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AN ANNOTATED CHECKLIST OF THE AQUATIC AND SEMIAQUATIC DRYOPOID COLEOPTERA OF CALIFORNIA

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Abstract.—All the species of aquatic and semiaquatic dryopoid Coleoptera known to occur in California are listed. Genera with identification problems and undescribed species are indicated. Factors that might influence the collection of species, such as ecological preferences and/or annual occurrences of certain life stages, are cited.

Key Words.—Insecta, Coleoptera, Dryopoidea, Elmidae, Psephenidae, Dryopidae, Limnichidae, Ptilodactylidae, Eulichadidae, Heteroceridae, distribution, habitat

Various families in the superfamily Dryopoidea have evolved to take advantage of a diversity of aquatic and semiaquatic habitats. Most species of water-associated dryopoids are found in streams and rivers. Others, however, are found in seeps and springs, in lakes, in and on riparian vegetation, and in and on the mud and sand margins of water bodies. California has a particularly rich dryopoid fauna (Table 1), perhaps richer than any other area in North America. This undoubtedly reflects the very diverse ecology of California, as well as its great north to south length. Similar richness is seen in Plecoptera (Table 2) and in aquatic and semiaquatic Hemiptera (Table 3), the only other orders for which appropriate distributional information is available. Even with this known richness, many new species of aquatic insects are still being discovered in California. Another factor adding to the richness of the dryopoid fauna is that various elements from the dryopoid faunas of the Nearctic, Palaearctic, and Neotropical biogeographic regions meet in the state. Nowhere else on the continent do these elements so combine.

This list was compiled because California, like many other areas, has seen an upsurge in studies of stream ecology, water pollution, impact of logging, etc. These studies have been hampered by workers not knowing just which species occur in the state. Another part of the impetus for this checklist was requests for information on rare or endangered status of dryopoid species.[2] Only two previous publications (Usinger et al. 1956, Brown 1972) have attempted to list California dryopoids. Both are now out-of-date. Thus an updated list is warranted, although many taxonomic problems remain; I am developing identification keys to the species here.

The general ecology of aquatic and semiaquatic dryopoids has been well addressed by Brown (1987). I have tried to indicate under each genus (family in two cases) where the larvae and adults are most apt to be collected, at least as indicated

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[2] Most species for which more data were needed appeared rare because of insufficient collecting. Only two, *Dubiraphia brunnescens* (Fall) and *Microcylloepus formicoides* Shepard, both from a single locality, now deserve a protected status.

Table 1. Number of genera and species of aquatic and semiaquatic dryopoid Coleoptera in North America and California. Number in parentheses is the percentage of the North American number.

Families	North America		California	
	Genera	Species	Genera	Species
Elmidae	26	95	14 (54)	23 (24)
Dryopidae	4	13	3 (75)	5 (39)
Limnichidae	7	31	6 (86)	13 (42)
Psephenidae	6	15	3 (50)	3 (20)
Heteroceridae	9	31	6 (67)	9 (29)
Eulichadidae	1	1	1 (100)	1 (100)
Ptilodactylidae	3	3	2 (67)	2 (67)
Totals	56	189	35 (63)	56 (30)

by my experiences. Most genera and species are rather catholic in microhabitat choice(s). A few (i.e., *Atractelmis, Dubiraphia brunnescens, Araeopidius, Throscinus*) appear to be very habitat-specific.

FAMILY ELMIDAE

Subfamily Larainae

Tribe Laraini

Lara LeConte 1852

Lara avara LeConte 1852
Lara gehringi Darlington 1929

These two species will probably be synonymized at a later date unless new distinguishing characters can be discovered. As yet, there are no characters that consistently separate the taxa. Larvae gouge soft submerged wood; adults are typically on log-jams and debris piles, or on the undersides of undercut streambanks.

Subfamily Elminae

Tribe Elmini

Ampumixis Sanderson 1954

Ampumixis dispar (Fall) 1925

This species is quite variable in elytral color pattern, ranging from all red, to having red maculae of variable size, to all black. The relatively long legs give it a spidery look. Both larvae and adults occur in higher, cooler mountain streams.

Atractelmis Chandler 1954

Atractelmis wawona Chandler 1954

Once considered quite rare, this species is now known to be widespread in the northern half of the state (Shepard and Barr 1991). Larvae and adults particularly prefer submerged mosses, but they have been taken on roots of riparian vegetation.

Table 2. Number of genera and species of Plecoptera (stoneflies) in North America and California. Number in parentheses is the percentage of the North American number. Data from Stewart & Stark (1988).

Families	North America		California	
	Genera	Species	Genera	Species
Capniidae	9	132	6 (67)	29 (22)
Leuctridae	7	52	5 (71)	10 (19)
Nemouridae	11	64	6 (55)	15 (23)
Taeniopterygidae	6	32	4 (67)	9 (28)
Chloroperlidae	12	73	9 (75)	24 (33)
Peltoperlidae	6	18	3 (50)	6 (33)
Perlidae	15	48	4 (27)	5 (10)
Perlodidae	29	118	18 (62)	34 (29)
Pteronarcyidae	2	10	2 (100)	3 (30)
Totals	97	547	57 (58)	135 (25)

Cleptelmis Sanderson 1954

Cleptelmis addenda (Fall) 1907
Cleptelmis ornata (Schaeffer) 1911

These two species may be synonymized in the future unless good distinguishing characters are found. Large enough population samples of each almost always include individuals with the color pattern of the other species. I have found no difference between the genitalia of the two species. Both the larvae and adults occur most often in roots and moss.

Dubiraphia Sanderson 1954

Dubiraphia brunnescens (Fall) 1925
Dubiraphia giulianii (Van Dyke) 1949

These two species may be synonymized due to overlapping characters. Although most individuals of each species are distinguished by different color patterns, some specimens of *D. giulianii* have been found with the color of *D. brunnescens*. *Dubiraphia brunnescens* appears to be restricted to Clear Lake (on willow roots), Lake County, while *D. giulianii* occurs widely over the state. Larvae and adults occur on roots of riparian vegetation, and on submerged macrophytes. Larvae can be particularly hard to locate.

Heterelmis Sharp 1882

Heterelmis obesa Sharp 1882

Table 3. Number of genera and species of aquatic and semiaquatic Hemiptera in North America and California. Number in parentheses is the percentage of the North American number. Data from Menke (1979).

	North America	California
Genera	65	36 (55)
Species	415	113 (27)

This very distinctive elmid has, so far, been collected in only a few spring-fed canyon streams in the Mojave Desert of far southeastern California. It represents one of the Neotropical lineages whose distribution just enters our area. Although preferring submerged wood, larvae and adults may be taken in many microhabitats.

Heterlimnius Hinton 1935a

Heterlimnius corpulentus (LeConte) 1874
Heterlimnius koebelei (Martin) 1927

One of the main characters distinguishing these species is the number of antennal segments, *H. corpulentus* having 10 and *H. koebelei* having 11. The area of concern is between the pedicel and the club—*H. corpulentus* has five segments there, while *H. koebelei* has six. Unfortunately a number of specimens have been found having 10 segments on one side and 11 on the other side. Other antennal aberrations have also been found. Both larvae and adults are commonly found in gravel. They typically occur in cold, higher-elevation streams, where they replace *Optioservus* spp.

Microcylloepus Hinton 1935a

Microcylloepus formicoideus Shepard 1990
Microcylloepus similis (Horn) 1870

This genus is in need of revision. Problems involve the numerous populations isolated in springs and spring-fed streams on the east front of the Sierra Nevada, and in the Basin and Range Desert. I presently find it difficult to understand the morphological variation, both external and genitalic, between and within the populations. A confounding factor is that many of these populations occur in warm springs where the constant warm environment may be contributing to morphological changes simply by altering developmental times. However, with all these factors in mind, I still think that a third, as yet undescribed, species occurs widely across an area south of Lake Mono from the east front of the Sierra Nevada to the eastern border of Nevada. Both larvae and adults occur in a variety of microhabitats in warm streams and springs.

Narpus Casey 1893

Narpus angustus Casey 1893
Narpus concolor (LeConte) 1881

Narpus concolor is far more variable in its size, shape, and size of maculae than is *N. angustus*. Fortunately adults of these two species do not often co-occur. In both species the larvae and adults are also generally not found occurring together in any great number. I have yet to understand the microhabitat requirements of the larvae. *Narpus angustus* adults are more typical of larger rivers in the various mountains in the northwestern part of the state. They can be especially abundant where bars of coarse gravel drop off into deep pools. Adults of *N. concolor* are more often found a few at a time in the gravel and litter in small streams.

Optioservus Sanderson 1954

Optioservus canus Chandler 1954
Optioservus divergens (LeConte) 1874
Optioservus heteroclitus White 1978
Optioservus quadrimaculatus (Horn) 1870
Optioservus seriatus (LeConte) 1874

A particularly troublesome problem exists here in separating *O. quadrimaculatus* from *O. seriatus.* Although individuals of both species appear different, no consistent distinguishing character has been found. A similar problem exists with *O. divergens* and *O. heteroclitus,* whose distinguishing characteristics seem only to relate to size. The break between the sizes of the two species appears to me to be rather artificial. Larvae and adults of all species are typically found in gravel in warm to cool streams.

Ordobrevia Sanderson 1953

Ordobrevia nubifera (Fall) 1901

The characteristics of this species are more variable than originally described and the variability may be controlled by water temperatures (Shepard 1992). Both larvae and adults are typically found in gravel and under boulders in the faster parts of streams.

Rhizelmis Chandler 1954

Rhizelmis nigra Chandler 1954

Occasional specimens are bimaculate or quadrimaculate. Quadrimaculate specimens with large maculae have the elytra appear banded with red. These specimens strongly resemble *Ampumixis dispar* (which is very closely related) and some *Heterlimnius koebelei.* Although widespread, this species is relatively uncommon. Both larvae and adults seem to prefer coarse gravel substrates in cool, small-to-medium sized streams. However, I have collected too few specimens to feel confident that they do not like other microhabitats.

Zaitzevia Champion 1923

Zaitzevia parvula (Horn) 1870

A second, undescribed species is known to occur in the northcentral part of the state. Larvae and adults occur in gravel in most streams.

Undescribed Genus

Recently specimens of an undescribed genus and species have been found in cool mountain streams in northwestern California. This genus was first collected (in Oregon and Washington) and recognized as new a few years ago by Cheryl B. Barr. The California specimens appear to represent an additional species in this new genus. This genus has close affinities with *Cleptelmis, Ampumixis* and *Rhizelmis.* Like these other genera, the larvae and adults of the new species show a decided preference for aquatic mosses.

FAMILY DRYOPIDAE

Dryops Olivier 1791

Dryops arizonensis Schaeffer 1905

Adults occur on emergent material and readily come to lights at night. This species has only been found along the border with Mexico (H. P. Brown, personal communication).

Helichus Erichson 1847

Helichus columbianus Brown 1931
Helichus suturalis LeConte 1852

Larvae are now known to be terrestrial (Ulrich 1986); adults are found in many stream microhabitats, but particularly associated with roots, and debris piles containing leaves and sticks.

Postelichus Nelson 1989

Postelichus immsi (Hinton) 1937
Postelichus productus (LeConte) 1852

Habitat as for *Helichus* spp. *Postelichus* occurs in the warmer streams of the southern part of the state, and north in the Coastal Mountains almost to the Bay Area.

FAMILY LIMNICHIDAE

Adults are riparian. They are commonly found on vegetation overhanging the water, on sand and mud bordering the water, and on various materials in the strandline. Only a single larva has been collected in the Nearctic region. It was in a cell under moss just at the edge of the water.

Subfamily Limnichinae

Tribe Limnichini

Limnichoderus Casey 1889

Limnichoderus lutrochinus (LeConte) 1879
Limnichoderus naviculatus (Casey) 1889

Lichminus Casey 1889

Lichminus tenuicornis (Casey) 1889

Eulimnichus Casey 1889

Eulimnichus analis (LeConte) 1879
Eulimnichus californicus (LeConte) 1879
Eulimnichus evanescens Casey 1912
Eulimnichus montanus (LeConte) 1879
Eulimnichus perpolitus (Casey) 1889

Limnichites Casey 1889

Limnichites foraminosus Casey 1912
Limnichites nebulosus (LeConte) 1879
Limnichites perforatus (Casey) 1889

Tribe Bothriophorini

Physemus LeConte 1854

Physemus minutus LeConte 1854

Subfamily Cephalobyrrhinae

Throscinus LeConte 1874

Throscinus crotchi LeConte 1874

Adults are intertidal and found on mudflats in southern California.

FAMILY PSEPHENIDAE

Larvae are flattened, coppery in color, and more-or-less circular in outline; thus their common name, water penny, is apt. Larvae are most commonly found on rocks, but they may be on wood. Adults are terrestrial and riparian, and located near the streams. Once mated, females crawl underwater to oviposit. Adults are only found during the summer months.

Subfamily Eubrianacinae

Eubrianax Kiesenwetter 1874

Eubrianax edwardsii (LeConte) 1874

There may be more than one species in the state as one population has recently been found pupating underwater. This habit is typical for some species from Taiwan (Lee & Yang 1990). *Eubrianax edwardsii* pupates away from the stream. Adults may be found on streamside vegetation or flying nearby.

Subfamily Eubriinae

Acneus Horn 1880

Acneus quadrimaculatus Horn 1880

Although only this species is definitely known from California, the other three species in the genus may occur in the far northern part of the state. They are known from southern Oregon (Fender 1951, 1962). Adults may be found on riparian vegetation.

Subfamily Psepheninae

Psephenus Haldeman 1853

Psephenus falli Casey 1893

Although pupation normally occurs away from the stream, one population has been found pupating underwater. Adults may be found on wet emergent parts of boulders in fast currents.

FAMILY PTILODACTYLIDAE

The larvae are aquatic and occur in seeps, springs, and streams. The adults are terrestrial and only occur during the late spring through summer months. Adults are most commonly swept from riparian vegetation.

Anchycteis Horn 1880

Anchycteis velutina Horn 1880

Adult specimens that I have seen were from widely scattered locations across northern California. Larvae are uncommon in the gravel of mountain streams.

Araeopidius Cockerell 1906

Araeopidius monochus LeConte 1874

Although occurring widely in northern California, more specimens are collected in the Coastal and Cascade Mountains than in the Sierra Nevada. The single larva that I have collected was in a muck-filled seep.

FAMILY EULICHADIDAE

Stenocolus LeConte 1853

Stenocolus scutellaris LeConte 1853

Larvae occur under rocks and in leaf packs in streams and rivers. Larvae are common and have been collected widely across northern California. Adults have been collected infrequently.

FAMILY HETEROCERIDAE

Larvae and adults of all species are riparian. They occur on mud and sand flats. There they tunnel through the substrate, ingesting all material and digesting the organic portion. They can be collected during the warmer months of the year.

There is disagreement over generic status within the family. Pacheco (1964) elevated various species groups to genera. Miller (1988), however, prefers to retain the single genus *Heterocerus,* and to recognize species groups only as such. Either way, the morphological similarities between species make identifications difficult, at best.

Tribe Augyliini

Microaugyles Pacheco 1964

Microaugyles mundulus (Fall) 1920

Tribe Heterocerini

Lanternarius Pacheco 1964

Lanternarius brunneus (Melsheimer) 1844
Lanternarius gemmatus (Horn) 1890
Lanternarius parrotus Pacheco 1964
Lanternarius sinuosus Pacheco 1964

Neoheterocerus Pacheco 1964

Neoheterocerus gnatho (LeConte) 1863

Dampfius Pacheco 1964

Dampfius mexicanus (Sharp) 1882

Lapsus Pacheco 1964

Lapsus tristis (Mannerheim) 1853

Tribe Tropicini

Tropicus Pacheco 1964

Tropicus pusillus (Say) 1823

UNCERTAIN STATUS

Heterocerus Fabricius 1792

Heterocerus unicus Miller 1988

This species fits into the *H. undatus* group that Pacheco calls *Dampfius.*

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NOTES ON THE ETHOLOGY OF *DICOLONUS SPARSIPILOSUM* BACK (DIPTERA: ASILIDAE)

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Abstract.—The presented data are the first biological and behavioral information recorded for the genus *Dicolonus*. Prey, consisting of small Diptera, Hymenoptera and Coleoptera, are taken in flight and manipulated during feeding with the predator's fore tarsi. Males do not exhibit courtship. Mated pairs take the tail-to-tail position, resting on stems of grass and twigs of sagebrush.

Key Words.—Insecta, Diptera, Asilidae, *Dicolonus sparsipilosum,* bionomics

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The genus *Dicolonus* is largely confined to the western United States, with only two species barely reaching British Columbia (Adisoemarto & Wood 1975). Prior to 1975, only two species had been described, *D. simplex* Loew, for which the genus was erected in 1866, and *D. sparsipilosum* described by Back (1909). Three additional species, *D. medium* Adisoemarto & Wood, *D. nigricentrum* Adisoemarto & Wood and *D. pulchrum* Adisoemarto & Wood, were added to the genus by Adisoemarto & Wood (1975). Since the erection of the genus, no biological or behavioral data have been published for any species.

In late June 1977, a small population of *D. sparsipilosum* was studied on a rangeland plateau located beneath Teton Point Overview in Grand Teton National Park, Wyoming, USA. The area was bordered by a grove of quaking aspen (*Populus tremuloides* Michaux), and it was within this ecotone that the majority of *D. sparsipilosum* individuals were encountered. The dominant vegetation within the ecotone was *Artemisia tridentata* Nuttall and *Agropyron* sp.

Forage flights were initiated from vegetation, usually from a perch on a stem of grass or sagebrush. Rarely did the robber flies return to the same perch twice sequentially. The foraging flights covered a distance ranging from 7.6 to 61 cm.

When potential prey was observed, the whole body of the predator was turned to face it. Prey was captured in the air and impaled on the mouthparts before the asilid landed. It was usually manipulated, at least once, during feeding. During this process, the robber fly grasped the substrate with its mid and hind tarsi, and used its fore tarsi to rearrange the prey. Upon completion of feeding, the predator moved its mouthparts in such a way that the emptied body fell in front of the asilid at the feeding site.

Prey taken by *D. sparsipilosum* included one chironomid, and one muscid (Diptera); one tenthredinid, two winged reproductive formicids, three Chalcidoidea (Hymenoptera) and one Coleoptera. Insects larger than the predator were not attacked.

