use, with specimens appearing intermediate or not definite. Western specimens of *T. nivalis* examined are similar in all respects to eastern specimens examined in vesicle and aedeagal characteristics. Females of *T. nivalis* are distinguished by the U-shaped notch of the 8th sternum with strongly sclerotized shoulders.

The distribution of *T. nivalis* in the West has been discussed by Ricker (1964). He suggested that there was a postglacial or interglacial dispersal across the northern plains, and southward down the chain of the Rocky Mountains followed by extinction(s) in northcentral North America.

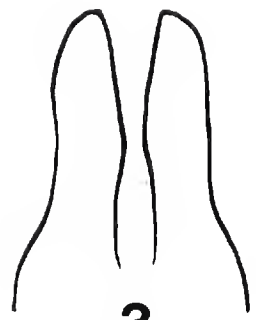
Western records examined: CANADA, Manitoba, Little Ochre R., 4 IV 1984, J. F. & P. M. Flannagan, 23♂, 3♀; Roseau River, 25 III 1977, J. F. Flannagan, 4 N; CALIFORNIA: Plumas Co., Middle Fork Feather, R., Hwy 70, above Portola, 14 II





Figures 1–2. Male terminalia, lateral view. 1. *Taeniopteryx burksi,* 2. *Taeniopteryx nivalis.*

1985, R. W. Baumann & C. R. Nelson, 21 N; Siskiyou Co., Shasta R., N of Yreka, 25 II 1968, S. G. Jewett, 1♂, 1♀; IDAHO: Adams Co., Mud Cr., Hwy 95, 3 mi. W of New Meadows, 24 III 1965, A. V. Nebeker, 2♂; Benewah Co., Fernwood, 5 III 1952, R. S. Vail, 1♀; Latah Co., Big Bear Cr., nr. Kendrick, 8 III 1984, G. R. Fiala, 2♂, 1♀; Potlatch R., ca. 3 mi. S Helmer nr. Little Boulder Campgrd, 26 III 1986, R. S. Zack, 3♂, 11♀; Potlach R., jct. Hog Meadow Cr., 26 IV 1985, R. W. Baumann, & C. R. Nelson, 1♂, 7♀; OREGON: Baker Co., Powder R., Hwy 86, jct.



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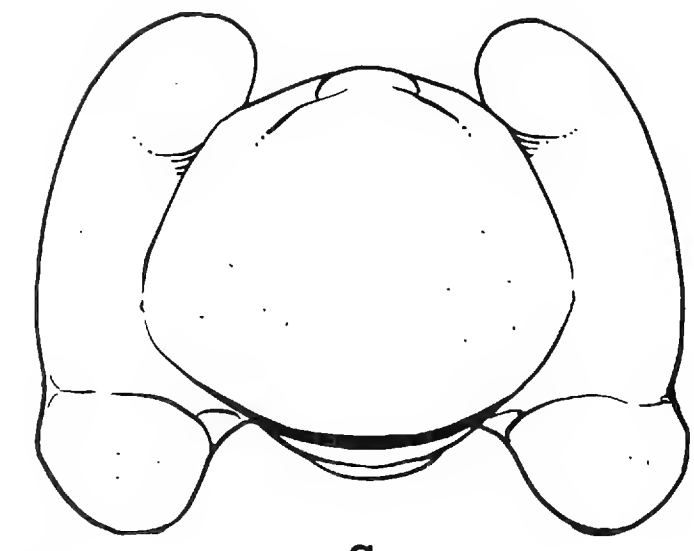

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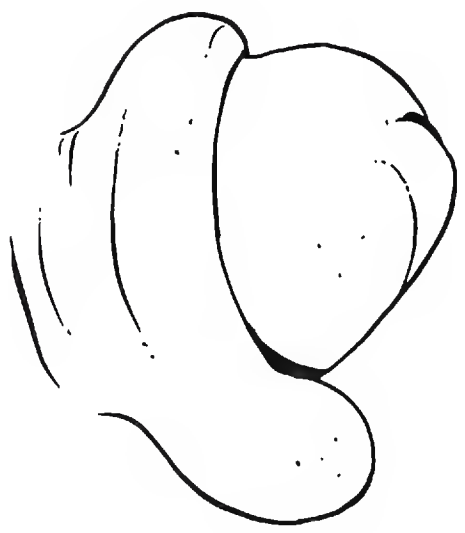

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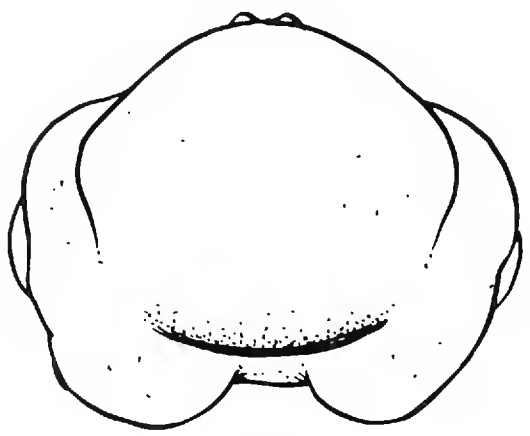

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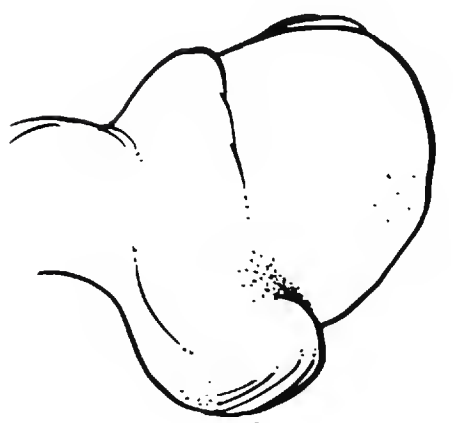

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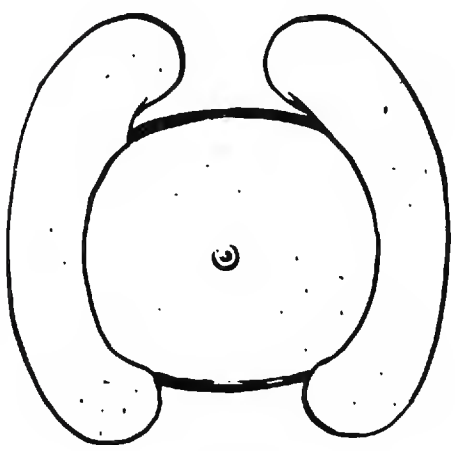

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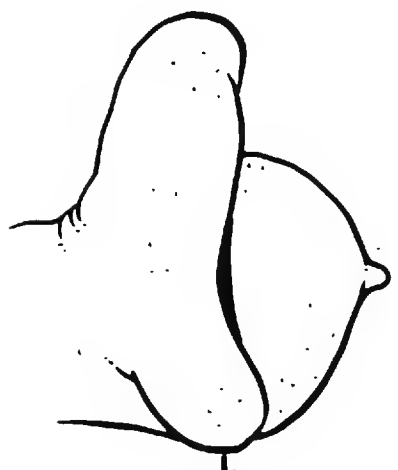
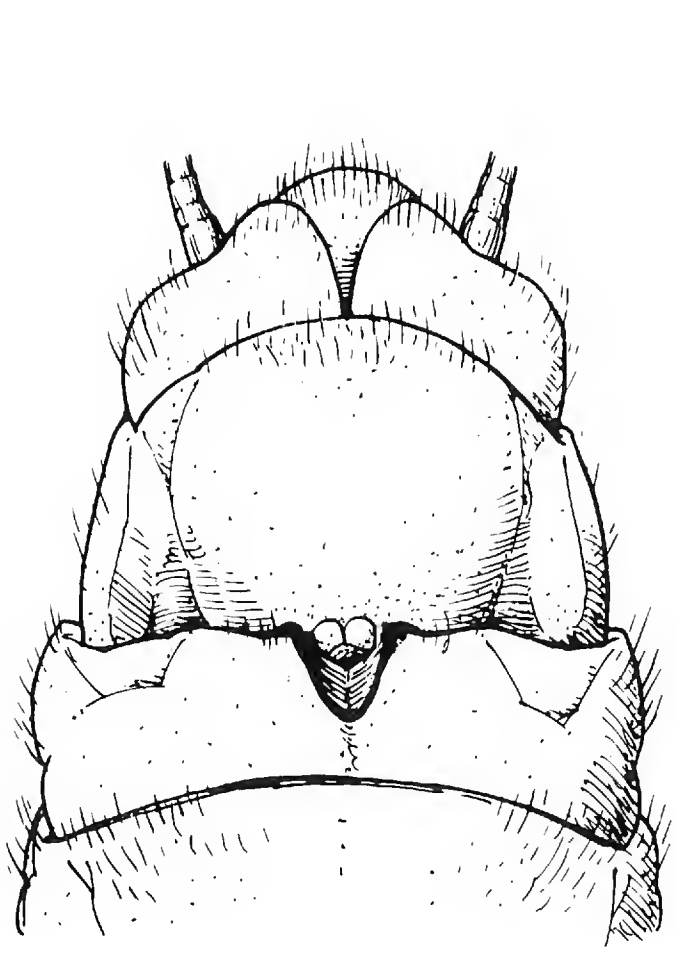


b

Figures 3–4. Paraprocts. 3. *T. burksi,* 4. *T. parvula.*

Figures 5–7. Extruded aedeagus, a. from behind; b. lateral. 5. *T. burksi,* 6. *T. nivalis,* 7. *T. parvula.*