Occasionally an asilid stopped in mid-flight, before making contact with the potential prey, but usually the predator grasped the espied insect and returned to the substrate. On four occasions, *D. sparsipilosum* was unable to subdue the prey

Figure 1. Mating pair of *Dicolonus sparsipilosum.*

it had captured; two such insects that escaped were cuckoo wasps (Chrysididae), both being slightly smaller than the asilid, and more heavily sclerotized than any of the subdued prey.

It is probable that males of *D. sparsipilosum* spend considerable time searching for females, similar to that recorded for other studied species of robber flies (Dennis & Lavigne 1975). Around midday and early afternoon, males were observed making long flights of 1.2 to 1.5 m along grass corridors which occur between groups of sagebrush plants.

No courtship was exhibited by males. The males flew at, and seized, both males and females at random. These encounters sometimes included falling into the vegetation while the pair were still grappling. If the seized fly was a male, contact was broken and the two tended to fly off in opposite directions; if the seized fly was a female, and she successfully eluded his grasp, the male flew off in pursuit of her. Otherwise, mating took place on site.

Mated pairs were observed between 10:33 and 17:30 h. Temperatures at the height the pairs were resting on vegetation ranged from 24.4 to 28.9° C. The pairs take a tail-to-tail position, usually resting vertically with the female facing upwards. Separation occurs when the male releases his claspers and walks away.

Three pairs, timed from the point when first observed, to completion, remained en copula 26, 30 and 58 minutes. Only one mating of 49 minutes duration was followed from start to finish. In this instance, the male flew into a clearing already occupied by a female. When the female initiated a forage flight, the male flew up and grappled with her. They fell into a clump of tangled grass, still struggling, and copulation occurred at 13:14 h. The pair then crawled up a grass stem into a partially shaded location, where the temperature was 24.4° C. At 13:16 h the pair flew 61 cm landing on a sagebrush plant at a height of 25.4 to 30.5 cm. Almost immediately, they flew 61 cm more, landing on a dead sage stem 30.4 cm above the ground, with the female resting on the trunk and the male dangling in the air. At 13:40 h, the female cleaned her eyes, and then her fore tarsi. The male started struggling almost immediately, and after about 10 seconds attained the same perch as the female, with their bodies forming an angle of approximately 140° (Fig. 1). At 13:54 h, the male climbed on the female's back; a short struggle ensued and the former position was resumed. At 14:03 h, the male released his claspers and flew 2.44 m. The female remained in place an additional 2 minutes before flying away.

Acknowledgment

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TOADS (*BUFO BOREAS* BAIRD & GIRARD) OBTAIN NO CALORIES FROM INGESTED *SPHENOPHORUS PHOENICIENSIS* CHITTENDEN (COLEOPTERA: CURCULIONIDAE)

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Abstract.—Ninety percent (865/962) of the billbugs (*Sphenophorus* spp.) in 145 toad (*Bufo boreas* Baird & Girard) fecal pellets were egested alive. Dead billbugs (*S. phoeniciensis* Chittenden) found intact in toad fecal pellets have an average weight and caloric content that was 1.4% (0.13/9.06 mg) and 4.5% (0.225/5.049 kcal) *greater,* respectively, than that found for non-egested billbugs. Toads (*B. boreas*) derive no calories from billbugs (*S. phoeniciensis*) that pass intact through the digestive tract.

Key Words.—Insecta, *Bufo boreas, Sphenophorus phoeniciensis, Sphenophorus venatus vestitus,* Curculionidae, weevils, billbugs, toads, fecal pellets, survival

Beetles (Coleoptera) constitute a major portion of the diet of western toads (*Bufo boreas* Baird & Girard) (Barrentine 1991b). However, some beetles (Curculionidae: *Sphenophorus* spp.) can resist digestion, pass through the digestive tract of the toad and emerge alive from fecal pellets (Barrentine 1991a, Barrentine & Seeno 1988, Fair 1969). Although longevity is reduced for egested billbugs, some individuals (*S. phoeniciensis* Chittenden) can live three weeks post-egestion (Barrentine 1991c). Moreover, some individuals can survive three trips through the digestive tract of the toad (Barrentine in press).

Not all billbugs survive digestion by toads. Barrentine (1991a) found that 32% (1428/4406) of egested *Sphenophorus* spp. failed to emerge from fecal pellets within four days. Because nearly all of these dead billbugs were intact (fully articulated), it was suggested that toads may derive little, if any, nutrition from ingested billbugs. Further, it was hypothesized that because egested billbugs were rarely disarticulated by digestive processes, billbug mortality may be due to post-egestive causes (i.e., death may result from an inability to escape entombment from a desiccating pellet).

This study reports: (1) that 90% of the billbugs (*Sphenophorus* spp.) found in the fecal pellets of the toad (*B. boreas*) are egested alive, and (2) that toads (*B. boreas*) obtain no calories from billbugs (*S. phoeniciensis*) that pass intact through the digestive tract.

METHODS

Survival.—Freshly egested fecal pellets were obtained from western toads foraging from a fenced, 0.06 ha residential lawn [cultivar of *Cynodon dactylon* (L.) Pers. × *C. transvaalensis* Burtt-Davy 'Tifgreen'] in Bakersfield, California. Pellets were collected daily from the turfgrass surface, in the evening (21:00–23:00 h) or early morning (05:00–08:00 h), from mid-August to early September 1988, early April to mid-July 1989, and July 1991. Individual pellets were immediately rinsed

Table 1. Weight (mg) and caloric content (kcal) for egested and non-egested *Sphenophorus phoeniciensis.*

	No. samples	No. billbugs (*n*)	Total dry weight of samples (mg)	Individual dry weight, $\bar{x}$ + SD (mg/n)	Total caloric content of samples (kcal)	Caloric content, $\bar{x}$ + SD (kcal/g)	Individual caloric content, $\bar{x}$ + SD (kcal/n)
Egested	3	153	1405.7	9.19 + 0.12	7.415	5.274 + 0.031	0.0485 + 0.002
Non-egested	3	222	2010.8	9.06 + 0.06	10.152	5.049 + 0.039	0.0457 + 0.001

with water and egested billbugs (*S. phoeniciensis* and *S. venatus vestitus* Chittenden) were collected on a 1 mm mesh screen. These were transferred to vials and dried for 24 h at 24–28° C and 35–45% RH. Vials were examined twice daily and live billbugs were removed and tallied.

Calorimetry.—Live billbugs, *S. phoeniciensis,* were collected by hand from infested turfgrass (between 21:00–23:00 h), immediately frozen, and then oven dried at 68° C to constant weight (± 0.1 mg). Samples of dead billbugs (i.e., fully articulated *S. phoeniciensis* that failed to emerge alive from fecal pellets) were obtained from fecal samples preserved from an earlier study (see Barrentine 1991a). These billbugs, preserved by freezing, were washed and then oven dried to constant weight, as described above. Caloric content (kcal/g) for non-egested and egested *S. phoeniciensis* was determined with a Parr oxygen bomb calorimeter (see Dimmitt & Ruibal 1980). Weight and caloric content of *S. venatus vestitus* is not reported here because sample sizes were too small for reliable calorimetric analysis.

Results and Discussion

Survival.—A total of 962 billbugs (*S. phoeniciensis* and *S. venatus vestitus*) were isolated from 145 toad pellets. Of these, 90% (865/962) were egested alive in pellets. This survival frequency, significantly higher ($\chi^2 = 192.44$, df = 1, $P < 0.001$) than that reported in an earlier study (Barrentine 1991a), lends support for the hypothesis that egested billbug mortality may be increased by an inability to escape entombment from desiccating fecal pellets. In the earlier study, survival was determined by counting the number of billbugs that emerged from fecal pellets. In the present study, survival was not predicated on an ability to emerge from fecal pellets because billbugs were removed from fecal pellets.

Calorimetry.—The weight and caloric content for egested and non-egested *S. phoeniciensis* are shown in Table 1. Dead egested billbugs have an average weight and caloric content that is 1.4% (0.13/9.06 mg) and 4.5% (0.225/5.049 kcal/g) *greater,* respectively, than that found for non-egested billbugs. That the caloric content for egested billbugs should exceed that found for non-egested billbugs was unexpected. It may be possible that greater weight and caloric content of egested billbugs is due to exogenous organic debris (i.e., mucoid intestinal secretions with a high lipid content and undigested chitinous fragments from other arthropods) that may have adhered to egested billbugs. Exogenous lipid would be difficult to remove with water and would inflate the caloric content for egested billbugs.

Conclusion

Ninety percent of billbugs (*Sphenophorus* spp.) egested by toads (*B. boreas*) are egested alive in fecal pellets. The survival frequency for egested billbugs is mark-

edly higher than that reported in other studies. Weight and calorimetric data indicate that billbugs (*S. phoeniciensis*) found dead and intact in toad fecal pellets show no evidence of digestion. Toads (*B. boreas*) obtain no calories from billbugs (*S. phoeniciensis*) that pass intact through the digestive tract.

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LIFE HISTORY AND DESCRIPTION OF IMMATURE STAGES OF *PROCECIDOCHARES STONEI* BLANC & FOOTE ON *VIGUIERA* SPP. IN SOUTHERN CALIFORNIA (DIPTERA: TEPHRITIDAE)

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Abstract.—*Procecidochares stonei* Blanc & Foote is a facultatively multivoltine, stenophagous, gall-forming fruit fly on *Viguiera laciniata* Gray and *V. deltoidea* Gray var. *parishii* (Greene) Vasey and Rose (Asteraceae) in southern California. The latter host record is new; other published host records are questioned. Eggs, first through third instar larvae, and puparia are described for the first time. Galls formed on both host plants are described. The severe drought in southern California during the last 5 years has reduced the densities of *P. stonei* on *V. d.* var. *parishii.* Fly reproduction was restricted to one generation per year on the few host plant individuals that thrived in favored sites where they received supplemental water (i.e., along drip lines of boulders and margins of paved roads). Adult behaviors described include grooming, feeding, wing displays, courtship, copulation and oviposition. Females typically lay eggs in clusters of two or more in axillary buds. Larvae develop gregariously, mainly as two, but up to 13 per gall. Four species of hymenopterous parasitoids are reported, the most common of which was *Eurytoma* sp. (Eurytomidae).

Key Words.—Insecta, *Procecidochares, Viguiera,* gall, immature stages, larval morphology, mating behavior, parasitoids

This paper continues a series of life history studies on non-frugivorous species of Tephritidae (Diptera) native to southern California. *Procecidochares stonei* Blanc & Foote is one of several, little known species in this genus currently under study (Goeden, Headrick, & Teerink, unpublished data). It was previously known only from a taxonomic description of adults reared from galls on *Viguiera laciniata* Gray, and from a published biology, as well as host records that we believe instead apply to other species of *Procecidochares.* Adults of these species are morphologically and biologically similar, but differ in their host-plant associations and subsequently their gall morphology. These undescribed species have been (Silverman & Goeden 1980) or are currently under study; however, the present study based on biological data collected from the type locality distinguishes *P. stonei* from its related species, defines its host range, and resolves biological data from previously published reports.

MATERIALS AND METHODS

Galls in different stages of development were collected from plants at six different localities in southern California. Galls on *V. laciniata* were sampled at Otay Mesa and Otay Valley, in coastal, southwestern San Diego County. The Otay Mesa site is the type locality for the species, and overlooks San Ysidro just north of Tijuana, Mexico, at 45 m elevation. The Otay Valley site is nearby in San Ysidro at 35 m elevation on a south-facing roadside slope.

Galls on *V. deltoidea* Gray var. *parishii* (Greene) Vasey & Rose were sampled

at Oriflamme Canyon in eastern San Diego County, at Mountain Springs in southwest Imperial County, at Chino Canyon and along the Palms-to-Pines Highway above Palm Desert in Riverside County. Oriflamme Canyon is located at 665 m elevation, east of the Laguna Mountains, in a transition zone between the Colorado Desert and high chaparral. The Mountain Springs site is in a rocky area at 645 m, just north of the Mexican border; the Chino Canyon site is near the entrance to the Palm Springs Aerial Tramway, at 725 m elevation. The Palms-to-Pines Highway site is at 945 m above and west of Deep Canyon, on rocky, barren slopes.

Samples were returned to the laboratory, measured and dissected. More than 500 galls were dissected during this study. All larvae and 10 puparia dissected from these galls were preserved in 70% EtOH for scanning electron microscopy (SEM). Puparia were placed in separate glass rearing vials stoppered with absorbant cotton and held in humidity chambers for adult emergence. Specimens for SEM later were rehydrated to distilled water in a decreasing series of acidulated EtOH. They were osmicated for 24 h, dehydrated through an increasing series of acidulated EtOH, critically point dried, mounted on stubs, sputter-coated with a gold-palladium alloy and studied with a JEOL JSM C-35 SEM in the Department of Nematology, University of California, Riverside.

Up to 12 adults of each sex from each study site were point-mounted as vouchers for the research collection of RDG; vouchers of immature stages were placed in the collection of immature Tephritidae of DHH; reared parasites were placed in a separate collection of parasitic Hymenoptera associated with Tephritidae belonging to RDG. The description of immature stages follows the terminology and format defined by Headrick & Goeden (1990), including the modifications addressed by Headrick & Goeden (1991). Most adults reared from isolated puparia were individually caged in 850 ml, clear-plastic, screened-top cages fitted with a cotton wick and basal water reservoir and provisioned with a strip of yeast hydrolyzate and sucrose-impregnated paper toweling. The cages were used for longevity studies and oviposition trials.

Virgin male and female flies obtained from emergence vials were paired in clear-plastic petri dishes provisioned with a flattened, water-moistened pad of absorbant cotton (Headrick & Goeden 1991) for direct observations, videotaping, and still-photography of their general behavior, courtship, and mating. Pairs were held together for at least 1 week, and observations were made throughout the day.

To quantify the effects of drought, galls were categorized as current-year's, last-year's, and previous-years' in a field survey at the Palms-to-Pines site in April, 1990, and gall abundance on 11 host plants was tabulated (Table 1). Each host plant was measured and diagramatically divided into four quadrants along compass coordinates, within which the position of each gall was noted.

Plant names follow Munz (1974); insect names, Foote & Blanc (1963). Means ± standard errors are reported herein.

Taxonomy

Procecidochares stonei Blanc & Foote

Egg.—Smooth, white, cylindrical, elongate, and tapered on both ends (Fig. 1A). Length 0.4–0.5 [0.5 ± 0.02] mm, width, 0.06–0.12 [0.08 ± 0.01] mm (n = 5). Apical end bears nipple-shaped pedicel with few aeropyles (Fig. 1B).

Table 1. Gall numbers and locations on 11 *Viguiera laciniata* plants at the Palms-to-Pines site in April 1990.

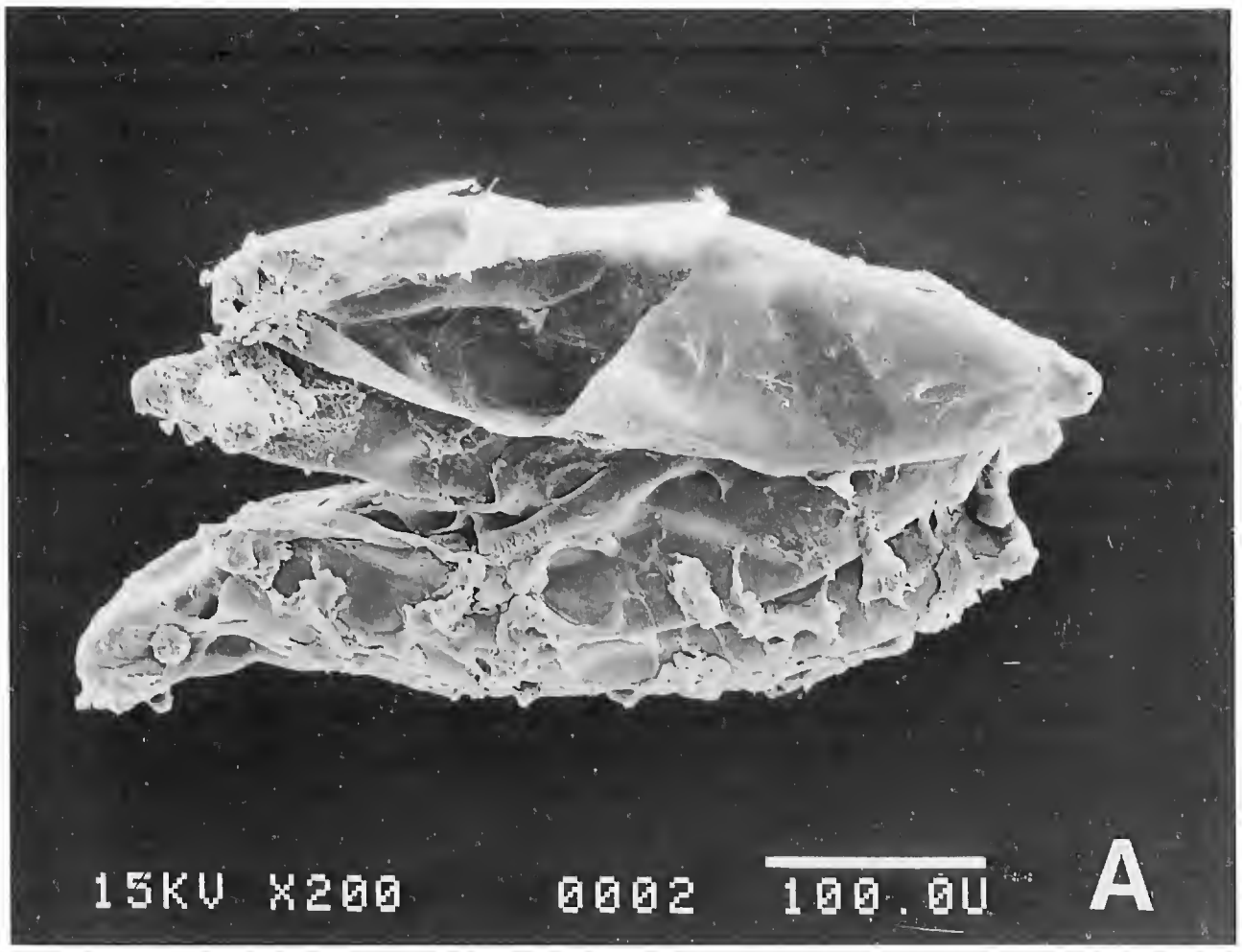
Quadrant	Galls sampled		
	Previous years'	Last year's	Current year's
NW	99	6	2
NE	117	8	1
SW	86	15	5
SE	102	15	8
Totals	404	44	16

Third Instar Larva (fully grown).—White, barrel-shaped, tapered anteriorly, rounded posteriorly (Fig. 2A). Gnathocephalon conical, flattened dorsally, rounded lateroventrally; slightly protruding ventrally from prothorax (Fig. 2B), where it forms the mouth lumen at its anterioventral apex. Integument surrounding lumen rugose ventrally, with 4 smooth petals dorsally (Fig. 2B—1). Paired tridentate mouth hooks, directed ventrally (Fig. 2B—2), protrude from lumen. A laterally flattened median oral lobe lies between mouth hooks (Fig. 2B—3), with no ventral papilla (we were unable to see if it was attached basally to the labial lobe). Dorsad of mouth lumen, on anteriormost face of gnathocephalon, are paired anterior sensory lobes (Figs. 2B—4, 2C), each with flattened lobes bearing several sensory organs; a protruding, dome-shaped, dorsal sensory organ (Figs. 2B—5, 2C—1) is adjacent to dorsomedial apex of each anterior sensory organ. On dorsolateral margin of each lobe lies 1 small sensillum (Fig. 2C—2). Each anterior sensory lobe bears 1 lateral sensory organ (Fig. 2C—3), as a small, slightly raised papilla; a pit sensory organ (Fig. 2C—4), as a slightly raised area with an invagination on its surface; and a terminal sensory organ (Fig. 2C—5) of several papillae on a slightly raised area covering about 20% of the total lobe, not surrounded by a cuticular ring. A stomal sense organ (Fig. 2B—6) lies ventrolaterad of each anterior sensory lobe, and is located on gnathocephalon edge near the mouth lumen; each of these organs bears several small sensory papillae. Prothorax widens posteriorly (Fig. 2B—P); integument smooth, relatively featureless, but bears 1 row of flattened sensilla circumscribing its anterior margin. One pair of dorsolateral anterior thoracic spiracles on posterior margin of prothorax (Fig. 2D); each normally consists of 2 or 3, dome-like spiracular papillae each bearing a slit-like opening. Meso- and metathorax widen posteriorly, in similar appearance to abdominal segments. Typical abdominal segment bears a spiracular complex laterally along the midline (Fig. 2E); spiracles circular, do not protrude (Fig. 2E—1); each spiracular complex with dome-like sensillum anterior to its opening (Fig. 2E—2). Abdominal integument relatively smooth, featureless; abdominal segments I–III widen posteriorly, reach maximum width at segments IV–VI; segments VII and VIII narrow slightly, latter (caudal) bluntly rounded posteriorly, bearing posterior spiracular plates that bear 3 oval rimae with spiracular slits (Fig. 2F—1), an ecdysial scar (Fig. 2F—2) (found only on second and third instars), and thorn-like interspiracular processes on outer margins of each greatly reduced and often indistinct spiracular slit (Fig. 2F—3).

Second Instar Larva.—White, barrel-shaped, tapered anteriorly, rounded posteriorly (Fig. 3A). Mouth hooks tridentate (Fig. 3B—1), median oral lobe present (Fig. 3B—2). Prothorax bears anterior spiracles, each with 2 domed openings (Fig. 3C); lateral spiracles not observed; each posterior spiracular plate bears 3 rimae (Fig. 3D—1) and an ecdysial scar (Fig. 3D—2); interspiracular processes extremely small (Fig. 3D—3).

First Instar Larva.—White, barrel-shaped, tapered anteriorly, rounded posteriorly (Fig. 4A): differs from later instars with: mouthhooks bidentate (Fig. 4B—1); median oral lobe rounded anteriorly (Fig. 4B—2); anterior sensory lobes directly above mouth lumen, their sensilla much reduced, with only dorsal sensory organ (Fig. 4C—1) and terminal sensory organ (Fig. 4C—2) visible; anterior spiracles absent; no lateral spiracles observed; posterior spiracles reduced, their plates bear two indistinct oval rimae, each with no observable openings (Fig. 4D—1); interspiracular processes clearly visible, multibranched, and blade-like (Fig. 4D—2); no ecdysial scar present.

Puparium.—Black, barrel-shaped, gently tapering anteriorly, rounded posteriorly (Fig. 5A); 3.0–5.3 [4.2 ± 0.03] mm long (n = 180), 1.3–2.7 [1.9 ± 0.02] mm wide (n = 201). Most third instar larval structures retained in hardened and reduced state; gnathocephalon invaginated before pupariation, not visible (Fig. 5B). Posterior spiracular slits flattened, more sharply defined than in third instar (Fig. 5C—1); interspiracular processes reduced to barely distinguishable blemishes (Fig. 5C—2).



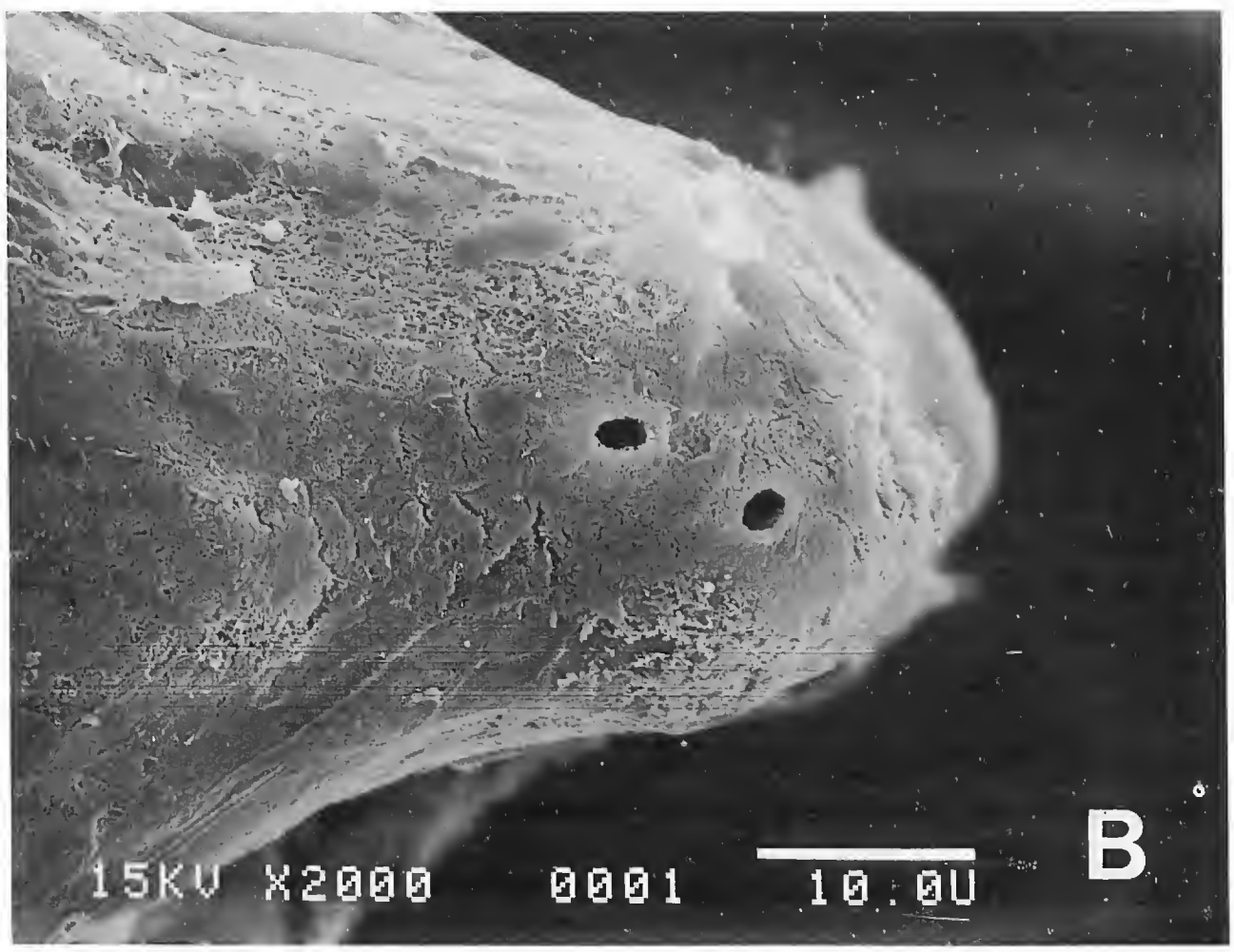


Figure 1. Egg of *Procecidochares stonei*: (A) cluster of three eggs; (B) detail of anterior end showing two aeropyles.

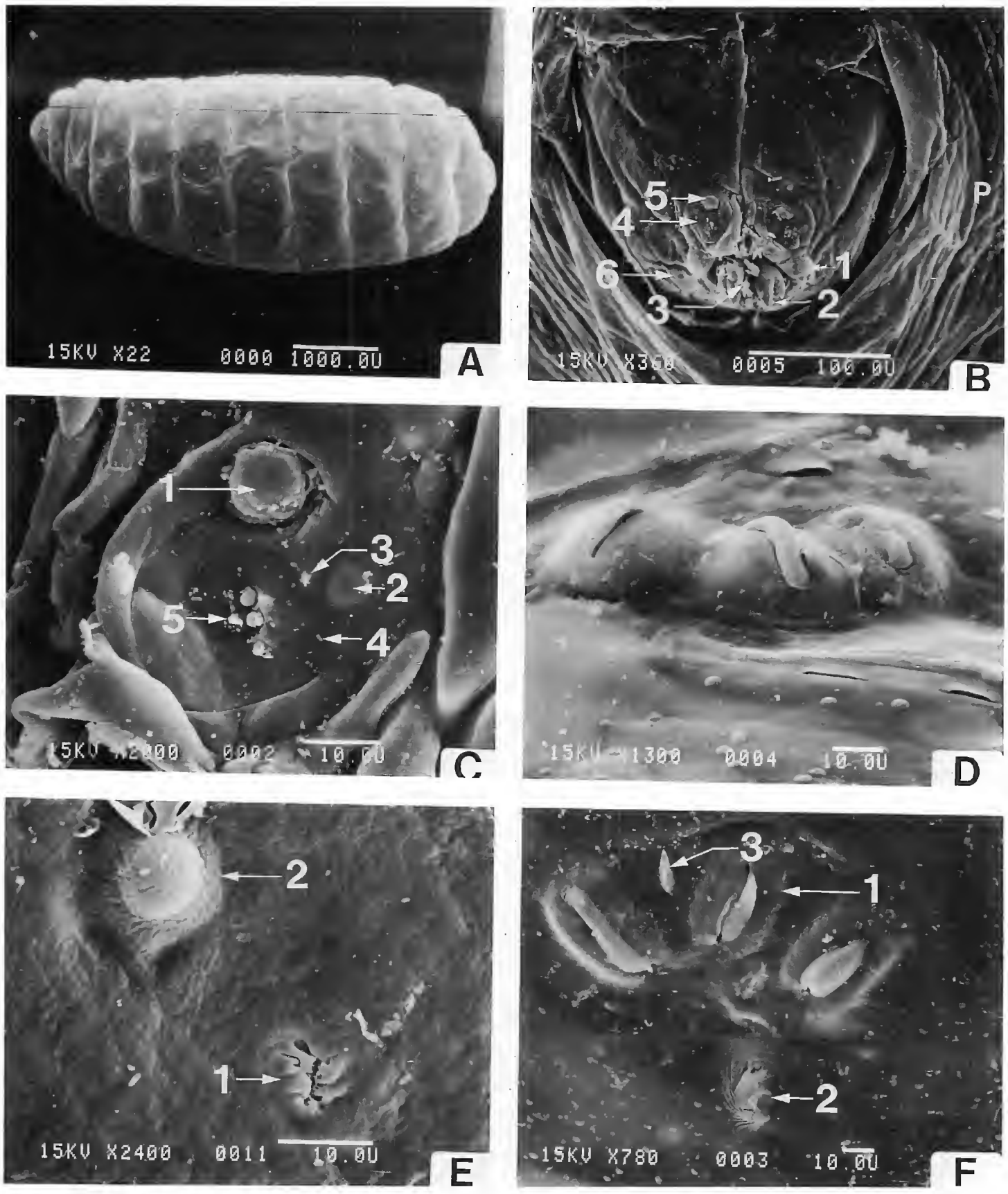


Figure 2. Third instar larva of *P. stonei*: (A) habitus, anterior to the left; (B) anterior view of gnathocephalon, 1—dorsal petals, 2—mouth hooks, 3—median oral lobe, 4—anterior sensory lobe, 5—dorsal sensory organ, 6—stomal sensory organ; (C) left anterior sensory lobe, 1—dorsal sensory organ, 2—sensillum, 3—lateral sensory organ, 4—pit sensory organ, 5—terminal sensory organ; (D) anterior spiracle; (E) lateral spiracular complex, 1—spiracle, 2—sensillum; (F) posterior spiracular plate, dorsal to right, 1—rima, 2—ecdysial scar, 3—interspiracular process.

Material Examined.—CALIFORNIA. *SAN DIEGO Co.*: San Ysidro, N of Tijuana, Mexico, 45 m, 27 Feb 1990, 12 Feb 1991, R. D. Goeden, *V. laciniata* Gray, galls containing immature stages.

Biology and Seasonal History

Gall.—Galls were collected from *V. laciniata,* the host plant at the type locality (Fig. 6A), and *V. deltoidea* var. *parishii,* a new host recorded here for the first

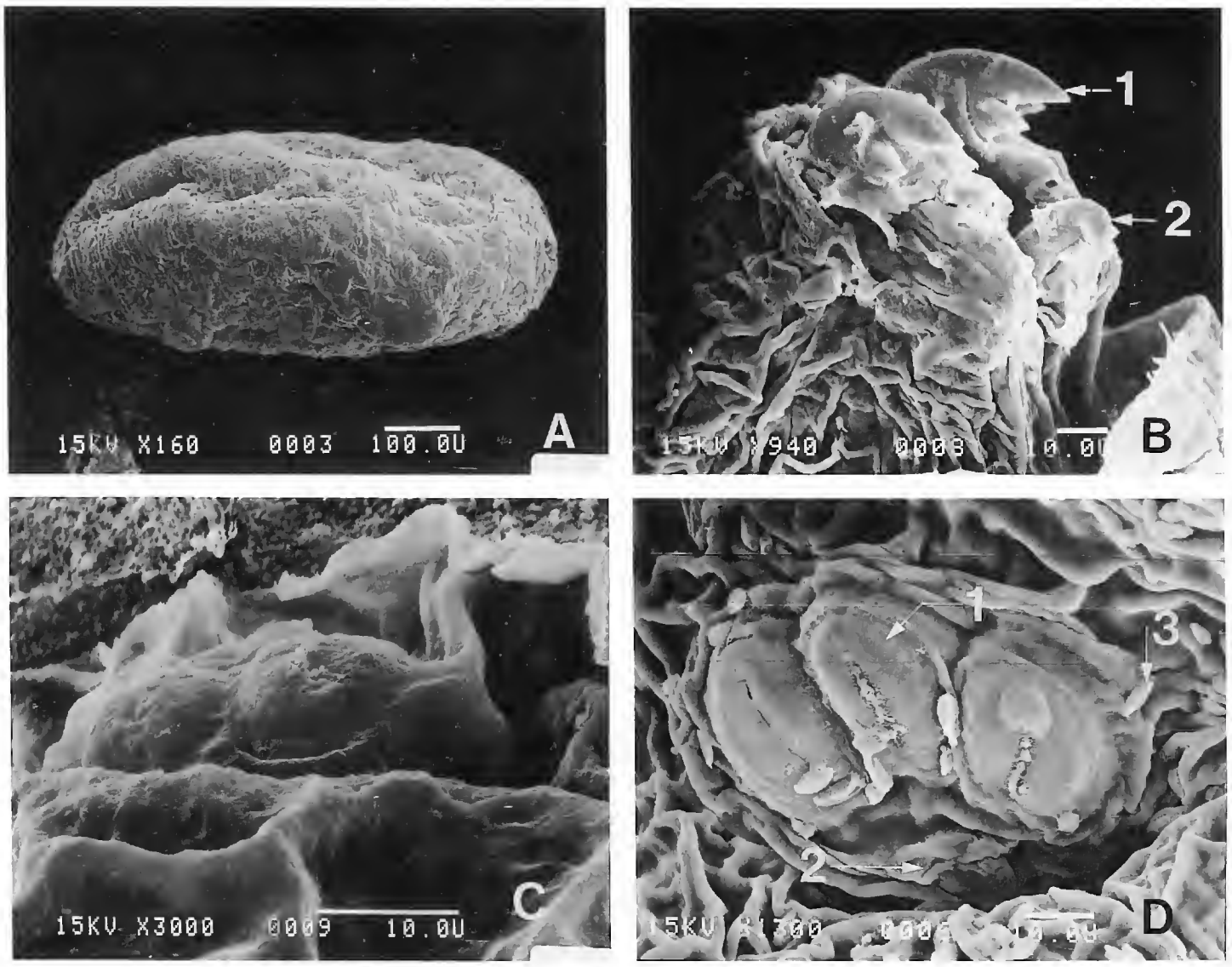


Figure 3. Second instar larva of *P. stonei*: (A) habitus, anterior to left; (B) lateral view of gnathocephalon, 1—mouth hooks, 2—median oral lobe; (C) anterior spiracle; (D) posterior spiracular plate, dorsal to right, 1—rima, 2—ecdysial scar, 3—interspiracular process.

time (Fig. 6B). *Viguiera* are short, bushy, multibranched perennials with yellow flower heads in the tribe Heliantheae of the Asteraceae. In southern California, *V. laciniata* is found only in southern San Diego County on dry slopes below 760 m in coastal sage scrub and chaparral. *Viguiera d.* var. *parishii* is found in the Colorado and East Mojave Deserts in sandy canyons and mesas below 1520 m in creosote bush scrub (Shreve & Wiggins 1964, Munz 1974). The axillary bud galls of *P. stonei* were found on the lower portions of previous growing season's branches of both host species. They lack or have short pedicels, and are dark green, subspheroidal, and bear many bract-like leaves, especially apically (Fig. 6B).