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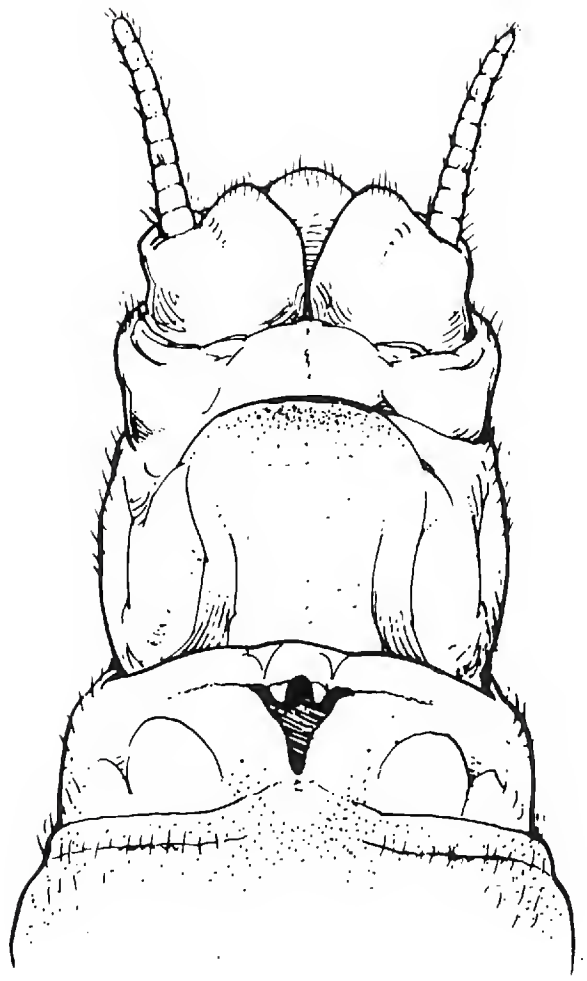

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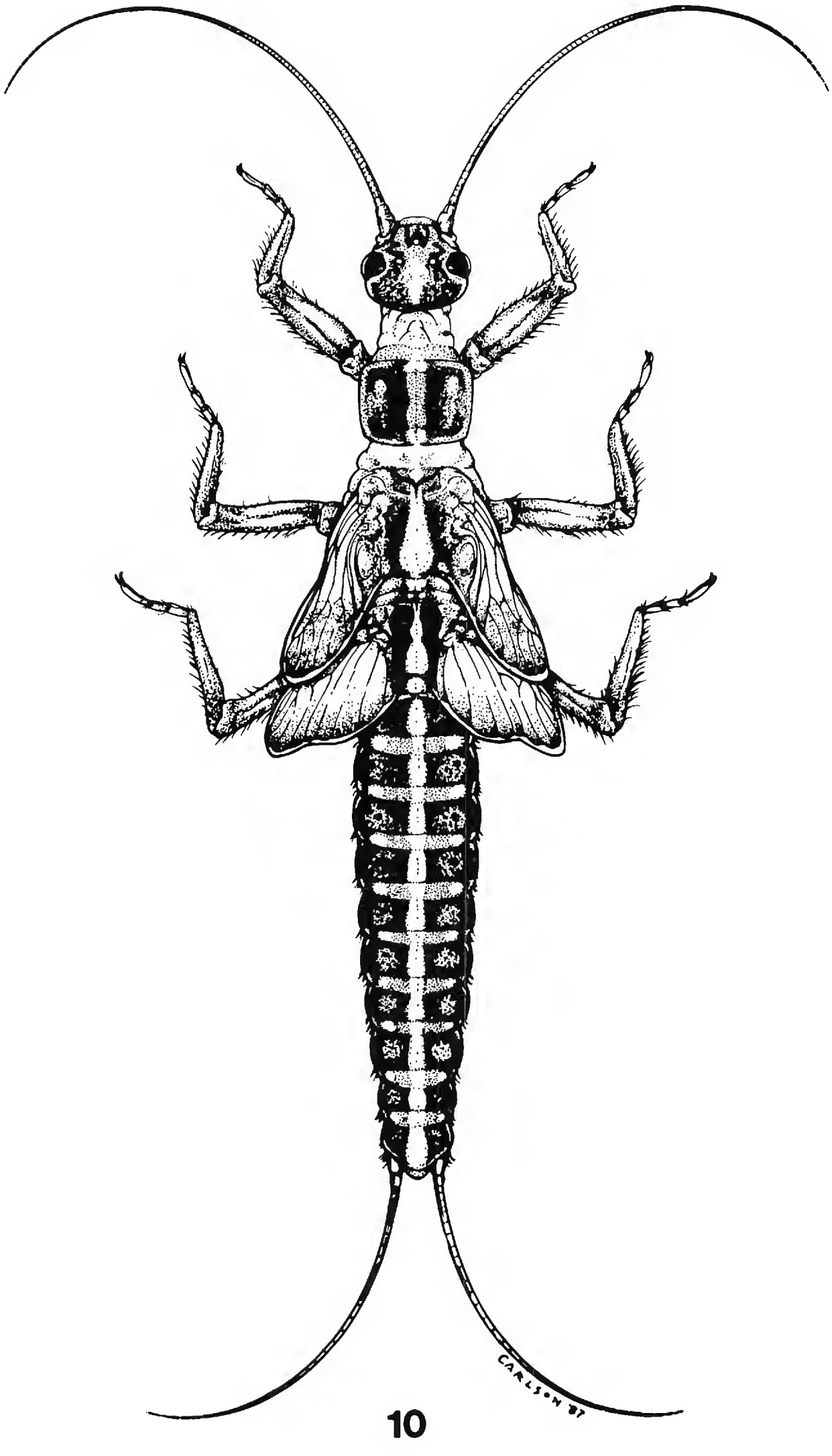
Figures 8–9. Female terminalia, ventral. 8. *T. nivalis,* 9. *T. parvula.*

Spring Cr., 24 IV 1985, R. W. Baumann & C. R. Nelson, 1♂; Spring Cr., Hwy 86, jct. Powder R., 3 III 1984, R. W. Baumann & C. R. Nelson, 3♀; Benton Co., Muddy Cr. 17 II 1985, G. R. Fiala, 1♀; UTAH, Box Elder Co., Raft R., Upper Narrows, 15 II 1979, R. W. Baumann & G. M. Webb, 1 N; same location, 28 III 1979, R. W. Baumann & G. M. Webb, 7♂, 5♀; WASHINGTON, Kittitas Co., Ellensburg, CWU Campus, 10 III 1981, M. Rush, 1♀; Lewis Co., N Fork Newaukum R., 16 II 1987, G. R. Fiala, 1♀; Scatter Cr., 9 mi N Centralia, 10 III 1964, S. G. Jewett, Jr., 1♀; Whitman Co., S Fork Palouse R., nr. Albion, 7 III 1984, G. R. Fiala, 1♀; Lyle Grove, 8 mi SW Pullman, 3 III 1973, M. C. Hunter, 8♂.

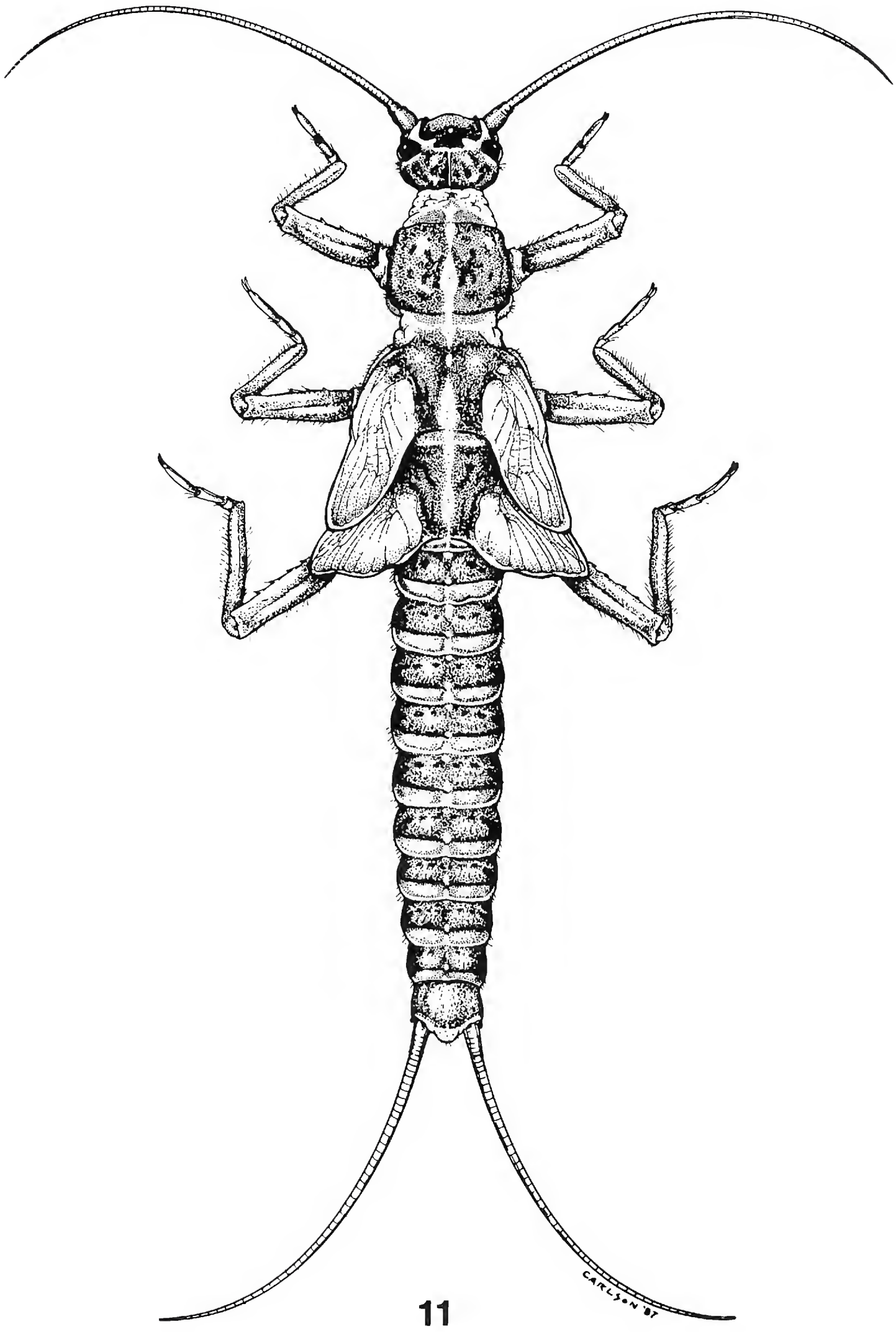
Taeniopteryx parvula Banks

Taeniopteryx parvula Banks 1918: 7.
Taeniopteryx parvula, Ricker and Ross 1968: 1436 (description of adults).
Taeniopteryx parvula, Harper and Hynes 1971: 946; Fullington and Stewart 1980: 254 (description of nymph).
Taeniopteryx pecos Baumann and Jacobi 1984: 147. *New Synonym*

Baumann and Jacobi (1984) described *T. pecos* from a series of specimens from the Pecos River, San Miguel Co., New Mexico. They indicated that this species was "very close to *T. parvula.*" The characters used to separate *T. pecos* from *T. parvula,*



Figures 10–11. Nymphal habitus, dorsal. 10. *T. burksi,* 11. *T. parvula.*



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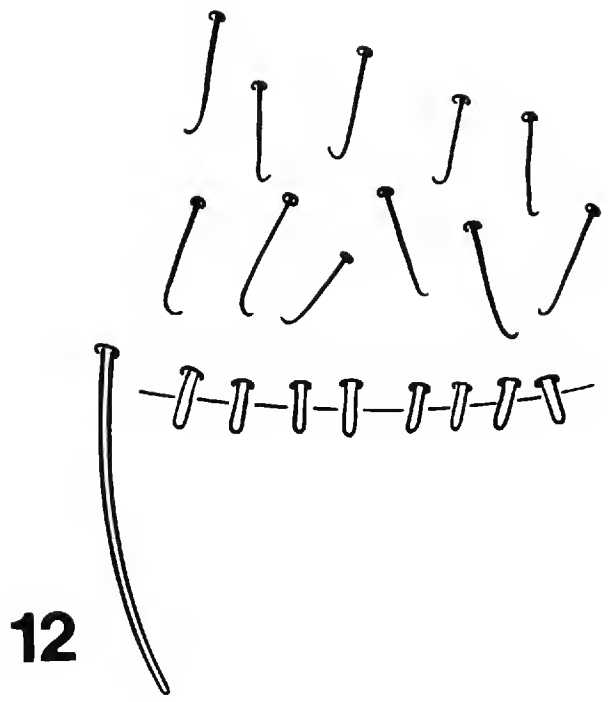

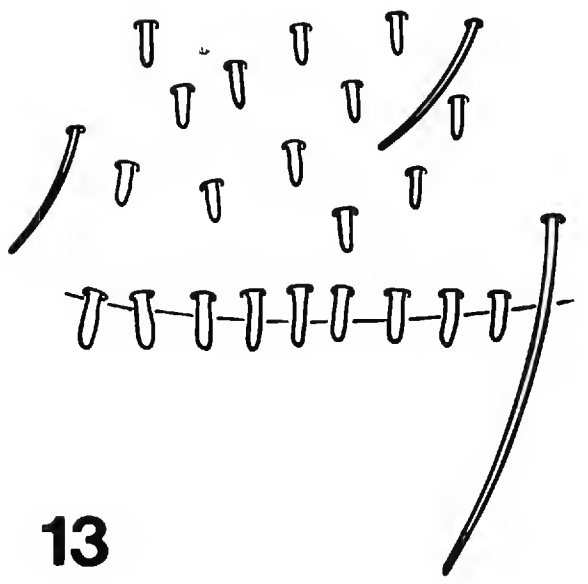

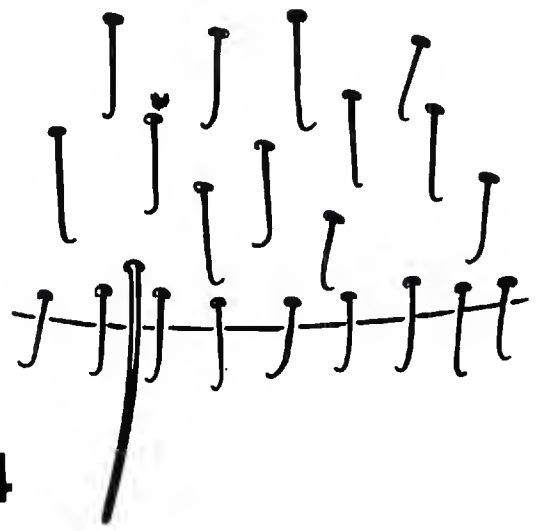

Figures 12–14. Nymphal eighth abdominal tergum. 12. *T. burski,* 13. *T. nivalis,* 14. *T. parvula.*

size and curvature of the paraproctal hooks and size of the epiproct are relative and agree with specimens from Colorado and Wyoming and typical *T. parvula* from eastern North America. The aedeagus (Fig. 7) of *T. parvula* is very distinctive and was first illustrated by Frison (1942: Fig. 7). Males of *T. parvula* are easily separated from all western *Taeniopteryx* by the lack of a vesicle, and the distally hooked paraprocts (Fig. 4). Females can be distinguished by the pale medial portion of the 8th sternum and notch shape (Fig. 9).

The nymphs of *T. parvula,* as with *T. nivalis,* have two forms, striped (at least with a partial stripe) (Fig. 11) or lacking a middorsal stripe. Fullington and Stewart (1980) only treated *T. parvula* as being the latter. In the series of nymphs examined from Colorado and Wyoming, individuals varied from lacking a middorsal stripe to having at least a partial stripe. This same condition has been observed by Kirchner (personal communication) in populations from West Virginia.