Several features were measured on mature galls containing puparia from both host species. Galls from *V. laciniata* measured 2.9–12.5 [7.9 ± 0.25] mm in width and 3.9–15.2 [9.5 ± 0.3] in length ($n = 80$). Galls from *V. d.* var *parishii* measured 2.9–13.8 [7.1 ± 0.16] mm in width and 3.2–18.27 [8.8 ± 0.25] mm in length ($n = 149$). These means were not significantly different (t-statistic width = 1.27, length = 1.61; df = 227; $P = 0.025$). The single cavity within galls of *V. laciniata* measured 1.49–8.1 [4.5 ± 0.13] mm in width, and 2.8–9.9 [6.1 ± 0.18] mm in length ($n = 80$). Each cavity in galls from *V. d.* var. *parishii* measured 2.0–11.2 [4.76 ± 0.12] mm in width and 2.0–11.18 [5.9 ± 0.14] mm in length ($n = 149$).

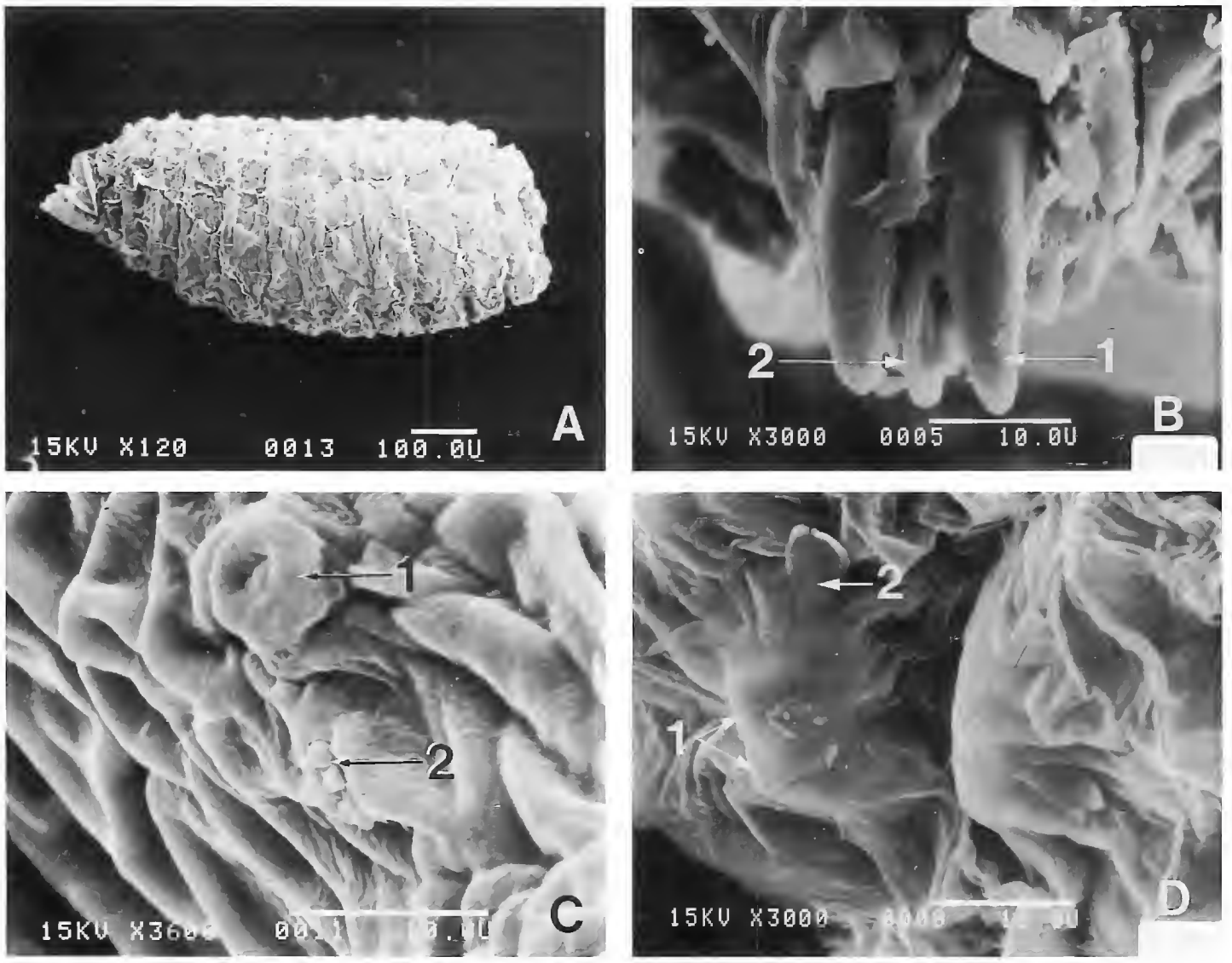


Figure 4. First instar larva of *P. stonei*: (A) habitus, anterior to left; (B) anterior view of mouth, 1—mouth hooks, 2—median oral lobe; (C) anterior sensory lobe, 1—dorsal sensory organ, 2—terminal sensory organ; (D) posterior spiracular plates, dorsal end up, 1—rimae, 2—interspiracular processes.

Again, these means for cavity sizes were not significantly different (t-statistic width = 1.75, length = 0.69; df = 227; $P = 0.025$).

Procecidochares stonei larvae develop gregariously within a gall. The number of individuals per gall on *V. laciniata* was 1 to 13 averaging 2.5 ± 0.1 ($n = 309$), and on *V. d.* var. *parishii* was 1 to 3 averaging 1.4 ± 0.04 ($n = 192$); these means were significantly different (t-statistic = 7.7; df = 489; $P = 0.025$).

Egg.—Females begin to oviposit eggs, usually in clusters of two or more, shortly after their emergence in mid-spring (i.e., late March though April). Eggs are inserted into the axil between a branch and the base of a leaf petiole on the new growth (Fig. 6C).

Larvae.—First instar larvae eclose shortly after oviposition and begin to feed head-down in an axillary bud. The larva inhibits axillary branch elongation and induces thickening (Fig. 6D). First instar larvae aestivate in the small, incipient

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Figure 5. Puparium of *P. stonei*: (A) habitus, dorsal view, anterior to left; (B) anterior end, arrow denotes right anterior spiracle; (C) posterior spiracular plate, dorsum to right, 1—spiracular slit, 2—interspiracular process.


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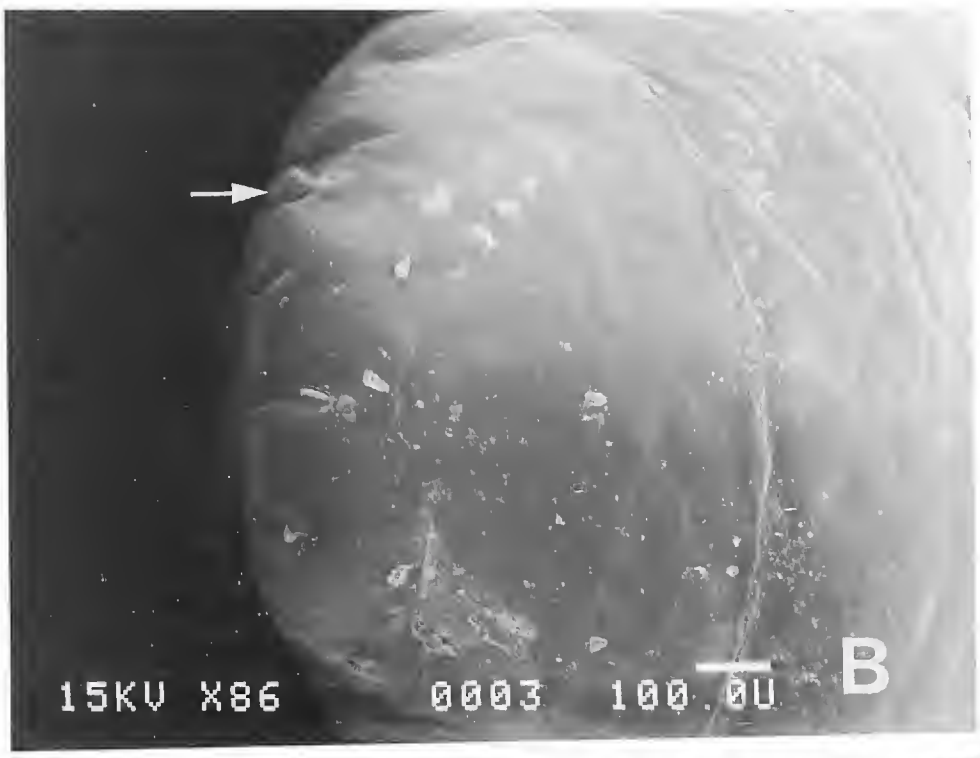
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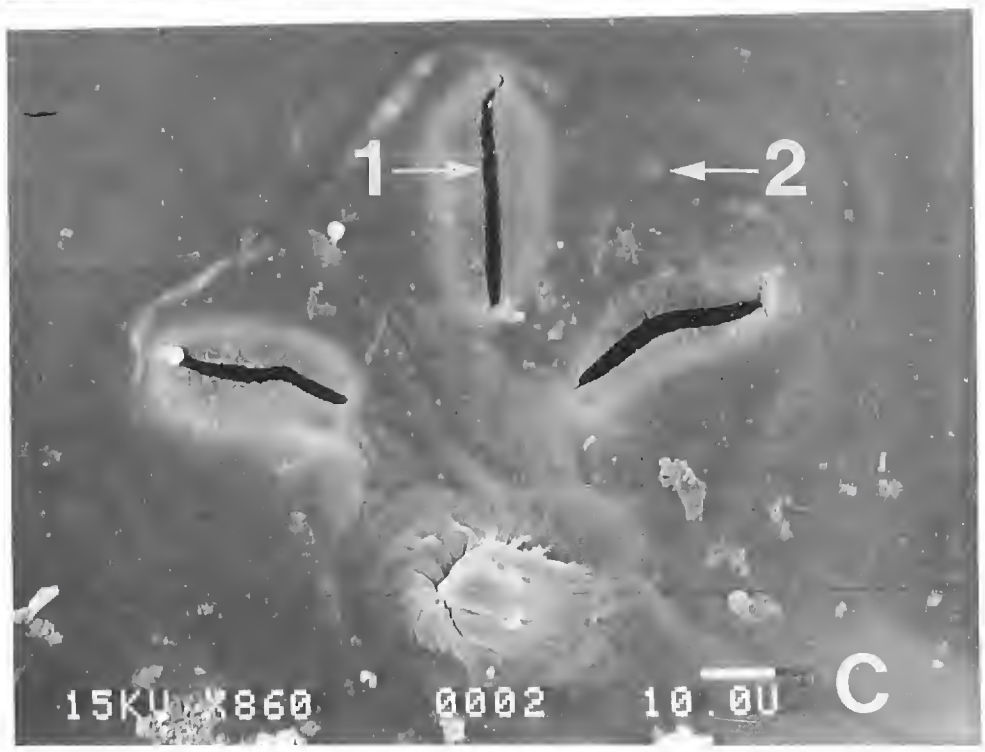
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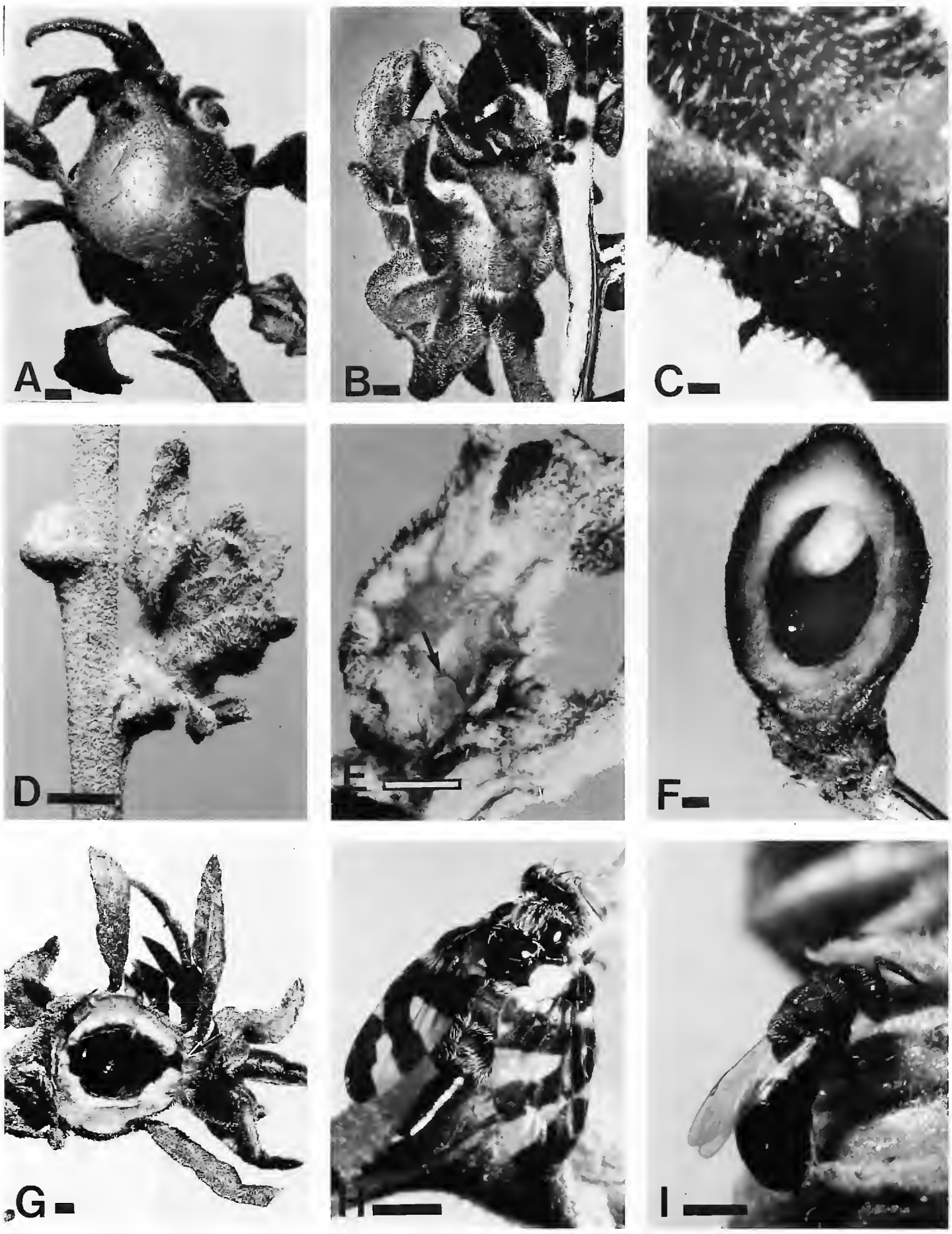

Figure 6. (A) gall of *P. stonei* on type host, *Viguiera laciniata*; (B) gall of *P. stonei* on *V. deltoidea* var. *parishii*; (C) cluster of three eggs laid in leaf axil on *V. laciniata*; (D) immature gall on *V. d.* var. *parishii*; (E) immature gall on *V. d.* var. *parishii* dissected to show first instar larva (arrow) in small cavity; (F) saggital section of gall on *V. laciniata* containing a third instar larva and puparium; (G) saggital section of gall on *V. laciniata* containing two puparia and showing the exit tunnel (arrow); (H) adult female of *P. stonei*; (I) Adult female of *Eurytoma* sp., the most common parasite of *P. stonei*. Bars = 1 mm.

galls (Fig. 6E) until rain stimulates plant regrowth in late-winter/early-spring, as described for *Procecidochares* sp. on *Ambrosia dumosa* (Gray) Payne by Silverman & Goeden (1980). Occasional late-summer rains also may stimulate a second annual flush of plant growth and host and fly reproduction (Silverman & Goeden 1980). A sample of 27 galls collected from *V. d.* var. *parishii* at Chino Canyon on 31 October 1991 yielded 25 dormant first instar larvae, 19 (86%) of which were found singly in galls. Of 22 galls collected from *V. laciniata* at Oriflamme Canyon in December 1989, 12 (55%) contained second or third instar larvae, and 10 (45%) held puparia (Fig. 6F). Larval growth proceeds rapidly through the second and third stadia as host-plant growth resumes. Of 260 galls collected in February 1990 and 1991, from both host species, four (2%) contained first instar larvae, eight (3%) had second instar larvae, 25 (10%) had third instar larvae, 234 (90%) contained puparia (Fig. 6G); 10 galls contained both larvae and puparia. Before pupariation, the third instar larva chews an exit tunnel in the gall wall out through the leafy apex (Fig. 6G—arrow), as reported by Silverman & Goeden (1980).

Puparia.—By March 1990 and 1991, 71 (88%) of 80 galls contained puparia (Fig. 6G); and flies had emerged from 38 (60%) of 64 of these puparia examined more closely. In April 1990, a sample of 46 galls from the Palms-to-Pines site contained only puparia, and flies had emerged from 46 (70%) of 66 puparia within them. Puparia were oriented with their cephalic ends toward the exit tunnels. In galls with more than one puparia, they were usually bound together with a thin, clear, oily liquid. Adults emerged from puparia held in vials during late February through mid-March.

Effects of Drought.—*Viguiera d.* var. *parishii* was common at the Palms-to-Pines site, but 4 years of drought had taken their toll, as only 10–40% (visual estimate) of each galled plant showed new growth. Most regrowth occurred on plants that grew at the bases of boulders or rocky outcrops and thus benefitted from additional water runoff. Eleven galled host-plants along a 500-m, east–west transect averaged 72 ± 10 cm in diameter and 50 ± 5 cm in height. Previous-years' galls, i.e., 2 or more years old, were found on all 11 plants and totalled 404, with the galls evenly distributed basally among the four quadrants (Table 1). Last-year's galls were found on eight of the 11 (72%) plants and totalled 44, with most concentrated in the southwest and southeast quadrants, and typically located half way up the stems. Current-years' galls were found only on four of the 11 (36%) plants and totalled only 16, with most concentrated in the southeast quadrant, and located distally half to two-thirds of the distance along the stems (Table 1). These data suggested that as water-stressed plants put on less new growth each year of the current drought, the numbers of galls also decreased commensurately.

A few *V. d.* var. *parishii* at each desert site remained relatively healthy because of their location along the driplines of boulders, as mentioned, or along paved roads, where rain runoff also gave them an added measure of water. By locating and ovipositing on these few relatively flush plants, at least a small population of *P. stonei* had survived the drought conditions. Larval development is a facultative process dependent on host-plant physiology (Freidberg 1984). Evidence suggests that in years of extreme drought, first-instar larvae may remain dormant for a year or more, until they die along with their hosts or incipiently infested parts of their hosts (Silverman & Goeden 1980). The galls sampled at Chino

Canyon in October, 1990, the fourth year of the drought, mentioned above, contained only dormant first-instar larvae.