The occurrence of *T. parvula* in the Rocky Mountains is probably also the result of postglacial and interglacial dispersal across the northern plains. The emergence of this species in isolated areas of the northcentral Rockies in March and often under ice, may account for the rarity of specimens in collections.

Western records examined: COLORADO, Jackson Co., Grizzly Cr., Rt 14, 14 III 1987, B. C. Kondratieff, 10♂, 3♀, 15 N; Roaring Fork, 1 mi. above jct. N. Platte R., 22 X 1987, D. Rees, 1 N; NEW MEXICO, San Miguel Co., Pecos R. Hwy. 119, Tecolotito, 27 II 1979, G. Z. Jacobi, 4♂, 2♀ (paratypes); Guadalupe Co., Pecos R., Hwy. 119, Anton Chico, 5 I 1980, G. Z. Jacobi, 9 N; WYOMING, Carbon, Co., N Platte R. 2 mi. above jct. Big Cr., 24 X 1987, D. Rees, 1 N; same location 15 III 1988, 1♂, 1♀.

Key to the males of western North American *Taeniopteryx*

1. Ninth sternum with a vesicle; paraprocts straight and bluntly pointed (Fig. 3) . 2
   Vesicle absent; tips of paraprocts hooked (Fig. 4) ..... *parvula*
2. Aedeagus with short dorsolateral lobes (Fig. 6); vesicle short, 2–3 times as long as wide ..... *nivalis*
   Aedeagus with long dorso- and ventrolateral lobes (Fig. 5); vesicle long, 3–5 times as long as wide ..... *burksi*

Key to the females of western North American *Taeniopteryx*

1. Middle portio of 8th sternum somewhat pale, not as heavily pigmented as central plate (Fig. 9) ..... *parvula*
   Middle portion of 8th sternum as darkly pigmented as central plate 2
2. Notch with strongly sclerotized shoulders (Fig. 8) ..... *nivalis*
   Notch without strongly sclerotized shoulders ..... *burksi*

Key to the Nymphs of western North American *Taeniopteryx*

1. Thorax and abdomen without middorsal pale stripe 2
   Thorax and abdomen with at least a partial pale middorsal stripe (Figs. 10 & 11) 3
2. Posterior margins of abdominal terga with short blunt setae (Fig. 13) ... *nivalis*
   Posterior margins of abdominal terga with long setae, apically curved and an occasional long hair (Fig. 14) ..... *parvula*
3. Abdominal terga with mostly short blunt bristles, posterior margins with short blunt setae (Fig. 13) ..... *nivalis*
   Abdominal terga with long bristles, many apically curved, posterior margins with long setae curved apically or short blunt setae (Figs. 12 & 14) 4
4. Posterior margins of abdominal terga with long setae curved and an occasional hair (Fig. 14) ..... *parvula*
   Posterior margins of abdominal terga with short blunt setae (Fig. 12) ... *burksi*

ACKNOWLEDGMENTS

We thank Dave Carlson, Colorado State University for the illustrations. Ralph F. Kirchner is thanked for advice concerning *Taeniopteryx* nymphs.

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PAN-PACIFIC ENTOMOLOGIST
64(4), 1988, pp. 391–402

Trichogramma species in a chaparral community of southern California, with a description of a new species (Hymenoptera: Trichogrammatidae)

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Abstract.—Five species of *Trichogramma* were collected during a two year period in a chaparral community in southern California. Only *T. deion* Pinto and Oatman, and *T. funestum,* **sp. n.** were common. Both species occur together throughout the year but apparently are dominant in different habitats. *T. funestum* is described. It is most similar to *T. exiguum* Pinto and Platner, and *T. fuentesi* Torre.

INTRODUCTION

Our knowledge of *Trichogramma* systematics in North America primarily rests on collections from agricultural ecosystems. This is as expected considering the long-standing and widespread use of this genus of egg parasites in biological control (Ridgway et al., 1977). In an attempt to reverse this bias we have begun surveying a variety of natural areas, especially those adjacent to agriculture. By such efforts we hope not only to better estimate the taxonomic diversity of *Trichogramma* in North America but also to gain a better appreciation of intraspecific habitat diversity, a factor that should be considered when selecting agents for biological control.

Herein are reported results of a survey from 1985–1987 in a chaparral community in southern California. Although hundreds of collections in nearby agricultural areas have been made, this is the first effort at a site dominated by natural vegetation. Five species were collected but only two were common. One of these, *T. funestum,* is new and described below. The other species, *T. deion,* only recently described (Pinto et al., 1986), is the most commonly collected species in the western United States. Seasonal and habitat distribution of these two species within chaparral are reported here.

METHODS

The sampling site is located in hills immediately west of Menifee Valley, ca. 10 km E. Lake Elsinore in SW Riverside Co. Most collections were restricted to an area of 2.0 hectares along a north-south running ridge (33°39′ N, 117°13′W; 550 m. el.). The few additional collections made elsewhere were within 1 km. of this site.

The study area is dominated by chaparral with a strong influence of Coastal Sage Scrub vegetation (see Munz, 1959 for characterization of these communities). As is typical of the low hills bordering the hot, dry interior valleys of southern California, perennial vegetation is relatively sparse. About 50% of the surface is covered by perennial canopy; the remainder is bare ground, much of it strewn with large granitic boulders. Dominant perennials at the site are *Salvia* spp. (primarily *S. mellifera*

Greene), *Eriogonum fasciculatum* Bentham, *Adenostoma fasciculatum* Hooker & Arnott, and *Ceanothus crassifolius* Torrey. Vegetation composition varies considerably with slope, slope exposure, and substrate. Contribution to total vegetation cover by the dominant perennials in areas sampled for *Trichogramma* is as follows: *Salvia* spp., 2–28%; *Eriogonum,* 14–21%; *Adenostoma* 2–18%, *Ceanothus* 1–4%.

The study site is bordered on all sides by vast areas of similar vegetation. Dwellings with small concentrations of domestic plants are scattered, but occur primarily to the east and west. Grain fields and greater human population density occur 2.5 km. W. of the site. A dwelling and a small irrigated vegetable garden (10 m. x 10 m.) surrounded by natural vegetation occur on the study site. Collections were made both in the garden and in natural vegetation at least 20 m. from all domestic plants. A collection was made once immediately adjacent to the garden on *Ceanothus*.

Almost all *Trichogramma* were collected by placing eggs of laboratory-reared *Trichoplusia ni* (Hübner) and *Plodia interpunctella* (Hübner) on vegetation (host egg traps). A few were taken in yellow-pan traps, sweeping vegetation, and by collecting naturally occurring Lepidoptera eggs. For host egg traps, eggs of both species were attached to individual strips of stiff index card (6.5 × 1.8 cm). Each card held approximately 150 *T. ni* eggs and 2500 *P. interpunctella* eggs. *T. ni* eggs were laid on paper towelling which was then cut into strips and glued to the index card with white glue. *Plodia* eggs were attached to the card with Scotch® double stick tape. Cards were clipped directly to vegetation. Eggs of *Trichoplusia* were irradiated with Cobalt 60 (12 krads for 5 min.) prior to use to prolong time of acceptability to *Trichogramma*. The *Plodia* eggs were not irradiated.

5169 cards were placed on various plants over 76 sampling dates (ca. every 1.5 wk) from 6 April 1985–19 May 1987, an average of 68 cards/sampling date. Cards were left in the field 1–2 da., depending on weather and levels of egg predation. Predation often could not be avoided. The use of Tanglefoot® around stems deterred ants and other crawling predators but did not preclude flying forms such as vespids, various Coleoptera and chrysopids. Predators rarely consumed all eggs on a given card, and often the few remaining eggs were parasitized by *Trichogramma*.

Egg cards were placed primarily on *Eriogonum, Adenostoma, Ceanothus* and garden plants (usually tomato or/and pepper). They were placed on *Eriogonum* and garden plants on almost every sampling date. *Adenostoma* and *Ceanothus* were used during time of bloom the first year but on almost every sampling date the second year of the study. Other plants sampled infrequently via egg cards were *Salix* sp. (twice), *Quercus agrifolia* Nee (4), *Lotus scoparius* (Nutt.) Otley (2), *Keckiella antirrinoides* (Benth.) (6), *Salvia mellifera* (3), and *Prunus ilicifolia* (Nutt.) Walp. (1).

A limited supply of laboratory-reared host eggs and relatively low parasitization rates by *Trichogramma* in the field prevented use of an adequate number of cards on all major perennials throughout the study. *Adenostoma, Eriogonum* and *Ceanothus* were chosen for extensive sampling because they were common in the area and are evergreen throughout the year. Several of the other plants (e.g. *Keckiella, Salvia mellifera*) are drought-deciduous and lack green foliage much of the time from May–November.

Limited numbers of laboratory eggs also resulted in some variation in the number of cards placed on particular plants on each date. For example, fewer egg cards were usually placed in the garden since they were more commonly parasitized than those on native plants. Uncontrollable levels of egg predation also necessitated placing

more cards on certain plants at certain times of the year. The number of cards placed on plants on each date ranged from 7–20 on garden plants, 10–50 on *Eriogonum,* 8–40 on *Adenostoma,* and 9–20 on *Ceanothus.* The number of times each plant was sampled also varied considerably but all were sampled at least once during every month (Table 3). This variation precluded a quantitative treatment of much of the data but was allowed since we were attempting to maximize parasitization in a given habitat.

All plants sampled were in close proximity. However, egg cards were always attached to those that did not contact other species. Distances between species in sampling areas varied as follows *Ceanothus–Eriogonum,* 1–10 m.; *Adenostoma–Eriogonum,* 8–80 m.; *Ceanothus–Adenostoma,* 1–50 m. The garden was 1, 8 and 12 m. from the nearest *Ceanothus, Eriogonum* and *Adenostoma,* respectively.

Host trap cards were returned to the laboratory and held for observation. If one or more eggs on a card was parasitized (evidenced by its black appearance) the *Plodia* and/or *Trichoplusia* portion was isolated and placed in a vial with fresh host eggs. A sample of emerging adults was mounted from each collection. Most cultures were discontinued once the identity of the collection was determined. Although rarely occurring, parasitization of eggs of one of the hosts on a card by more than one species of *Trichogramma* was detected soon after emergence by obvious color and antennal differences.

Results

Five species of *Trichogramma* were collected (Table 1). *T. thalense* Pinto and Oatman, and *T. brevicapillum* Pinto and Platner were collected once in pan traps. *T. platneri* Nagakatti was taken from host trap eggs twice, once in the garden (on tomato) and once on *Keckiella. T. deion* Pinto and Oatman, and *T. funestum* were commonly collected from parasitized trap host eggs throughout the year, and both also were retrieved from sweep samples of natural vegetation. The latter two were the only species consistently parasitizing trap host eggs. Of the 5169 egg cards utilized, 409 (7.9%) were parasitized by either *T. deion* or *T. funestum. T. deion* also was reared from natural host eggs, *Manduca sexta* (L.) (Sphingidae) on tomato, *Pieris rapae* (L.) (Pieridae) on wild mustard, and *Plebejus acmon* (Westwood and Hewitson) (Lycaenidae) on *Lotus scoparius.* Natural hosts of *T. funestum* were not collected at the site. However, it has been recorded from eggs of *Vanessa cardui* (L.) (Nymphalidae) and *Plebejus emigdionis* (Grinnell) (Lycaenidae) at other locales (see below).

Although *T. deion* and *T. funestum* frequently were reared from trap eggs, the two apparently were not randomly distributed in the chaparral. *T. deion* was the only one to parasitize natural eggs and trap eggs in the garden; it also was more commonly retrieved from cards placed on *Eriogonum.* In comparison, *T. funestum* was commonly reared from cards placed on *Adenostoma* and *Ceanothus; T. deion* rarely was. The dramatic differences in habitat distribution in the chaparral is illustrated by comparing numbers of trap host cards parasitized by each species at the different positions (Table 2) and by the number of sampling dates/mo. each species was collected on each plant throughout the study (Table 3).

The association of *T. deion* and *T. funestum* on other plants in chaparral has not been adequately studied. However, limited additional host trap sampling on other plants retrieved both species from *Keckiella antirrhinoides; T. deion* from *Salix* sp.

Table 1. Species of *Trichogramma* in southern California chaparral and their method of collection.

Species	Method of Collection[1]			
	A	B	C	D
T. brevicapillum[2]	–	+	–	–
T. deion	+	+	+	+
T. platneri	+	–	–	–
T. funestum	+	–	+	–
T. thalense[3]	–	+	–	–

[1]A = Egg host trapping; B = Yellow pan traps; C = sweeping; D = reared from natural host eggs (see text).

[2]A single female collected V–8/15–1982.

[3]One male collected XII–1981 beneath canopy of *Quercus agrifolia.*

and *Prunus ilicifolia;* and *T. funestum* from *Quercus agrifolia.* Also, as already indicated, *T. deion* was taken from lycaenid eggs on *Lotus scoparius.*

Since eggs of *Trichoplusia* and *Plodia* were available on each card, relative host preferences by females of the two dominant *Trichogramma* species could be estimated. *T. funestum* more commonly parasitized *Plodia* [(on 66% of 145 cards parasitized $x^2 = 14.0$; $P < 0.01$)], whereas *T. deion* more commonly parasitized *Trichoplusia* (68% of 295 cards parasitized); $x^2 = 38.8$; $P < 0.01$. Laboratory rearings suggest that *T. funestum* is more successful on *Plodia. T. deion,* however, does well on both.

The percentage of cards parasitized by *T. deion* and *T. funestum* in 1986 is shown in Fig. 1. Percentages refer to cards parasitized per month. Data for garden plants and *Eriogonum* are separated for *T. deion* because parasitization in the garden was usually much higher. Percentages for *T. funestum* refer to cards placed on *Ceanoths* and *Adenostoma* since parasitization rates on both were similar. These data suggest that *Trichogramma* activity was highest from April–August, but continued at low levels in the winter and spring months. Although only *T. funestum* was retrieved from Oct.–Dec. in 1986, *T. deion* parasitized egg cards at low levels (1.7%–5.0%) on both *Eriogonum* and garden plants throughout this period in 1985. *T. deion* is more active on garden plants than on *Eriogonum.* Cards placed on the three native chaparral plants were less commonly parasitized than those on garden plants, except early and late in the year. These results must be considered tentative since the degree of acceptability of laboratory reared hosts relative to natural hosts is unknown, and indeed, may vary throughout the year as the quantity and species of natural hosts vary.

Discussion

T. deion and *T. funestum* were the only species collected commonly. *T. deion* is a common species in western North America in disturbed and natural habitats (Pinto et al., 1986). *T. funestum* was collected for the first time in this study and has since been taken at other sites in California (see below).

Both species occur together in chaparral throughout the year (Fig. 1, Table 3). Although occurring together, they apparently are not evenly distributed. *T. deion*

Table 2. Percentage of parasitized trap host egg cards parasitized by *T. deion* and *T. funestum* on three chaparral perennial shrubs and in an adjacent vegetable garden from April 1985–May 1987.

Trap host egg card placement			
Garden	*Eriogonum*	*Adenostoma*	*Ceanothus*
	Total number cards parasitized		
235	46	61	67
	% Parasitized by *T. deion*		
100.0%	93.5%	6.6%	10.4%
	% Parasitized by *T. funestum*		
0%	6.5%	93.4%	89.6%

was most commonly taken on *Eriogonum; T. funestum* was more frequent on *Ceanothus* and *Adenostoma. T. deion* also was abundant in the vegetable garden, far more so than it was on *Eriogonum. T. funestum* was never collected in the garden, even though this small plot of disturbed land was surrounded by chaparral and was within 5 m. of *Ceanothus* on which this species was collected. Both species parasitized trap eggs, but frequency of parasitization depended on the specific habitat (plants) the hosts were placed in. The absence of *T. funestum* from the garden plot correlates with our general experience collecting *Trichogramma* in California. Although the species is common in chaparral it never has been taken in the hundreds of parasitized eggs collected in agricultural and other disturbed areas at locales close to the study site.

Previous studies of *Trichogramma* have stressed the importance of habitat preference in partially explaining varying levels of parasitization on given host eggs (Flanders, 1937; Salt, 1935). Some studies implicate vertical stratification. For example, Thomas (1966), and Kemp and Simmons (1978) found *T. minutum* parasitizing more eggs of the spruce budworm (*Choristoneura fumiferana*) in the upper crown of balsam fir than in the lower crown. That levels of parasitism can be correlated with height is supported by Thorpe (1985), who showed that *T. pretiosum* and *T. minutum* had no obvious habitat preference within uncultivated and soybean fields, but that they did differentially parasitize eggs placed at varying heights.