Adults.—A total of 79 females and 76 males were reared from isolated puparia. Adults emerged during February and March 1990 and 1991, from galls collected on *V. laciniata* at Otay Valley and Otay Mesa. Females are proovigenic (Fig. 6H). Five, newly emerged females contained an average of 200 ± 12.1 (range 156–216) ova in their ovaries. Adults emerge ready to mate, and females oviposit shortly thereafter on the current branch growth.

The average longevity of 92 individuals obtained from *V. d.* var. *parishii* and *V. laciniata* individually caged was 19.5 days. Forty-one males lived an average of 24 days; five mated males lived an average of 23 days. Fifty-one females lived an average of 16 days; 12 mated females lived an average of 16 days, and 10 of those that were allowed to oviposit lived an average of 15 days. Death occurred an average of 5.5 days after they ceased oviposition. The greatest longevity recorded was 64 days for a male obtained from *V. laciniata* at Otay Mesa. Flies from Otay Mesa on average lived longer, i.e., 39 days for males, 20 days for females, and 30 days for all flies.

Wing Displays.—Adults of *P. stonei* are dark-bodied and have three dark, transverse bands on their hyaline wings (Fig. 6H). At rest, the wings are usually held parted at about 45°, with the wing blades supinated ca. 45°, such that their anal margins touch the sides of the abdomen at ca. 160°. The medial margin of the wings forms a straight line across the posterior margin of the body, and completes a triangle with the costal margins of the wings (Fig. 6H). From this position, the wings are synchronously and quickly extended forward and returned through 30° to 45° arcs. This motion is repeated several times in 1-sec bursts, which usually involve three repetitions. This general wing movement we call "enantion," a term derived from the Greek preposition meaning "against." This wing display is typical of *Procecidochares* (Headrick, unpublished data), all species of which have a similar habitus. Resting or grooming adults of *P. stonei* spontaneously displayed wing enantion; males also displayed enantion during courtship. Moreover, both sexes visually oriented to nearby movement by turning and facing the conspecific fly, predator, or other stimulus, and displaying rapid wing enantion. The male apparently uses wing enantion to further stimulate the female while gaining intromission (see below).

Males exhibited more variation in wing displays than did females, which only displayed enantion. Wing display intensity depended on the time of day and state of sexual excitment of the male. When a male approached a female for courtship, his wings vibrated very rapidly, appearing as a sustained blur. Males rarely showed asynchronous extension of their wings during courtship. The asynchronous display involved one wing extending slightly forward, then returning to its resting position, at which point the other wing similarly was extended. This wing movement was much slower than the rapid synchronous thrusts of enantion.

Grooming.—Adults used their hind legs to clean all sides of their abdomen, both sides of their wings, and the top of their thoraces. The hind legs were rubbed together beneath the abdomen for cleaning. The foretarsi were used to clean the head and also, were rubbed together for cleaning. The middle legs were used only to help clean the fore and hind legs. Females exerted their ovipositors occasionally

to clean the eversible membrane and aculeus with their hind tarsi and the distal parts of their hind tibia.

Feeding and Waste Excretion.—The mouthparts of both sexes pumped rapidly and nearly continuously, regardless of other activities. The female mouthparts pumped at about half the rate of the males. Adults readily drank water provided to them in cages and arenas.

Courtship.—Males faced females and began asynchronous wing displays, starting at two to three extensions per sec and increasing in speed to a blur as excitation of the males increased. Males trailed females while continuing their asynchronous wing displays. Females answered with only one type of display (i.e., synchronous wing extension without supination). When a male followed a female, he attempted to mount her by jumping onto her dorsum. Although females were able to escape the advances of a male by jumping away, males usually were able to grasp the females and hang on. Once the male had mounted, females did not try to escape.

Copulation.—The male positioned himself on a female with the claws of his foretarsi hooked basally around the costal veins of the females. His middle legs wrapped around her abdomen near her thorax, and his hind legs were brought underneath her abdomen near the base of the oviscape (= syntergosternite VII of Norrbom & Kim 1988). Non-virgin males raised the oviscape at a 45° angle by means of his hind legs; whereupon, the female in response immediately exerted her aculeus; he then held his terminalia against the oviscape apex and the epandrium received the aculeus. Next, the female fully exerted her ovipositor, an action that stretched the abdomen of the male to its limits. After a few minutes, the female relaxed and the male assumed a normal copulatory position with his forelegs on her abdomen near her thorax, his middle legs around her abdomen near the ovipositor, his hind legs on the substrate, and the epandrium held against the partially exerted, eversable membrane.

If the female did not exert her aculeus immediately, the male drummed his hind legs against the venter of her abdomen and ovipositor. If this did not elicit a response, he displayed wing enantion coupled with drumming. This behavior was usually followed by the female exerting her aculeus. The aculeus was held in place by the surstyli, with its tip raised, thus opening the ventral flap. The aedegus was then inserted through the ventral flap into the oviduct while the ovipositor was fully extended. As the ovipositor was slowly retracted, the aedeagus was further thrust into the oviduct by pulsations of the abdomen of the male. Mated pairs remained *in copula* from 20 min to 8 h, averaging about 2 h ($n = 13$), which was longer than averages of 1 h observed for *P. minuta* (Snow) (Headrick, unpublished data) and 30 min reported for *Procecidochares* sp. from *A. dumosa* (Silverman & Goeden 1980). To terminate copulation, the male turned 180°, and walked off the dorsum of the female and away from her while pulling his aedeagus out of her aculeus. Once free, the male groomed and recoiled his aedeagus, while the female also groomed herself. No post-mating activity other than grooming was observed.

On one occasion, a male of a pair that had mated 5 days earlier was observed trying to remount the same female. The male jumped on the female from the front and turned around on her back to gain access to the oviscape; however, she kept it covered with her wings so he could not reach down and grasp it with his

hind legs. He turned 360° twice while on top of her, and crawled down her side twice while trying to grasp her oviscape. He then moved back on top of her and tried to grasp her oviscape posteriorly with his hind legs. The female exerted her aculeus as if to initiate coitus, and the male fell off. He did not attempt to mount the female again.

Virgin males showed one of the few examples of naïve mating behavior reported among Tephritidae. During two separate trials, while a naïve male was on top of a female in the typical initial position, he began drumming with his hind legs against her oviscape without raising it. The female exerted on command, but she extended her aculeus so that the male couldn't move posteriorly far enough to engage the aculeus tip with his epandrium. This drumming by both males and exertions of the aculeus by both females continued for nearly an hour in each case, when finally each male successfully raised the oviscape and engaged the aculeus, thus gaining intromission.

Oviposition.—Oviposition trials were carried out in the field and laboratory with mated females from the above trials. Individual females were caged on branches of *V. laciniata* or *V. d.* var. *deltoidea* obtained from the University of California, Riverside, Botanic Garden. *Viguiera d.* var. *parishii* was unavailable locally. The variety *deltoidea* is found naturally only in Baja California (Shreve & Wiggins 1964). Females actively explored, and probed leaf axils of both test species immediately after being caged on plants in the field, or with freshly cut branches in the laboratory. When a female was ready to oviposit she turned away from the stem and pushed the tip of her deflexed ovipositor into the axil between a leaf base and stem (Fig. 6C). Except for a single group of two eggs laid near a branch tip, females always chose axils on current season's growth lower on branches near the main axis of the plant for oviposition. This corresponded with field data on gall positions on plants.

Natural Enemies.—At least four species of parasitic Hymenoptera emerged from puparia in rearing vials. A *Eurytoma* sp. (Eurytomidae) was the predominant parasitoid at all locations. This solitary, internal larval-pupal parasitoid was recovered from 300 puparia from all sample dates and locations (Fig. 6I). Nineteen individuals of a *Halticoptera* sp. (Pteromalidae) also were reared singly from puparia collected at Otay Valley and Otay Mesa in 1991. A *Tetrastichus* sp. (Eulophidae) was represented by 140 individuals recovered from 26 puparia from all locations except Otay Mesa. A single male of a *Spilochalcis* sp. (Chalcididae) was recovered from puparium from Mountain Springs. Five solitary, ectoparasitic torymid larvae, one of which had an internal hyperparasite, were found feeding on larvae of *P. stonei* in separate galls.

Host Range

Tauber & Tauber (1968) described the biology of *P. stonei,* which they had identified from a single, dead, teneral adult that had partly emerged from a gall on *Chrysothamnus viscidiflorus* (Hooker) Nuttall. At that time, several undescribed species of *Procecidochares* were identified as *P. stonei* or near (Silverman & Goeden 1980). However, the gall Tauber & Tauber (1968) described and illustrated is quite different morphologically from the galls described from the type host plant and type locality of *P. stonei* in the present paper. This gall also is radically different morphologically from those of a *Procecidochares* sp. on *A.*

dumosa (Silverman & Goeden 1980) and at least five additional species of *Procecidochares* currently under study by Goeden, Headrick & Teerink (unpublished data); at least two of these occur on another *Chrysothamnus* species, *C. nauseosus* (Pallen) Britton. It only has a very small central cavity and is largely composed of a series of overlapping, sessile, linear leaves (Tauber & Tauber 1968: figs. 1, 2), which is strongly reminiscent of certain cecidomyiid galls (Gagné 1989), and unlike any other tephritid gall (*Procecidochares* included) seen by RDG in California to date. In June, 1986, a sample of 62 galls from *C. viscidiflorus* like those first described by Tauber & Tauber (1968) were collected in Deep Spring Valley, Inyo County, dissected, and thoroughly examined by RDG (unpublished data). Unfortunately, they contained only empty puparia, but these were similar in size and color to those of the species of *Procecidochares* described by Tauber & Tauber (1968) (i.e., smaller, narrower, and partially pigmented dark brown, only a few completely black, unlike those of *P. stonei* described here). These data suggest that the species studied by Tauber & Tauber (1968) was not *P. stonei,* but rather the "*Procecidochares* sp. A" of Wangberg (1980), which Novak et al. (1967) reported as *P. minuta.*

Based on the present study, and published (Silverman & Goeden 1980) and unpublished field and laboratory studies of other *Procecidochares* in California (Goeden, Headrick, & Teerink, unpublished data), we suggest that the host records in Wasbauer (1972) for *P. stonei* from *Ambrosia dumosa, Corethrogyne filaginifolia* (Hooker & Arnott) Nuttall, and *Chrysopsis* (as *Heterotheca*) *villosa* (Pursh) Nuttall are misidentifications of other *Procecidochares* species. *Procecidochares stonei* apparently is restricted to *Viguieria* spp., which are found in a different tribe of Asteraceae than are *C. filaginifolia* and *C. villosa,* both in the Astereae.

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EXTENDED DEVELOPMENT OF *POLYCAON STOUTII* (LECONTE) (COLEOPTERA: BOSTRICHIDAE)

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Abstract.—*Polycaon stoutii* (LeConte) adults emerged from wood cabinets 21 to 24.5 years after they were installed in homes. The cabinets were likely white ash, *Fraxinus americana* L. This represents the first record of this bostrichid from an eastern hardwood.

Key Words.—Insecta, *Polycaon stoutii,* extended development, *Fraxinus americana*

In September 1986, a homeowner in Berkeley, California (1375 Summit Rd., Berkeley, California, Alameda Co.) contacted us after observing large black beetles emerging from ash cabinetry. Two adjacent homes with similar cabinetry were constructed by the same builder in 1967 and beetles had been observed emerging from cabinetry by homeowners of both structures. The cabinetry in one of the structures had been varnished, but the cabinetry in the second structure had been treated with linseed oil. We collected boards from the varnished cabinets, sawed them into smaller lengths, and placed them into rearing containers. We noted that all emergence tunnels were through the finished surface indicating that infested lumber was used to manufacture the cabinets. In July 1987 an adult (18 mm in length) emerged from a board in a rearing container and was identified as *Polycaon stoutii* (LeConte). A second adult of the same species, 21.5 mm in length, emerged between June 1988 and March 1991.

The black polycaon, *Polycaon stoutii,* occurs in British Columbia, the Pacific coast states, and Arizona (Ebeling 1975, Fisher 1950). It is a wood-boring insect, generally attacking non-coniferous woods used for building material, furniture, and cabinetry (Doane et al. 1936). It will also develop in the wood of fruit trees and ornamentals (Essig 1958). Normally, the larvae require one to several years to complete development (Linsley 1943b). However, Middlekauff (1974) reported three instances of extended life cycles ranging from 8 to 22 years. As is often the case with other pests associated with wood in service, this species is transported in wood products to regions where it is not indigenous [e.g., collection record from a redwood dresser in Tennessee and from a mahagony table in Texas (Fisher 1950)].

There is some question in the literature regarding the condition of the host required for oviposition by *P. stoutii.* It appears that its usual habit is to attack dead and occasionally living trees (Doane et al. 1936, Essig 1958). However, Doane et al. (1936) imply that adults are capable of ovipositing in curing plywood and lumber in warehouses. Linsley (1943b) states that *P. stoutii* is "not known to infest finished products after manufacture nor to re-infest materials in which

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it has previously been breeding"; furthermore, "emergence, even after long periods of time, is generally regarded as evidence that the product was infested before manufacture." However, Mallis (1982) states that *P. stoutii* will also attack cured hardwoods in lumber yards, buildings in mountainous areas, and furniture and other wood products (probably prior to finishing).

In this case, we consider that oviposition in the finished cabinetry from indigenous sources of beetles (e.g., firewood, moribund trees, etc.) was an unlikely source of this infestation. Besides the low probability of oviposition occurring through two different finished surfaces, individuals of this insect species were observed simultaneously emerging from cabinetry in both adjacent homes. Because the cabinets were built into the homes during construction in 1967, it is likely that both specimens developed over the 21 and 22 to 24.5-year periods, respectively.

Surprisingly, the extended developmental period in the seasoned wood did not seem to affect the vigor of the individuals that emerged. If length is taken as an indicator of health of the specimen, the lengths of the two (18 mm and 21.5 mm) are at the extreme end of the normally expected range (11 mm to 22 mm: Ebeling 1975). It is likely that development in this nutrient-poor environment was aided by microbial symbionts.

The infested wood was identified as white ash (solid), either Oregon ash, *Fraxinus latifolia* Bentham, or white ash, *Fraxinus americana* L. These two species are indistinguishable based on wood anatomical characteristics. However, in contrast to *F. americana, F. latifolia* is rarely cut for commercial lumber. Thus, it seems probable that the infested lumber is *F. americana.* Although we have no detailed history of the origin of the lumber used to construct the cabinetry, the infestation probably was initiated in lumber after it was transported from the East to the West coast. *Fraxinus americana* is normally shipped following kiln drying to lower the moisture content thereby reducing the cost of shipment. This treatment would have killed any insects present in the raw lumber. We believe that this is the first host record for *P. stoutii* from an eastern hardwood species. Middlekauff (1974) also reported a case where *P. stoutii* was collected from "ash" cabinetry, but the species status of the wood sample was not determined.

We conclude in this instance that *P. stoutii* can undergo a greatly extended developmental cycle rivaled only by the Buprestidae (Linsley 1943a, Smith 1962) and termite queens (Krishna & Weesner 1969) and can continue its development in finished wood products (Middlekauff, 1974).

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ERNOBIUS MOLLIS (L.) (COLEOPTERA: ANOBIIDAE) ESTABLISHED IN CALIFORNIA

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Abstract.—The bark anobiid, *Ernobius mollis* (L.), was collected in Oakland, California; thus providing the first unequivocal North American record of this species west of Texas. Adult and larval *E. mollis* were collected from a laboratory cage containing the originally infested branches over a nineteen-month period, and adults were observed *in copulo,* suggesting re-infestation of the same bark-covered wood. Because *E. mollis* is generally considered among pests of structures in Europe and the southern hemisphere, the literature pertaining to *E. mollis* is reviewed here in the event that it may assume economic importance in California.

Key Words.—Insecta, *Ernobius mollis,* California

We have found the bark anobiid, *Ernobius mollis* (L.) (Coleoptera: Anobiidae) in branches cut from a Norway spruce, *Picea abies* (L.) Karsten, planted as an ornamental tree (diameter at breast height 30.5 cm) in a homeowner's yard in Oakland, California. Adults and larvae were also observed in the stem of the declining, yet live, tree from which the branches were cut. In both the stem and branches, the adults and larvae were clustered together with adults and larvae of the Monterey pine engraver beetle, *Ips mexicanus* (Hopkins) (Coleoptera: Scolytidae). In the cut branches, adult and larval *E. mollis* were also intermixed with adults and larvae of the California five-spined ips, *I. paraconfusus* Lanier. Larval *E. mollis* had excavated extensive tunnels in the phloem and bark that contained uniformly shaped, dark fecal pellets. The mines deeply scored and sometimes entered the xylem.

Branches (diameter 3–7 cm) containing larvae, pupae, and adults were collected on 22 Feb 1990 and placed into a laboratory cage at room temperature (16.1° C–29.4° C). Adults began emerging from the branches immediately, and 28 insects emerged over a two-month period with a peak emergence occurring between 15 Mar 1990 and 1 Apr 1990. Additional adults, many of which were alive, were recovered from the cage on the following dates: 17 Nov 1990 (1); 27 Apr 1991 (16); 11 May 1991 (3); 8 Jun 1991 (9); 13 Oct 1991 (42); 18 Jul 1992 (543, including 97 live beetles); 30 Jul 1992 (114, including 88 live beetles); 15 Sep 1992 (115, including 22 live beetles); and 24 Sep 1992 (4, including 1 live beetle). In addition, larvae were found on the bottom of the same cage on: 18 Jul 1992 (37, including 19 live larvae); 15 Sep 1992 (6, all alive); and 24 Sep 1992 (2, both alive). On 18 Jul 1992, adults were observed mating on the bark surface, and on 30 Jul 1992 eight different pairs were recovered *in copulo* from the cage. Living larvae were also recovered from the floor of a second cage containing stem material from the same tree, thirteen months after that material was placed into the cage. This long period of collection of live adults suggests either (1) delayed emergence

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or (2) re-infestation of the same bark-covered branches or stem material; observation of mating adults seems to suggest the latter.