Studies in crop systems by Norlund et al. (1984) showed that *Trichogramma* species were more common on *Heliothis* on tomato and beans than on corn. Further studies appear to explain these differences in distribution (Norlund et al., 1985a, b) showing that females of *T. pretiosum* responded to extract and to volatile synamones from tomato, whereas corn apparently does not possess the same attracting properties.

We have not conducted the studies to explain the differential distribution of *T. deion* and *T. funestum* in chaparral. Vertical stratification is a possible, but unlikely, explanation. *Ceanothus* and *Adenostoma* do represent higher habitats than either *Eriogonum* or garden plants. Yet egg cards were placed at varying heights on both *Adenostoma* and *Ceanothus,* levels which broadly overlapped those on *Eriogonum*

Table 3. Frequency of occurrence of *T. deion* and *T. funestum* in various vegetation components of chaparral as indicated by number of sampling dates per month each was collected[1] from 6 April 1985–19 May 1987.

	Plants sampled											
	Adenostoma			*Ceanothus*			*Eriogonum*			Garden[2]		
Month	*deion*	*funestum*	No. times sampled	*deion*	*funestum*	No. times sampled	*deion*	*funestum*	No. times sampled	*deion*	*funestum*	No. times sampled
Jan	0	1	2	2	2	6	2	1	4	2	0	6
Feb	0	2	2	0	1	5	0	0	4	2	0	5
Mar	0	2	4	0	1	3	0	0	4	0	0	3
Apr	1	8	8	1	3	3	1	0	3	2	0	5
May	0	1	9	2	2	3	4	1	9	3	0	7
Jun	1	1	3	0	2	3	3	0	7	3	0	7
Jul	0	0	3	0	2	3	3	0	6	6	0	8
Aug	0	0	2	0	1	2	2	0	5	5	0	5
Sep	0	0	1	1	0	2	0	0	5	3	0	6
Oct	0	1	1	0	0	1	1	0	5	1	0	5
Nov	0	0	2	0	0	2	1	0	6	1	0	6
Dec	0	1	2	0	0	4	1	1	6	1	0	5

[1]Based on parasitized laboratory-reared eggs (trap host cards).
[2]Usually only tomato and/or pepper plants sampled.

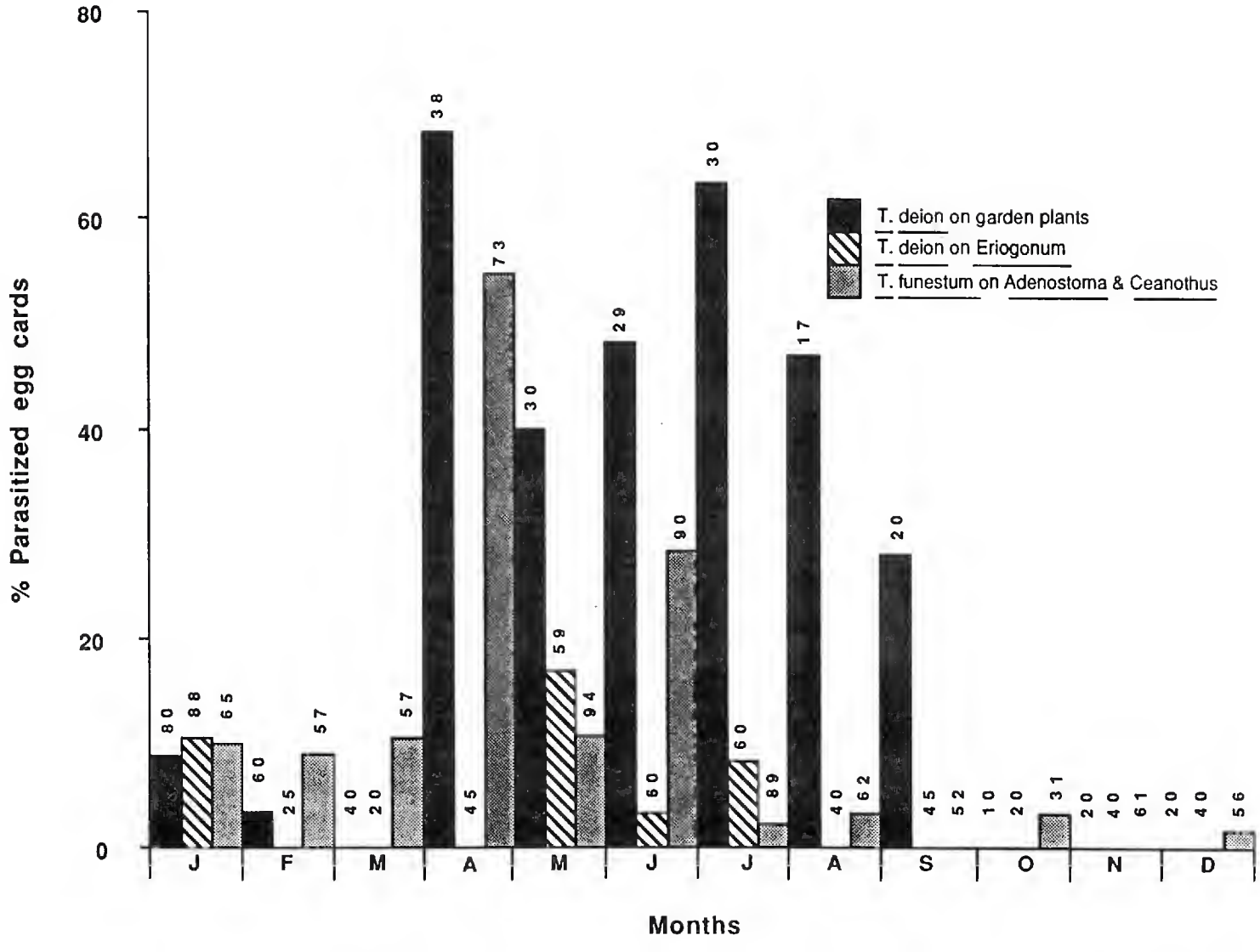

Fig. 1. Percentage of host egg trap cards parasitized per month by *T. deion* and *T. funestum* in various vegetation components of chaparral during 1986. Solid black = *T. deion* on garden plants; oblique lines = *T. deion* on *Eriogonum*; solid grey = *T. funestum* on *Adenostoma* and *Ceanothus*. Numbers above bars = total no. cards percentage is based on.

and garden plants. In fact, *T. funestum* was collected several times at positions on *Adenostoma* (less than 0.5 m.) which were as low or lower than sampling sites in the garden. More rigorous investigations of the possible effect of height are needed, however. The possibility that *T. deion* and *T. funestum* are initially attracted to plants of different height prior to host searching also should be investigated.

The differential distribution of both species possibly is dictated by natural host preferences. There is little value speculating on this possibility, considering our lack of knowledge of *Trichogramma* host preferences. That it is not an obvious explanation is suggested by the broad host range documented for *T. deion* (Pinto et al., 1986), and the common occurrence of the lycaenid, *Philotes battoides* (Behr), on *Eriogonum fasciculatum* (Emmell and Emmell, 1973), a plant rarely frequented by *T. funestum*. Although little host data are available for *T. funestum*, it has been collected from eggs of related lycaenids (see below).

Collections in this study were made in an area of considerable plant intermixture. All *Adenostoma* and *Ceanothus* sampled approximated *Eriogonum* plants and vice-versa; and all three plants grew near the garden plot. This proximity notwithstanding, *T. deion* and *T. funestum* overlapped minimally. Whether even this small degree of overlap occurs in the homogenous stands of *Adenostoma* and *Eriogonum* near the study site would be a logical follow-up study.

Three of the five species of *Trichogramma* collected in this study were rare. Their rarity may accurately reflect level of activity in chaparral or is attributable to the failure of our sampling methods to adequately sample all components of the plant community. Of the three rare species, *T. platneri* is the most common in southern California. It frequently is collected on Lepidoptera eggs on apple and avocado, and is commercially reared and released for biological control of these pests on avocado (Oatman and Platner, 1985). We also have collected it several times on codling moth eggs on apple (unpubl.). *T. brevicapillum* is abundant in parts of western United States but not in the southwest. In California, we have collected it only at three sites south of the San Bernardino Mts. North of there it is common. The third species, *T. thalense,* although rarely collected, is also known throughout much of western North America. Within California it has been taken primarily in the San Joaquin and Sacramento valleys. The single specimen collected in this study is the only record for southern California.