Ernobius mollis, referred to as the bark anobiid (Tooke 1946), pine bark anobiid (Hockey 1985), or the false furniture beetle (Bevan 1987) and as the "Weiche or Feinhaarige Nagekäfer or Klopfkäfer" (Gr: soft or finely haired, gnawing or knock beetle) (Schmidt 1971), has long been included among the pests of structures in Europe (Kemner 1915; Trägårdh 1938; Bletchley 1964, 1967). Hockey (1985) states that *E. mollis* is univoltine with adults present in spring and early summer. Its biology in Europe has been studied by Gardiner (1953); she lists coniferous softwoods, such as *Larix decidua* Miller, *P. abies, Pinus canariensis* C. Smith, *Pinus nigra* Arnold, *Pinus pinaster* Aiton, *Pinus radiata* David Don, *Pinus sylvestris* L., *Pinus taeda* L., and *Pseudotsuga taxifolia* (Poiret) Britton [= *menziesii* (Mirbel) Franco] as recorded hosts. *Ernobius mollis* does not appear to attack hardwoods. Although there are reports of damage to flooring, veneer, and furniture, *E. mollis* appears to be most often associated with bark-covered timbers installed or stored in new structures, rustic cottages, museums, or sawmill yards. Tooke (1949), Bletchley (1967), and Schmidt (1971) suggest that floorboards, veneers, and finishings might be damaged when *E. mollis* emerges from underlying support pieces containing bark. *Ernobius mollis* has even been noted to attack unfinished edges and knots in rough sawn boards, presumably deriving nourishment from the occluded bark around the knot (Tooke 1946, Bletchley 1967). Dominik (1958) has observed that several generations of *E. mollis* will attack the same piece of bark-covered wood. However, it is doubtful that this species can reinfest wood products once the bark has been removed or depleted by infestation. Because of its requirement for bark, which is rarely present in large quantities in modern home construction, Bletchley (1965) states that an active *Ernobius* infestation, although uncommon, is chiefly found in comparatively new homes.

In the forest, *E. mollis* is prevalent in burned timber (Clarke 1932) and has been noted in dead standing trees up to 20.0 cm in diameter (Kelsey 1946). In contrast with our observation in Oakland, Tooke (1946) states that *E. mollis* does not attack living trees or green wood. In fact, he found that *E. mollis* had a preference for dry seasoned timber and would only attack wood in timber stacks that had been seasoned for over six months. However, Tooke (1949) reports that infestations may commence in dead branches of living trees and spread down into the main trunk. In Great Britain, Bletchley (1967) indicates that the natural habitat for *E. mollis* is "recently dead softwood trees or fallen branches where the bark is still present," but Bevan (1987) notes that *E. mollis* causes obvious damage symptoms but has slight or no effect on "pole and older" sized conifers. In France, Roques (1983) describes damage by *E. mollis* to cones of the exotic species, *Sequoiadendron giganteum* Buchholz and *P. menziesii.*

Unger (1986) reports that larval damage is almost always restricted to the "Rinde" (Gr: inner and outer bark), giving the bun-shaped (Kelsey 1946) or lentil-shaped (Schmidt 1951) fecal pellets a brown color. Gardiner (1953) also states that the larva is restricted to the bark, but that the pupal cell penetrates the outer part of the wood. However, most authors (Clarke 1932; Kelsey 1946; Tooke 1946; Schmidt 1951, 1971; Dominik 1958; Bletchley 1967; Hickin 1968; Hockey 1985) suggest that the feeding by late stage larvae includes the xylem, which is consistent with our observations in California. Feeding by larvae results in frass that contains

both dark- (from the bark) and light-colored (from the sapwood) fecal pellets (Bletchley 1967). Schmidt (1971) states that fecal pellets from bark feeding are egg-shaped, although those from sapwood feeding are lentil-shaped. Microscopic examination of the fecal pellets can be used as a diagnostic character to differentiate damage by *E. mollis* from more economically important species (Schmidt 1951). According to Schmidt (1971) and Unger (1986), occurrences of *E. mollis* in Europe have been more frequent in recent years. However, Becker (1984) characterizes the damage as "relatively harmless." Preventative treatment involves timely removal of bark from wood intended for service in building construction (Bletchley 1967, Hockey 1985, Unger 1986).

From its native distribution in northern Europe, *E. mollis* has been introduced into the North American continent and the southern hemisphere (Tooke 1946, Casimir 1958, Hickin 1968). Tooke (1946) describes the entry of *E. mollis* into South Africa in 1937 via packing crates containing machinery for a sawmill. The crates were constructed of pine slabs that had a considerable surface area of bark, but during crate construction the infested, bark-covered regions of the slabs were turned inward and not readily visible. From the sawmill, the insect spread rapidly throughout the country in infested products.

Sometime during this century *E. mollis* became established in eastern North America (Craighead 1950, Simeone 1962) with collection records from Ontario to Nova Scotia in the north, and Texas to Florida in the south (White 1982). Simeone (1962) noted that although *E. mollis* appears to be quite abundant in the major insect collections in eastern North America, it was reported in only one instance in a survey of structural pest cases in New York state. Although historically it appears to have been of little significance in structures in North America, during the last decade it has been frequently found damaging bark-covered logs used in home and cabin construction in New York (J. B. Simeone, personal communication). In South Africa, New Zealand, and Australia, where *P. radiata* has been planted extensively and used for building material, *E. mollis* has been (Casimir 1958), and continues to be (Hockey 1985), a damaging pest of timber and occasionally buildings. In an examination of specimens at the California Academy of Sciences in San Francisco, we have found U.S. and Canadian locality records consistent with White (1982), and we noted five specimens collected in 1931 from Tokyo, Japan.

Although there are no California Department of Food and Agriculture interception records for *E. mollis,* our collection from Oakland is not the first North American record of this insect west of Texas. There is one specimen labelled *Ernobius mollis* in the University of California Essig Museum collected in 1952 and labelled "Slab crate, *ex* Michigan, Hueneme Calif." This interception most likely occurred in southern California at Port Hueneme located 6 km S of Oxnard. Our experiences show that this species is established in Oakland, California. This insect may have spread to California through rough-wood packing case timbers from the ports of Oakland or San Francisco as occurred in South Africa. However, it could also have entered the state through interstate overland commercial or residential traffic. It is significant that we found *E. mollis* contributing to the death of a living tree in California, because it appears to have caused greater damage as an introduced insect than it did in its old world habitat (Hickin 1968).

Although we have recovered this insect from a European tree species that has

been listed as one of its principal hosts (Gardiner 1953), it is important to note that *E. mollis* has again been introduced into a region that has abundant plantings of *P. radiata. Ernobius mollis* could act in concert with *Ips* spp. (unpublished data) and pitch canker disease (McCain et al. 1987) to contribute to mortality of *P. radiata.* Because of its requirement for sapwood with bark attached, it is doubtful that *E. mollis* will play a major role as a structural pest in urban California. In contrast to the situation in the southern hemisphere, the widespread urban and native stands of *P. radiata* in the San Francisco Bay Area are not used for wood products. However, it could enter structures through firewood and thus damage rustic finishings. It is important that pest control operators distinguish between the symptoms of damage by *E. mollis* and that by the California deathwatch beetle, *Hemicoelus gibbicollis* (LeConte). The latter species re-infests finished wood products, but the former does not. The adults and galleries of these species could be difficult to distinguish; however, they produce distinctive fecal pellets. In contrast to the bun-shaped, often dark-colored pellets produced by *E. mollis, H. gibbicollis* produces elongated, light-colored pellets.

Record.—CALIFORNIA. *ALAMEDA* Co.: 2 km SE of Lake Merritt, Greenwood Avenue, Oakland, 22 Feb 1990, S. J. Seybold, *Picea abies.*

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HOST PLANT PREFERENCES OF *ACANTHOSCELIDES AUREOLUS* (HORN) (COLEOPTERA: BRUCHIDAE)

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Abstract.—The discrimination of *Acanthoscelides aureolus* Horn (Coleoptera: Bruchidae) among individuals of its host plants, *Astragalus kentrophyta* var. *implexus* (Fabaceae), was investigated using a path analytical model that included seven demographic variables. Seed number proved to be the plant trait that contributed most to the rate bruchid use among host individuals. Seed number also exerted an important indirect effect on the correlations between the rate of bruchid use and the other variables in this analysis.

Key Words.—Insecta, Bruchidae, *Acanthoscelides aureolus, Astragalus kentrophyta* var. *implexus,* path analysis, oviposition preference

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Acanthoscelides aureolus Horn (Coleoptera: Bruchidae) is a generalist seed-eating bruchid that uses the seeds of host plants across a broad range of taxonomic affinities (Johnson 1970). At high elevations in the White Mountains of Inyo and Mono Counties in eastern California, *A. aureolus* uses the seeds of an alpine cushion plant, *Astragalus kentrophyta* var. *implexus* (Fabaceae) (hereafter referred to as Aki), to the exclusion of all other hosts (Owen 1991a). *A. aureolus* is the only predispersal consumer of Aki seeds at alpine elevations in the White Mountains (Owen 1991b). The size of the study population of *A. aureolus* varies greatly from year to year (Owen 1991b); a commonplace feature among species of seed eating insects with narrowly defined diets (Janzen 1970, Huffaker et al. 1984).

Patterns of predispersal seed predation have important demographic consequences for populations of flowering plants. By reducing the number of seeds released to the environment, seed-eating insects affect the density of propagules in the dispersal range of each parent plant. In turn, the recruitment of adults into the host population may be adversely affected by either a reduction in the absolute number of seeds in the soil or by decreasing the likelihood of propagules reaching safe sites (Harper 1977).

Because seed predators can have a profound impact on their host species (Janzen 1971, 1981; Louda 1982; Fenner 1985), knowledge of the criteria by which female insects discriminate among potential hosts would be especially useful in the management of rare plant species. Because several species of *Astragalus* in North America experience significant fecundity losses due to seed predation (e.g., Alverson 1985, Smithman 1988, Wright 1988, Lesica & Elliott 1989, Rittenhouse 1990), an analysis of the *A. aureolus*/Aki system could potentially serve as a robust model for the analysis of other bruchid/legume systems.

Seed predation patterns may be the result of the dispersal pattern of the insect or may be due to choices made by ovipositing females. Discrimination among

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potential oviposition sites may be influenced by a variety of host plant attributes including fruit color (Riedl & Hislop 1985, Owens & Prokopy 1986), fruit size (Messina 1990), leaf size (Whitham 1978, 1980), plant or shoot size (Everly 1959, Rausher 1983, Fritz & Nobel 1989, Cipollini & Stiles 1991), and flowering phenology (Feeny 1976, Pettersson 1991).

I investigated the rates of seed predation by *A. aureolus* on a group of Aki plants in the White Mountains. Seed predation at this site varies significantly and nonrandomly among individuals (0–100%, Owen 1991b) suggesting that females are discriminating among hosts (Rausher 1983). This discrimination is probably not due to differences in phenology among host individuals because Aki flowers and fruits continuously throughout the short growing season in the White Mountains (Owen 1991b). Furthermore, because the chemical constitution of a species' seeds tends to be very uniform within populations (Janzen 1978), it is unlikely that bruchids would discriminate among host plants on the basis of seed quality. Here, I test the importance of physical/reproductive characteristics among Aki individuals to the discrimination by ovipositing *A. aureolus* females. This particular bruchid/*Astragalus* interaction is interesting because of the unusual and severe nature of the environment that these species share. This paper presents an analysis of the relationship between the level of bruchid infestation and physical/reproductive attributes of Aki over a two year period.

Materials and Methods

I randomly selected a group of 80 Aki plants on the alpine dolomite barrens of Sheep Mountain in the White Mountains, Mono County, California (elevation 3620 m) for study. Little is known about the ways in which species of *Acanthoscelides* select oviposition sites. Cipollini & Stiles (1991) report that *A. obtectus* females select among *Phaseolus* flowers on the basis of their not having been previously visited by an ovipositing female, and that they do not discriminate among oviposition sites on the basis of expected seed size. Green & Palmbald (1975) report that *Acanthoscelides fraterculus* selects among potential *Astragalus* species for oviposition on the basis of their flowering phenology, and physical and chemical differences between the fruits of potential host species. In light of a general lack of a priori expectations as to which host plant traits might be most important to a female bruchid in her search for oviposition sites, I monitored seven demographic characteristics (Table 1) that could reasonably be assumed to be the basis of discrimination among host plants by ovipositing female *A. aureolus* throughout the 1989 and 1990 growing seasons. Plant size was measured as the area (mm^2) covered by individual cushions at the beginning of each growing season. At the end of each growing season all fruits and seeds produced on each plant were collected and individually weighed. Seed dispersal occurs very late in the growing season, is passive and very limited in distance (Owen 1991b), so I am confident that I was able to harvest every seed produced by every plant. The vigor of each plant was estimated as its relative annual growth (i.e., the total growth in area during a season divided by the initial plant size). Each seed produced by the 80 Aki plants was individually inspected for the evidence of predation. Because *A. aureolus* larvae leave a characteristic scar on seeds, their presence or absence can be unequivocally determined by visual inspection. Furthermore, microscopic inspection of several hundred Aki flowers showed that *A. aureolus* eggs and larvae

Table 1. Comparison of mean trait values across in the two years of the experiment.

	1989		1990			
	Mean	CV[a]	Mean	CV	t[b]	P
Plant size (mm square)	6580.04	57.28	7460.22	54.71	−4.94	0.01
Fruit number	24.53	118.50	29.27	110.45	−0.98	ns
Seed number	28.60	117.40	33.06	109.82	−0.91	ns
Fruit weight (milligrams)	1.54	23.50	1.46	24.40	2.03	0.05
Seed weight (milligrams)	1.78	17.99	1.68	23.63	2.26	0.05
Seed/fruit	0.98	57.00	1.04	40.95	−0.29	ns
Vigor (growth/size)	0.23	146.07	0.19	179.13	1.18	ns

[a] The coefficients of variation (CV) are given to indicate the relative variability of each character.
[b] Differences in the means tested with two-tailed paired Student's t.

are not present in abortive flowers (Owen 1991b). I am, therefore, confident that I have accounted for all oviposition events made by *A. aureolus* on the 80 Aki plants.

The effect of each plant trait on the level of seed predation was investigated with a path analytical model (Dewey & Lu 1959, Sokal & Rohlf 1981). A path analysis allows the simultaneous consideration of several intercorrelated variables in a linear regression frame work. In the path analysis, a cause and effect relationship between the predictor variables (the seven demographic characteristics presented in Table 1) and the criterion variable (rate of bruchid attack) is assumed. The standard partial correlation coefficients from the multiple linear regression are presented as path coefficients, and as such represent the direct influence of those variables on the criterion variable. All unknown (residual) factors are combined into a coefficient of nondetermination (U), which reflects the fraction of the model variance unaccounted for by the predictors. Because the path analysis requires data to conform to the distributional assumptions of linear regressions, the appropriate transformations have been made to improve the normality of some variables. Separate paths are constructed for the 1989 and 1990 data.

The rate at which *A. aureolus* uses *Astragalus* seeds is expressed as the ranked percentage (Conover & Iman 1981) of seeds per plant used by *A. aureolus*. Ranked rates of seed use best serve the objective of the model in that ovipositing females may not always choose the "best" host plant but must rank the quality of and choose among the host plants that they encounter (Rausher 1983).

Because many of the predictor variables are intercorrelated (Table 2), each may exert a telling influence on the correlation between other predictors and the criterion variable. The potential indirect effects of variables can be investigated by using the normal equations originally used to determine the path coefficients. For example, for the first variable in this analysis,

$$r_{1Y} = P_{1Y} + r_{12}P_{2Y} + r_{13}P_{3Y} + r_{14}P_{4Y} + r_{15}P_{5Y} + r_{16}P_{6Y} + r_{17}P_{7Y}.$$

In this expression, r is the coefficient of correlation between variables i and j, Y is the criterion variable, and P represents standard regression coefficients. There-

Table 2. Correlations among plant traits used in the path analysis. Values above the diagonal are based on 1989 data, those below the diagonal are for 1990 data.

	Plant size	Fruit number	Seed number	Fruit weight	Seed weight	Seeds/fruit	Vigor
Plant size	—	0.403**[a]	0.532**	0.015	0.025	−0.006	−0.255*
Fruit number	0.621**	—	0.509**	0.071	0.201	−0.341**	0.117
Seed number	0.585**	0.966**	—	0.035	0.177	0.253*	−0.017
Fruit weight	−0.053	0.054	0.086	—	0.368**	−0.010	0.155
Seed weight	0.035	0.102	0.076	0.284*	—	−0.070	0.255*
Seeds/fruit	−0.036	0.007	0.209	0.260*	0.100	—	0.230*
Vigor	−0.130	−0.069	−0.039	0.043	0.052	0.137	—

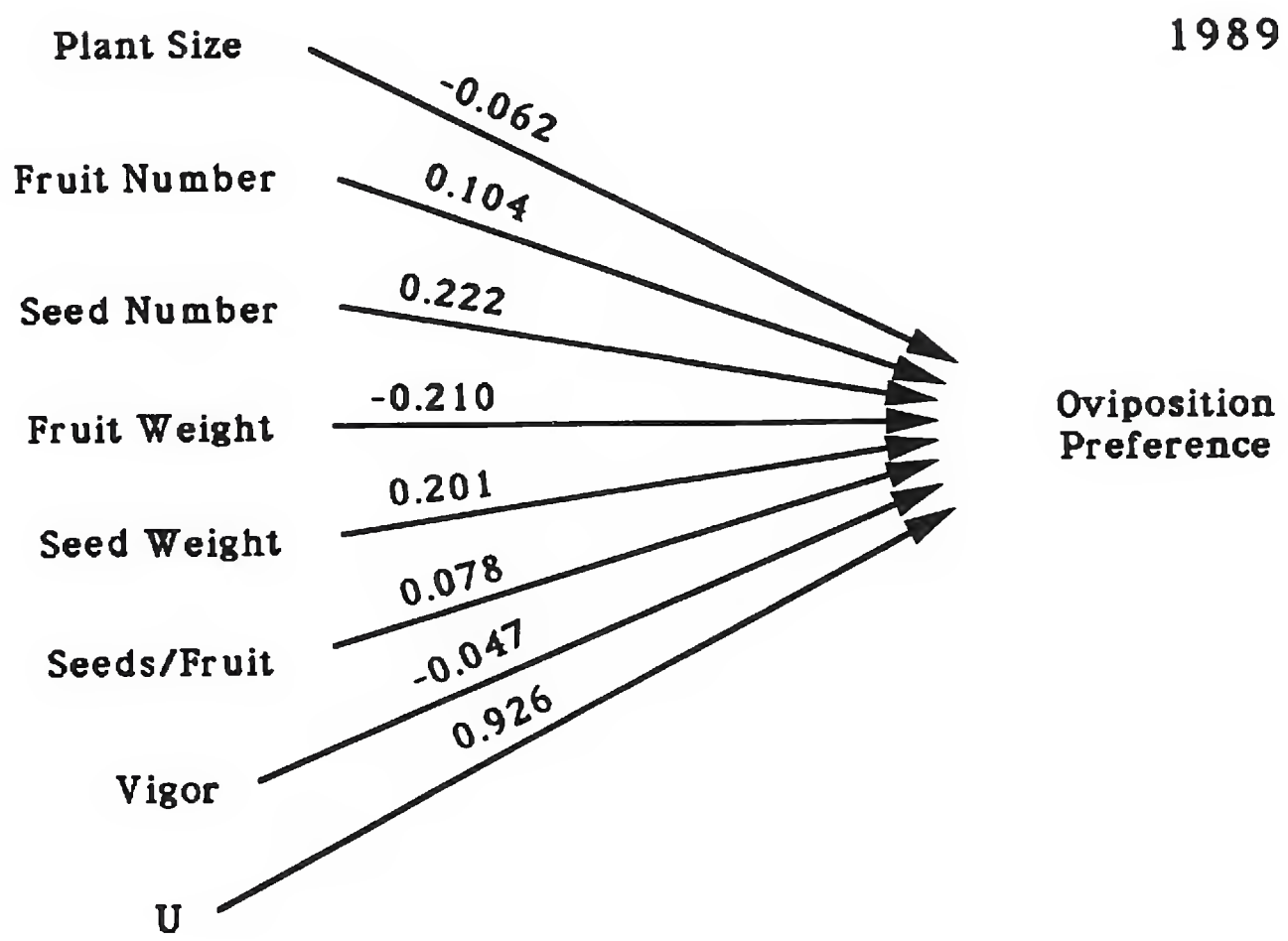
[a] Significance levels: * = $P < 0.05$; ** = $P < 0.01$.

fore, r_{1Y} is the correlation between predictor variable 1 and the criterion variable and P_{1Y} represents the direct effect (path coefficient) of predictor variable 1 on the criterion variable Y. The indirect effects are represented by the products $r_{ij}P_{jY}$. In the example above, a small correlation between predictor variables 1 and j will exert a minimal influence on the overall correlation between predictor 1 and the criterion variable by decreasing the contribution of $r_{1j}P_{jY}$ to r_{1Y}. Conversely, when r_{1j} is large, $r_{1j}P_{jY}$ exerts a nontrivial effect on r_{1Y}. An analysis of the indirect effects is crucial to gaining a complete understanding of the relationship between the predictor variables and the criterion variable.

Results and Discussion

Mean values and coefficients of variations for the seven plant traits used in this analysis are presented in Table 1. Paired Student's t-tests were used to discern whether trait values differed significantly between 1989 and 1990. Not surprisingly, plant size was significantly greater in 1990 than in 1989 (a reflection of annual growth). There were significant differences in the mean (within individual) weight of fruits and seeds between years (Table 1). Although 1989 reproductive products were heavier, the difference between years is no more than 0.1 mg (6% change). Although the coefficients of variation for mean seed size are small (Table 1), within-individual seed weights vary by as much as a factor of eight (Owen 1991b). This pattern of greater variation within, rather than among, individuals for seed size variation would make discrimination very difficult among host plants by the female bruchid on the basis of seed size. The number of fruits and seeds produced by individuals did not differ significantly between years (Table 1). In contrast, the number of fruits and seeds produced varied widely among test individuals. Individual plants produced 0–165 and 0–187 fruits, and 0–179 and 0–150 seeds in 1989 and 1990, respectively. Vigor, the relative growth rate of individuals, did not differ significantly between years, but varied widely among individuals. In both years, some individuals decreased in size by just over 50%, but others increased by approximately 70%. Finally, the number of seeds per fruit was consistent between years and among individuals.

The correlations among the demographic variables used in the path analysis are presented in Table 2. There are several significant correlations, most notable are the associations between fruit and seed number and plant size. The correlation between fruit and seed weight is likewise consistent across years. Other correlations



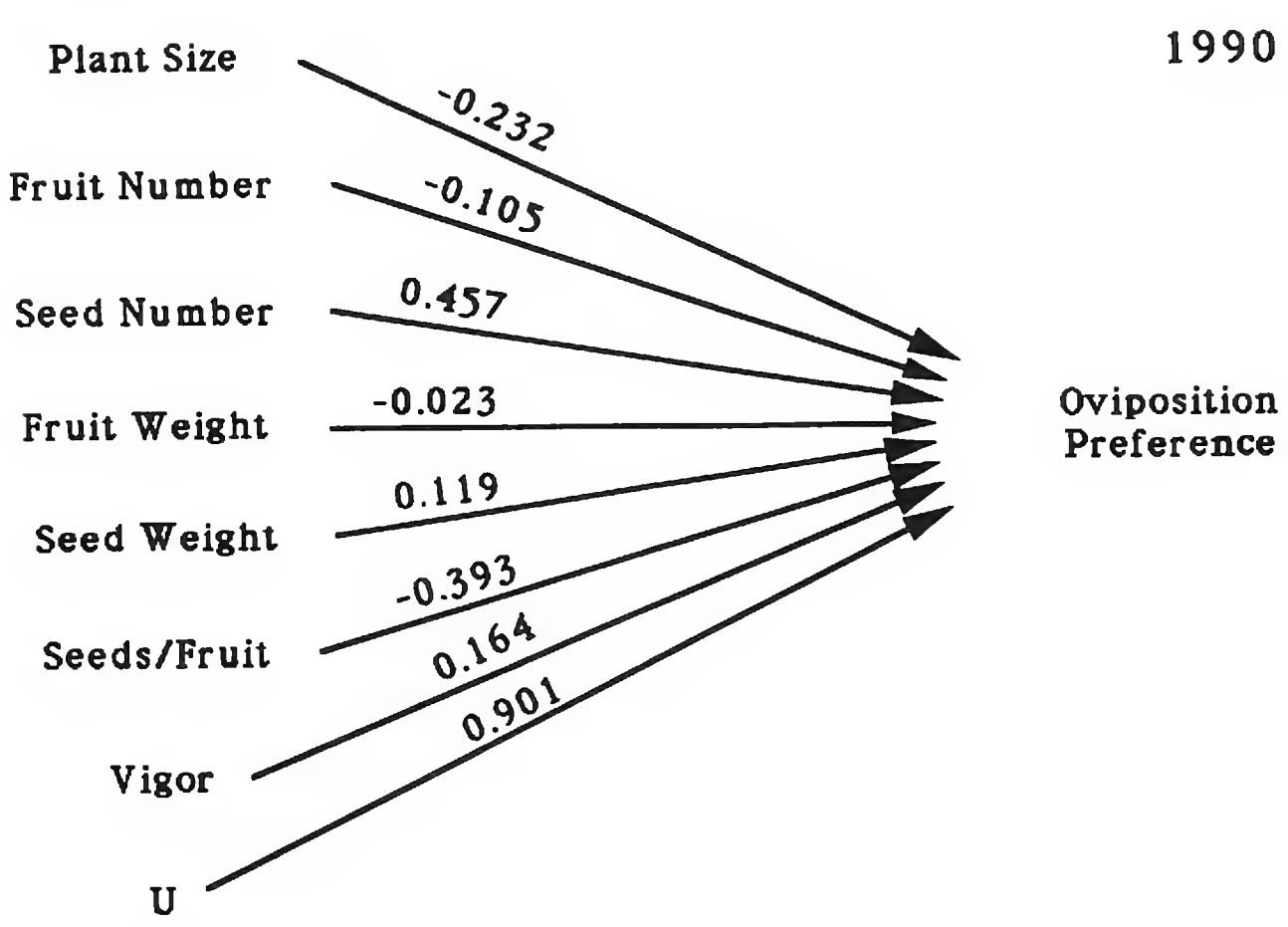


Figure 1. Path coefficients (direct effects) for predictor variables on the ranked percentage of seeds consumed by bruchid larvae in 1989 and 1990. Cross correlations among predictor variables are presented in Table 2. *U* represents the coefficient of nondetermination, a residual factor for the path model.

occur only in either 1989 or 1990. Such transient correlations are difficult to interpret alone and may, in fact, be spurious.

The results of the path analyses for 1989 and 1990 are presented in Fig. 1. Because there is no way of establishing statistical significance for path coefficients (but see Mitchell 1991), their value must be judged in accordance with their individual magnitudes. The large residual factors (U) indicates that most of the variation in bruchid infestation rate among plants was not accounted for by the path analysis. Although the paths for seed number consistently have the greatest coefficients, there are some potentially important inconsistencies in the results for the other predictor variables. The importance of fruit weight changes by an order of magnitude between years. Fruit weight becomes less important to the model in 1990, when fruit weight is significantly less compared to 1989. This correlation might be due to heavier fruits, with thicker walls, being more difficult to oviposit in than are lighter fruits with correspondingly thinner walls. The direct effect of fruit number, seeds per fruit, and vigor changes sign between years, indicating that they are poor predictors of host quality. The advantage of monitoring bruchid selection of host plants for more than one year is evidenced in the path coefficient for seeds per fruit (Fig. 1). In 1989 that direct effect was trivial (0.078), but in 1990 it was second in magnitude only to seed number (−0.393). Seed weight was consistently important in host plant selection in both years. Plant size, although consistently negatively associated with host plant preference, varied greatly in magnitude between years.

The effects of the predictor variables, through their influence on one another, are presented in Table 3. In Table 3, the correlation coefficients between individual predictors and bruchid infestation rates (r_{iY}) are presented as the sums of the path coefficients (P_{iY}) and the indirect effects ($r_{ij}P_{jY}$). These decompositions show that most variables contribute very little to the correlations between predictors and criterion variables and consequentially do not substantially affect individual correlations among predictors and bruchid use (r_{iY}). In contrast, the indirect effect of seed number ($r_{i3}P_{3Y}$) consistently exerts an important influence on the relationship between predictors and the ranked rate of *A. aureolus* infestation.

The combined results of the path analysis and the decomposition of the normal equations strongly supports seed number as the most important trait of Aki to *A. aureolus* females when making oviposition choices. However, at the time of oviposition the size of seed crop of each plant is ambiguous; this suggests that either the bruchids are cueing on some plant attribute, which is correlated with seed production, that is not considered in this analysis, or that they are somehow using the history of seed production for a given plant as an indicator of its future productivity. Table 4 provides the results of simple linear regressions for the values of each predictor variable in 1990 on the 1989 trait values. Plant size is the trait that is most consistent across years ($r^2 = 0.877$). However, the density of seeds produced by individual plants (seeds produced/plant size) is inconsistent across years ($t = 0.463$, $P = 0.645$), indicating that plant size is a poor predictor of seed production. Seed number is the next most consistent plant characteristic in Aki ($r^2 = 0.407$). Additionally, seed production by Aki is exceptionally stable in the face of environmental fluctuations. In an experiment using 189 Aki plants, no changes in fecundity were detected in response to supplemental watering, herbivore abatement, fertilization, or the removal of competitors (Owen 1991b).

Table 3. Indirect effects on the correlation between individual predictor variables and bruchid infestation rate.

Category/effect	Variable	Value	
		1989	1990
Plant Size vs. Bruchid Infest. Rate		0.112	−0.032
Direct effect	P_{1Y}	−0.062	−0.232
Indirect effect of fruit number	$r_{12}P_{2Y}$	0.042	−0.065
Indirect effect of seed number	$r_{13}P_{3Y}$	0.118	0.267
Indirect effect of fruit weight	$r_{14}P_{4Y}$	−0.003	0.001
Indirect effect of seed weight	$r_{15}P_{5Y}$	0.005	0.004
Indirect effect of seeds/fruit	$r_{16}P_{6Y}$	−0.001	0.014
Indirect effect of vigor	$r_{17}P_{7Y}$	0.012	−0.021
Seed Number vs. Bruchid Infest. Rate		0.291	0.139
Direct effect	P_{3Y}	0.222	0.457
Indirect effect of plant size	$r_{31}P_{1Y}$	−0.033	−0.136
Indirect effect of fruit number	$r_{32}P_{2Y}$	0.053	−0.101
Indirect effect of fruit weight	$r_{34}P_{4Y}$	−0.007	0.002
Indirect effect of seed weight	$r_{35}P_{5Y}$	0.036	0.009
Indirect effect of seeds/fruit	$r_{36}P_{6Y}$	0.020	−0.082
Indirect effect of vigor	$r_{37}P_{7Y}$	0.001	−0.006
Seed Weight vs. Bruchid Infest. Rate		0.165	0.097
Direct effect	P_{5Y}	0.201	0.119
Indirect effect of plant size	$r_{51}P_{1Y}$	−0.002	−0.008
Indirect effect of fruit number	$r_{52}P_{2Y}$	0.021	−0.011
Indirect effect of seed number	$r_{53}P_{3Y}$	0.039	0.035
Indirect effect of fruit weight	$r_{54}P_{4Y}$	−0.077	−0.007
Indirect effect of seeds/fruit	$r_{56}P_{6Y}$	−0.006	−0.040
Indirect effect of vigor	$r_{57}P_{7Y}$	−0.012	0.009
Vigor vs. Bruchid Infest. Rate		0.014	0.135
Direct effect	P_{7Y}	−0.047	0.164
Indirect effect of plant size	$r_{71}P_{1Y}$	0.016	0.030
Indirect effect of fruit number	$r_{72}P_{2Y}$	0.012	0.007
Indirect effect of seed number	$r_{73}P_{3Y}$	−0.004	−0.018
Indirect effect of fruit weight	$r_{74}P_{5Y}$	−0.033	−0.001
Indirect effect of seed weight	$r_{75}P_{5Y}$	0.051	0.006
Indirect effect of vigor	$r_{76}P_{6Y}$	0.018	−0.054
Fruit Number vs. Bruchid Infest. Rate		0.186	0.190
Direct effect	P_{2Y}	0.104	−0.105
Indirect effect of plant size	$r_{21}P_{1Y}$	−0.025	−0.144
Indirect effect of seed number	$r_{23}P_{3Y}$	0.113	0.442
Indirect effect of fruit weight	$r_{24}P_{4Y}$	−0.015	0.001
Indirect effect of seed weight	$r_{25}P_{5Y}$	0.041	0.012
Indirect effect of seeds/fruit	$r_{26}P_{6Y}$	−0.027	−0.003
Indirect effect of vigor	$r_{27}P_{7Y}$	−0.006	−0.011
Fruit Weight vs. Bruchid Infest. Rate		−0.130	−0.039
Direct effect	P_{4Y}	−0.210	−0.233
Indirect effect of plant size	$r_{41}P_{1Y}$	−0.001	0.012
Indirect effect of fruit number	$r_{42}P_{2Y}$	−0.007	−0.006
Indirect effect of seed number	$r_{43}P_{3Y}$	0.008	0.039
Indirect effect of seed weight	$r_{45}P_{5Y}$	0.074	0.034
Indirect effect of seeds/fruit	$r_{46}P_{6Y}$	−0.001	−0.102
Indirect effect of vigor	$r_{47}P_{7Y}$	−0.007	0.007
Seeds/Fruit vs. Bruchid Infest. Rate		0.076	−0.262
Direct effect	P_{6Y}	0.078	−0.393
Indirect effect of plant size	$r_{61}P_{1Y}$	<0.001	0.008

Table 3. Continued.

Category/effect	Variable	Value 1989	Value 1990
Indirect effect of fruit number	$r_{62}P_{2Y}$	−0.036	−0.001
Indirect effect of seed number	$r_{63}P_{3Y}$	0.056	0.096
Indirect effect of fruit weight	$r_{64}P_{4Y}$	0.002	−0.006
Indirect effect of seed weight	$r_{65}P_{5Y}$	−0.014	0.012
Indirect effect of vigor	$r_{67}P_{7Y}$	−0.011	0.022

Fruit and seed weight are likewise consistent among Aki individuals across years (Table 4), although there are significant between-year differences in population wide mean values of these traits (Table 1). Further complicating the reliability of fruit and seed weight as indicators of host quality are the generally small correlations between these traits and seed number (Tables 2 and 4). Finally, although the path coefficients for fruit and seed weight are the same magnitude as the path for seed number in 1989 (Fig. 1), their relative importance declines dramatically in 1990 suggesting instability in those traits that would not favor their use as a guide to host plant quality.

It is not surprising that *A. aureolus* would discriminate among potential hosts based on consistently high rates of fecundity. There should, however, be a cost incurred by Aki individuals in being consistently selected as an oviposition site for *A. aureolus*. I suggest that plants that are subject to chronic seed predation could reduce predation levels by increasing their interannual variance in seed production. This is commonly accomplished by the occasional production of large numbers of offspring, and producing very few offspring in intervening years (i.e., masting, see Janzen 1969). Although common among tree species, masting does not occur among herbaceous perennials in general (Fenner 1985), or in Aki specifically (Owen 1991b). The consequence of consistent seed production is chronic and, in some cases, heavy reductions in fecundity. For Aki, regressions of the number of seeds that escape predation on the total number produced in both 1989 and 1990 have slopes significantly less than, but very near, unity (Table 5). Consequently, greater seed production does not lead to proportionally greater survivorship among the annual progeny cohort of each plant. This pattern may be

Table 4. Results of simple linear regression analyses comparing predictor trait values between 1989 and 1990.

Predictor	F	P	r^2
Plant size[a]	550.05	0.0001	0.877
Fruit number	9.10	0.0035	0.107
Seed number	51.55	0.0001	0.407
Fruit weight	36.36	0.0001	0.339
Seed weight	22.26	0.0001	0.247
Seed/fruit	0.39	0.5343	0.007
Vigor	4.16	0.0448	0.052

[a] Data are transformed as required to impose normality.

Table 5. Slopes and confidence intervals for regressions of the number of seeds produced that escaped predation on the total number of seeds produced.

Year	Slope	99% lower	99% upper
1989	0.965	0.934	0.996
1990	0.823	0.766	0.881

responsible for the overall low fecundity observed among Aki plants. Although all plants produce many more flowers than seeds (i.e., many flowers are regularly aborted, Owen [1991b]), few plants produce many seeds. The maximum seed crops among Aki plants in this analysis were 179 and 150, in 1989 and 1990, respectively. Mean seed crops were much lower, however, at 28.6 in 1989 and 33 in 1990 (Table 1).

It is yet to be shown that the interaction illustrated here is common to other bruchid/*Astragalus* systems. It is important to note that the results reported here were recorded in an extreme environment and the ecology of these species may differ in fundamental ways in more amiable habitats. Because Aki and *A. aureolus* occur together at lower elevations (Owen 1991b), a broader investigation could be accomplished and would add to a greater understanding of the biology of both species.