One of the surprising results of this study is the absence of *T. pretiosum.* A species parasitising a variety of hosts in disturbed habitats in California, we collect it commonly at sites within 10–20 km. from the study area (e.g. Lake Elsinore, Temecula, Perris). We noted in an earlier paper (Pinto et al., 1986) that *T. pretiosum* had never been taken in natural habitats in California. We were surprised, however, not to encounter it in the garden collections despite over 2 yrs. of host trapping and collecting naturally occurring eggs. The absence of appropriate host eggs is certainly not an explanation since *T. pretiosum* readily parasitizes eggs of the two laboratory-reared species utilized here, as well as eggs of *Vanessa* and *Manduca,* both of which occurred. Its absence apparently is explained by the isolation of the small garden within an area of primarily natural vegetation. *T. funestum* represents the opposite end of the spectrum regarding general habitat association. It is fairly common in chaparral but has never been collected in adjacent agricultural or other disturbed habitats. Unlike *T. pretiosum* and *T. funestum, T. deion* is much more plastic in habitat association. It is commonly collected in a variety of habitats throughout the western United States (Pinto et al., 1986).

Trichogramma funestum, New Species
(Figs. 2, 3)

Description based on P_1 and F_1 material from various collections at the type locality. Color data were taken from critical point dried F_2 culture material reared at 23–27°C on *T. ni* eggs and at ca. 50% RH. Quantitative data are based on 10 randomly selected P_1 specimens of each sex.

Terminology for genitalic structures below follows that used in earlier papers (e.g. Pinto and Oatman, 1985). A more detailed explanation of the formula for the basiconic capitate peg sensilla on the antenna was introducted in Pinto et. al. (1986).

Color sexually dimorphic. Female: thorax orange yellow except pronotum brown; head orange yellow above and in front, light brown to brown behind and below eye; gaster brown; legs and antenna light yellow. Male: as in female except mid-lobe of mesoscutum brown, concolorous to gaster. Length: 0.4–0.5 mm. Hind tibial length: averaging 0.158 ± 0.02 (0.13–0.18) mm. in both sexes (n = 20).

Male.—Antenna (Fig. 2). Flagellum moderately elongate, averaging 0.165 mm (0.14–0.20) long, slightly arcuate, 5.59 ± 0.37 (5.1–6.2) as long as wide, 1.05 ± 0.04 (1.0–1.1) as long as hind tibia; setae relatively short, stout, abruptly tapered at apex,

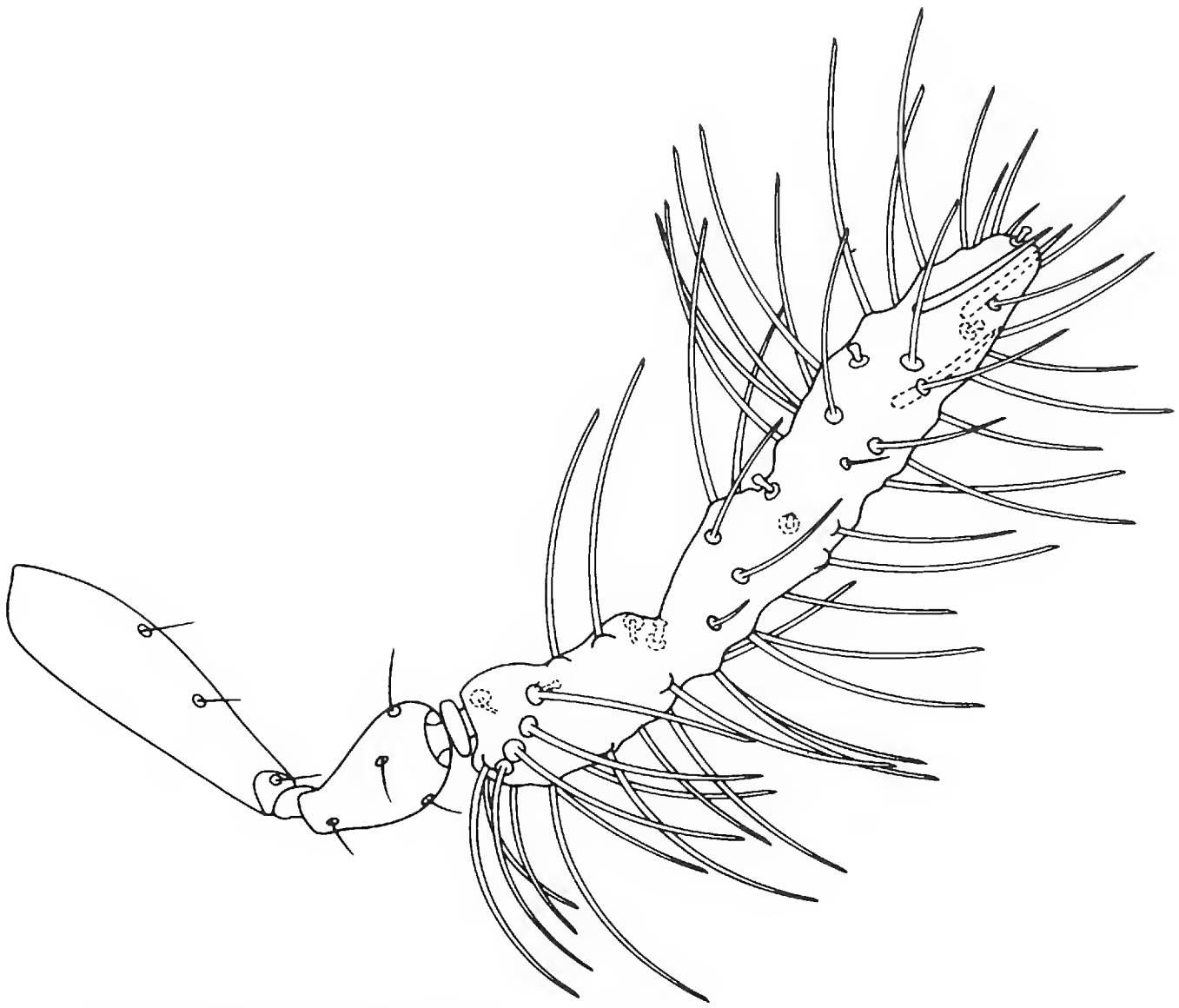

Fig. 2. *Trichogramma funestum:* Male right antenna.

longest seta 2.13 ± 0.12 (2.0–2.3) maximum width of flagellum, ca. 34–45 in number; formula for basiconic capitate peg sensilla (BCPS) = 1–1–2–1–1, infrequently with only 1 sensilla at third position. *Forewing.* Vein tracts well defined, moderate number of setae between tracts, 7–37 setae in area between 4th and 5th tracts; length of longest postapical seta on margin ca. 2× maximum width of hind tibia and 0.158 ± 0.03 (0.11–0.20) greatest wing width. *Hindwing.* Posterior vein tract with 5–7 setae, extending to ca. 1/2 the length of middle tract; anterior tract with 2 small setae *Mesoscutellum.* Anterior pair of setae short, ca. 1/4 the length of posterior pair. *Genital capsule* (Fig. 3). Moderately narrow, widest at base of dorsal expansion of gonobase (DEG), then evenly convergent to base and apex, sides straight, not distinctly sinuate near base of gonostyli (GS), 0.315 ± 0.01 (0.29–0.33) as wide as long, distance from apex of gonostyli to base of median ventral projection (MVP) composing 0.246 ± 0.01 (0.22–0.27) length of genital capsule; DEG subtriangular, only slightly notched at base, sides relatively straight to apex of posterior projection, not distinctly sinuate; apex of DEG attaining 0.886 ± 0.02 (0.85–0.92) length of genital capsule, usually attaining same level as MVP, but below apex of chelate structures (CS); MVP elongate, narrow, distinctly pointed apically, attaining 0.517 ± 0.06 (0.46–0.58) length of gonostyli; CS slightly to distinctly longer than MVP, attaining 0.689 ± 0.04 (0.62–0.75) length of GS; chitinized ridge (CR) distinct, relatively

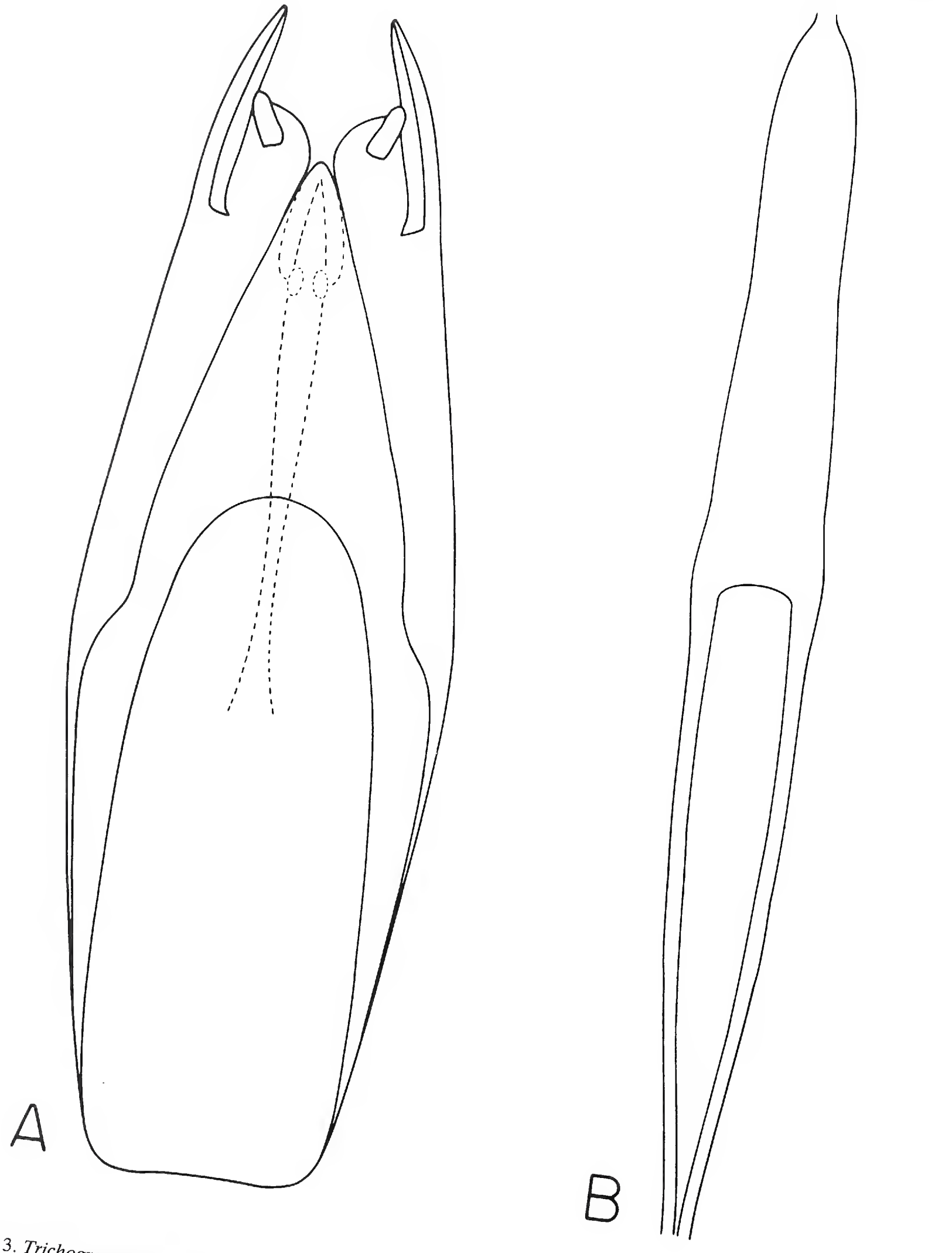

Fig. 3. *Trichogramma funestum:* A. Male genital capsule (dorsal view). B. Aedeagus.

elongate, extending 0.463 ± 0.03 (0.43–0.53) distance from MVP to base of genital capsule. *Aedeagus.* Usually slightly longer than genital capsule, 0.913 ± 0.04 (0.84–0.98) as long as hind tibia; apodemes comprising ca. 1/2 its total length.

Female.—Antenna. Funicle segments subquadrate; BCPS formula differing from male, 1–1–1–1–1, a single peg sensilla at apex of each funicle segment and three unpaired sensilla on club; four placoid sensilla and ca. 22 apicoventral setae arranged in 6 transverse rows. *Ovipositor.* 1.037 ± 0.05 (1.00–1.15) as long as hind tibia.

Etymology of specific name.—Latin: "causing death."

Types. Holotype ♂ and allotype ♀ from CALIFORNIA, Riverside Co., Menifee Valley, hills on W. end (33°39′ N, 117°13′ W; 550 m. el.). Types represent F_1 material; parentals reared from trap host eggs (*T. ni*) placed on *Ceanothus crassifolius*; 28 January 1986; J. D. Pinto, collr.; deposited in the collection of the National Museum of Natural History, Washington, D.C. Eight additional F_1 siblings designated as paratypes; deposited as follows: 1♂, 1♀, British Museum (Natural History); 1♂, 1♀, Canadian National Collection; 1♂, University of California, Berkeley; 2♂♂, 1♀, University of California, Riverside. All type material mounted on glass slides in Canada Balsam.

Geographic Distribution.—California from Glenn Co., S. to western Riverside Co.

Records and Hosts.—UNITED STATES. *California. Glenn Co.* Alder Springs, 16♂♂, 3 June 1987, trap host (*Plodia* on *Pinus*), J. Pinto. *Los Angeles Co.* Solemint, 1♂, 3 June 1982, ex. *Plebejus emigdionis* egg (Lycaenidae) on *Atriplex canescens,* G. Pratt. *Riverside Co.* Hemet, E. of at 4000′ el., 1♂, 30 June 1983, undetermined egg on *Adenostoma fasciculatum,* R. Velten. Menifee Valley, hills on W. end (33°39′ N, 117°13′ W; 550 m. el.), 168 ♂♂, 17 ♀♀, numerous dates 1985–87 (see above), trap host eggs (*Plodia* and *Trichoplusia*) on *Adenostoma fasciculatum, Ceanothus crassifolius, Quercus agrifolia,* and *Keckiella antirrhinoides,* J. Pinto. *San Bernardino Co.* Summit Valley (2 mi. E. Hwy. 15), 1♂, 7 May 1982, sweeping, J. Woolley. *Ventura Co.* Dome Springs Campground, Los Padres National Forest, 2♂♂, 7 June 1986, ex. *Plebejus emigdionis* egg on *Atriplex canescens,* G. Pratt. Dome Springs Campground, ca. 4 mi. SW on Lockwood Valley Rd., Los Padres National Forest, 4♂♂, 3♀♀, ex. *Plebejus emigdionis* eggs on *Atriplex canescens,* 10 May 1985, G. Pratt; ex. undetermined Geometridae eggs on *Atriplex canescens,* and *Vanessa cardui* egg on bush lupine, 22 May 1986, E. Oatman and J. Pinto.

Notes.—T. funestum is most similar to *T. exiguum* Pinto and Platner, and *T. fuentesi* Torre. These two species were recently treated by Pinto et al. (1983). In all three the flagellar setae of males are relatively short (length less than 2.5 the maximum width of flagellum) and stout, tapering noticeably at the apex only. *T. funestum* is separated from both by specifics of the genitalia. In the latter two the genital capsule is somewhat broader and more abruptly narrowed apically (Pinto et al., 1983: Figs. 1c, d). Also, the sides of the genital capsule are sinuate at the base of the gonostyli and the sides of the DEG also are distinctly sinuate. In *T. funestum* the sides of the genital capsule and the DEG are relatively straight (Fig. 3). *T. fuentesi* is further separated from *T. funestum* by its shorter CR and subequally long CS and MVP. *T. exiguum* is further separated by its lighter color (light yellow-brown abdomen) and BCPS formula of the male flagellum. In *T. funestum* the basal two positions have only a single basiconic peg sensilla. In *T. exiguum* there usually are two sensilla at each of the two basal positions.

T. fuentesi and *T. exiguum* are known from central and southeastern United States and are allopatric to *T. funestum*. However, a currently undescribed species, extremely close to *T. exiguum* is known in California and has been collected at one of the same locales as *T. funestum*. The latter is separated from this species by the same traits cited for *T. exiguum*.

A culture of *T. funestum* from the type locality successfully crossed with the sample from Adler Springs, Glenn Co., CA. It did not cross with *T. exiguum*.

Acknowledgments

Culture maintenance, specimen preparation and other laboratory assistance was provided by G. R. Platner and R. K. Velten. Collections of *T. funestum* from Lycaenidae eggs were made by G. Pratt, who also identified the lycaenid hosts. Figs. 2 and 3 were prepared by Linda Bobbitt.

This study was supported by Grant No. BSR-8415378 from the National Science Foundation (J.D.P., Principal Investigator).

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Contents for Volume 64

The Pan-Pacific Entomologist
Index to Volume 64
(New taxa in boldface)

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