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LOW ALLOZYME VARIATION IN FORMOSAN SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE) COLONIES IN HAWAII

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Abstract.—Cellulose acetate gel electrophoresis was used to assess allozyme variation among Hawaiian populations of *Coptotermes formosanus* Shiraki. Twenty-nine protein loci were resolved in an initial survey. Eight of these proved to be reliable, and 13 termite colonies from the islands of Oahu and Maui were surveyed for these loci. Individual workers (pseudergates) were monomorphic for all loci across all colonies, although preliminary results from starch gel electrophoresis suggest that a very low level of polymorphism is present at one locus. This finding is consistent with previous electrophoretic studies of *C. formosanus* populations, which have found little genetic variation. Low allozyme variation may be characteristic of this species, or Hawaiian *C. formosanus* colonies may be derived from a single introduction or from multiple introductions of very closely related individuals.

Key Words.—Insecta, termite genetics, cellulose acetate gel electrophoresis

The Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae) is native to China (Kistner 1985) but has been distributed extensively by man through the tropical and subtropical regions of the world. The range of this serious economic pest now includes South Africa, Sri Lanka, Japan, Taiwan, Guam, the Midway islands, the Hawaiian islands and the United States mainland (Su & Tamashiro 1987). *Coptotermes formosanus* was collected in Honolulu, Hawaii in 1907 and recorded as established in 1913 (Zimmerman 1948); however, it may have been present as early as 1869 (Tamashiro et al. 1987). Since then, it has spread throughout the islands of Oahu and Kauai, with distributions restricted to certain seaports or areas immediately surrounding seaports on the islands of Hawaii, Maui, Molokai and Lanai (Tamashiro et al. 1987). This termite has spread slowly through the state and has been distributed mainly via the actions of man (Higa & Tamashiro 1983, Tamashiro et al. 1987). However, it has become the most important economic pest in the Hawaiian islands (Tamashiro et al. 1987). Populations of mature colonies of *C. formosanus* number in the millions of individuals (Su et al. 1984).

Demographics, foraging dynamics, and biochemical characteristics of several *C. formosanus* colonies on Oahu are monitored regularly using a trapping technique (Tamashiro et al. 1973). Aggressive interactions have been observed between members of some, but not all, of these termite colonies (Su & Haverty 1991). Such agonistic displays may represent interactions between genetically differentiated colonies (Su & Scheffrahn 1988). Allozyme electrophoresis has frequently been used to obtain estimates of insect genetic relatedness (Berlocher

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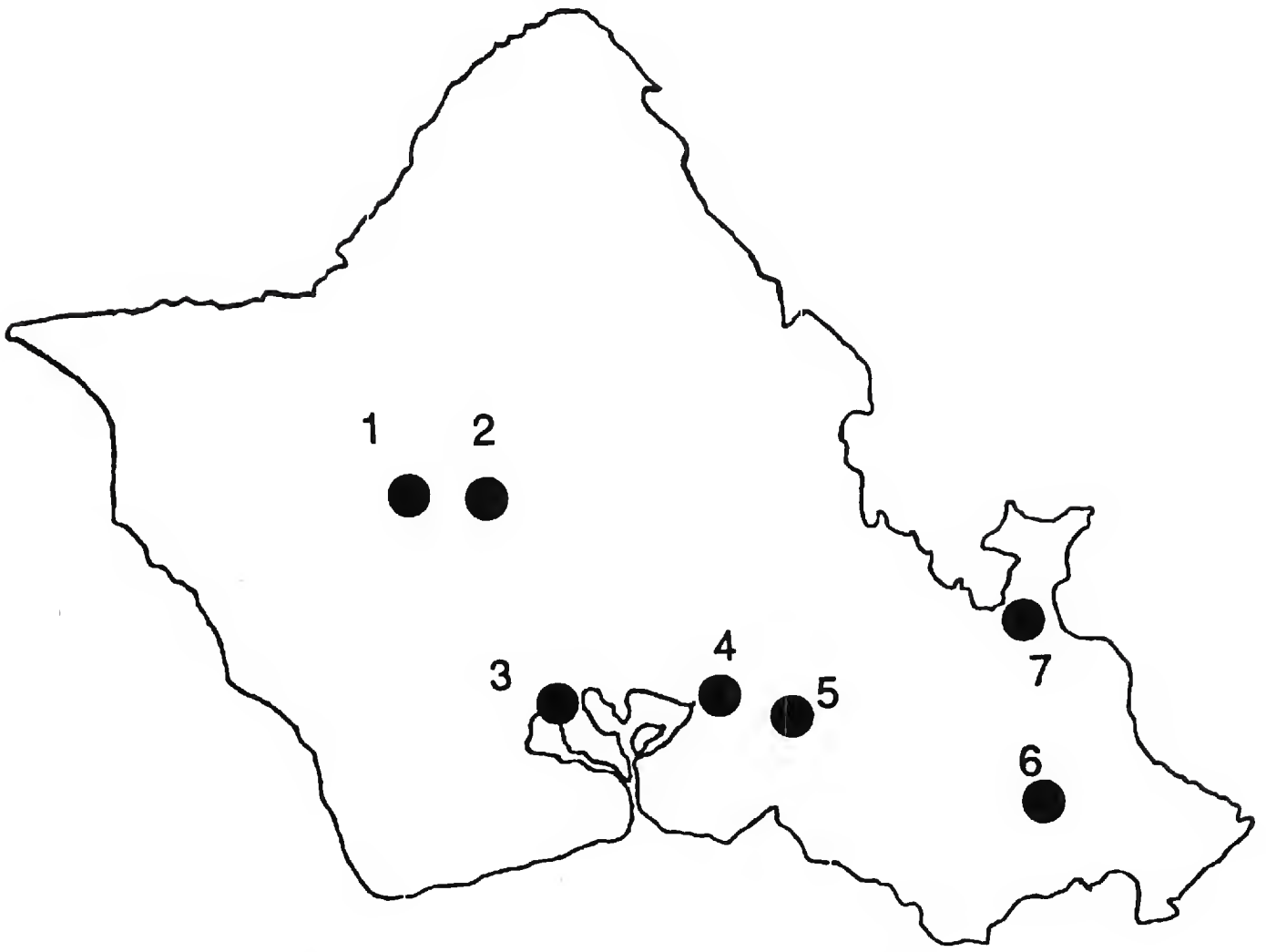

Figure 1. Locations of *Coptotermes formosanus* colonies sampled from the island of Oahu, Hawaii. An additional colony was sampled from Lahaina, Maui (not shown). 1, Poamoho Experiment Station field shed; 2, Poamoho Experiment Station (founded from laboratory stock); 3, Waipio peninsula; 4, Pearl Harbor; 5, Manana warehouses; 6, University of Hawaii at Manoa campus (six colonies); 7, Kaneohe residential yard.

1984). Similarly, this technique has been used to investigate the origin of introductions of *C. formosanus* to the United States mainland and the possibility of cryptic species within the range of *C. formosanus* in the United States (Korman & Pashley 1991).

Valuable information on the population structure and size of rhinotermitid colonies has been collected in previous studies of allozyme variation (Clement 1981, Reilly 1988). Our electrophoretic investigation was initiated to find allozyme markers useful in distinguishing among different *C. formosanus* colonies. Such markers could be used to determine the number and sources of termite introductions to Hawaii, and possibly to trace the spread of this termite throughout the state. We also wished to determine if the agonistic encounters between *C. formosanus* colonies recorded, by Su & Haverty (1991), were correlated with allozyme differences.

Materials and Methods

Termite collections.—Formosan subterranean termite workers (pseudergates, or undifferentiated individuals older than the third instar) were collected from 13 locations, representing 13 different colonies, on the Hawaiian islands of Oahu and Maui (Fig. 1). These included the colonies used by Su & Haverty (1991) in their study of intercolony agonistic interactions (N.-Y. Su, personal communi-

Table 1. Presumptive enzyme loci and buffer systems used in electrophoretic survey of Hawaiian *Coptotermes formosanus*.

Locus	Abbrev.	E.C. number	Buffer system[b]	No. of loci
Aconitase[a]	Acon	4.2.1.3	B	2
Glucose phosphate isomerase[a]	Gpi	5.3.1.9	A	1
B-hydroxybutyrate dehydrogenase	Hbdh	1.1.1.30	C	1
Aldehyde oxidase	Ao	1.2.3.1	A	1
Adenylate kinase[a]	Ak	2.7.4.3	A	2
Alcohol dehydrogenase	Adh	1.1.1.1	A	1
Amino aspartate transferase	Aat	2.6.1.1	C	1
Fructose 1,6-diphosphate dehydrogenase	Fdp	3.1.3.11	C	3
Hexokinase	Hk	2.7.1.1	D	2
Isocitrate dehydrogenase	Idh	1.1.1.42	B	1
Phosphoglucomutase	Pgm	2.7.5.1	B	2
Glucose 6-phosphate dehydrogenase	G6pd	1.1.1.49	D	1
Malic enzyme	Me	1.1.1.40	B	2
Malate dehydrogenase[a]	Mdh	1.1.1.37	B	2
6-phosphogluconate dehydrogenase	6Pgd	1.1.1.44	C	1
Fumerase hydratase	Fh	4.2.1.2	B	1
Esterase[a]	Est	3.1.1.1	A	2
Mannose 6-phosphate isomerase	Mpi	5.3.1.8	B	2
Glyceraldehyde 3-phosphate dehydrogenase	Gapd	1.2.1.12	A	1

[a] Reliable loci chosen for comparison among all termite colonies.

[b] Buffer systems: A, 100 mM tris maleate (pH 7.8); B, 100 mM tris citrate (pH 8.2); C, 100 mM phosphate (pH 7.0); D, 100 mM tris borate EDTA (pH 8.9).

cation). Six of the colonies are located on the Manoa campus of the University of Hawaii, and are monitored monthly using the trapping technique described by Tamashiro et al. (1973). Two other Oahu colonies that are regularly monitored are located at the Poamoho Experiment Station: one of these was originally founded from unknown laboratory stock in 1979 (M. Tamashiro, personal communication), but the other is adventitious in the vicinity of a field shed. The other two Oahu colonies subject to monitoring are located (1) in a sugarcane field on the Waipio peninsula, and (2) in a residential yard in Kaneohe. Two other collections were made on Oahu from infested wood found on the ground within the U.S. Navy's Pearl Harbor and Manana warehouse facilities. A single collection from fence posts in Lahaina, Maui, represents a recent introduction to that part of the island. Samples from each of these 13 colony sources were maintained alive in the laboratory, or snap frozen in liquid nitrogen, until prepared for electrophoresis.

Electrophoresis.—Cellulose acetate (Cellogel, Chemetron, Milan, Italy) horizontal gel electrophoresis was used to resolve the products of 29 presumptive enzyme loci (Table 1). This method is simple and efficient with small insects, because less than 1 μl of sample need be applied to the gel to achieve maximal stain intensity. The buffer systems and staining procedures used were those of Richardson et al. (1986). As noted in Table 1, buffer systems were: 100 mM tris maleate (pH 7.8) [A], 100 mM tris citrate (pH 8.2) [B], 100 mM phosphate (pH 7.0) [C], and 100 mM tris borate EDTA (pH 8.9) [D]. Individual termites were ground in Eppendorf centrifuge tubes using a fitted pestle and 0.1 ml of 100 mM

tris HCl (pH 8.0) buffer. Approximately 1 μl of each ground sample was applied to pre-made loading slots with a draughtsman's pen (Richardson et al. 1986).

In an initial screening, 6–21 individuals from each of the University of Hawaii *C. formosanus* colonies were assayed for each presumptive enzyme locus. Eight reliable loci were identified for comparison with the other termite colonies. All 13 colonies were then compared for these eight loci, with 4–26 individuals from each colony examined. The smaller sample sizes came from the colonies found at Pearl Harbor, Manana (Oahu), and Lahaina (Maui), where fewer individuals were collected.

Results and Discussion

Using cellulose acetate gel electrophoresis, no polymorphisms were found for any of the 29 loci (Table 1) in the 13 Hawaiian *C. formosanus* colonies surveyed, and thus no allozyme variation was identified within or between these colonies. In their survey of geographically disparate populations of *C. formosanus* from the mainland United States and Hawaii, Korman & Pashley (1991) reported that only 3 of 18 loci (16.7%) were polymorphic. They concluded that *C. formosanus* was depauperate of genetic variation, especially when compared to the approximate 40% polymorphic loci for the class Insecta as a whole (Nevo 1978). We were unable to reliably score two of the esterase loci that Korman & Pashley (1991) found to be polymorphic, and our methods did not elucidate the polymorphism reported by these authors for glucose phosphate isomerase (Gpi, Table 1). However, our preliminary results (unpublished data) with horizontal starch gel electrophoresis, using the methods of Korman & Pashley (1991), have subsequently confirmed that Gpi is polymorphic in Hawaiian *C. formosanus,* although no additional polymorphisms have been resolved.

Several studies have reported greater allozyme variation in other termite species. Korman et al. (1991) distinguished among *Zootermopsis angusticollis* (Hagen), *Z. laticeps* (Banks), and *Z. nevadensis* (Hagen) (Termopsidae) on the basis of 11 polymorphic loci. Clement (1981) found European *Reticulitermes* spp. (Rhinotermitidae) to have a high proportion of polymorphic loci (52%) and he used fixed electromorph differences to delineate different species. In contrast, allozyme electrophoresis by Reilly (1987) revealed only four polymorphic loci in *Reticulitermes flavipes* (Kollar) colonies from the southern United States, suggesting that these colonies were inbred and genetically isolated.

Cuticular hydrocarbon profiles have been used to separate colonies of *C. formosanus* from four geographically distinct areas (Florida, Hawaii, and two sites in Louisiana) (Haverty et al. 1990). In so much as cuticular hydrocarbon profiles reflect genetic phenomena, these results indicate that genetic differences may exist between *C. formosanus* colonies from disparate regions. However, Su & Haverty (1991) did not find any correlation between cuticular hydrocarbon profiles and intercolony agonistic behavior, which could also reflect genetic differences. The Hawaiian colonies studied by Su & Haverty (1991) were included in our allozyme survey and did not differ at allozyme loci. Thus, the genetic basis of these allozyme loci and of cuticular hydrocarbons appears to be unrelated to that of intercolony agonistic behavior.

Although we do not know what degree of allozyme variation is present in *C. formosanus* in China, where this species is indigenous (Kistner 1985), Hawaiian

populations may have lost variation either as a result of founder events and subsequent genetic drift, or of inbreeding. Natural movement of termites to nearby locations may take years, as demonstrated by an established colony on Maui that moved only a few kilometers in over 20 years (Tamashiro et al. 1987). Thus, the spread of *C. formosanus* throughout Hawaii was certainly aided by man via transport of partial colonies in infested wood. Inbreeding in rhinotermitids is facilitated by the common event of colony fission, or formation of new colonies by development and mating of supplementary reproductives within a large colony and subsequent "budding off" of these individuals and their offspring to form an adjacent independent colony (Weesner 1956). Asynchronous swarming of nearby termite colonies could also result in new colony formation by paired siblings, and has been suggested as a mechanism for generating inbreeding in *R. flavipes,* where winged alates captured before dispersal from different colonies are often at different stages of development (Reilly 1987).

A wider geographic sampling of *C. formosanus* colonies or alternative electrophoretic techniques may yield greater allozyme variation. However, the evidence to date from our study and that of Korman & Pashley (1991) suggests that lack of variation may be characteristic of this species and reflect an overall genetic homogeneity. Alternative, and currently equally acceptable, hypotheses are that *C. formosanus* colonies in Hawaii are derived from a single introduction, or from multiple introductions of very closely related individuals, possibly from the same geographic locale.

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YPONOMEUTA MALINELLUS ZELLER (LEPIDOPTERA: YPONOMEUTIDAE), A NEW IMMIGRANT PEST OF APPLES IN THE NORTHWEST: PHENOLOGY AND DISTRIBUTION EXPANSION, WITH NOTES ON EFFICACY OF NATURAL ENEMIES

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Abstract.— *Yponomeuta malinellus* Zeller is a recent invader of the Pacific Northwest. Its southern and eastern spread from northwestern Washington was determined with pheromone trapping surveys. Given the broad distribution of *Y. malinellus* in Europe and its spread east through the Cascade Mountains and south into Oregon, we perceive there will be no barrier to its movement through Oregon into California. Low rates of parasitism in Washington contrast with high parasitism throughout its native home of temperate Eurasia. Sleeve-cage exclusion of predators showed that generalist predators caused 40–60% and 20–50% mortality of young larvae and cocooned larvae or pupae, respectively. Egg mass predation through August of 1989 varied between 10% and 60% at two localities. Maximum daily pheromone trap catch and egg mass densities monitored from 1988–1992 indicated populations were relatively stable in the original infestation area of northwestern Washington.

Key Words.—Insecta, Lepidoptera, *Yponomeuta,* introduced species, apple pest, predation

Yponomeuta malinellus Zeller (Yponomeutidae), a univoltine defoliator of apples found throughout the temperate regions of the Palaearctic, was recently discovered in Washington and British Columbia. The first reports of the introduction were two interceptions on nursery trees in 1981 and 1982 on Vancouver Island, British Columbia (Anonymous 1985); by the summer of 1985, the species was found to be broadly established in the Fraser River Valley, east of Vancouver, and in Whatcom Co., Washington, especially in and around Bellingham (LaGasa, unpublished data). *Yponomeuta malinellus* first colonized North America 80 years ago in New York, but these populations were eradicated (Parrott 1913). Recently, Hoebeke (1987) outlined the status of three Palaearctic congeners of *Y. malinellus* that are presumed to be established in the eastern United States: *Yponomeuta cagnagellus* (Hubner), *Y. padellus* (L.) and *Y. plumbellus* (Denis and Schiffermueller).

Yponomeuta malinellus is a member of the "padellus complex" of small ermine moths, a group of five morphologically similar species that have been extensively studied as a model of host-plant associated sympatric speciation (Thorpe 1928, Menken et al. 1992). Like most species in this group, *Y. malinellus* is narrowly oligophagous, using *Malus* and occasionally *Pyrus* as hosts (Menken et al. 1992). Historically, *Y. malinellus* occurred at low, subeconomic levels punctuated by sporadic, localized outbreaks that would cause significant damage to apple or-

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chards throughout Europe (Affolter & Carl 1986). Such damage to commercial orchards is now largely precluded by synthetic insecticides used to control codling moth, *Cydia pomonella* (L.) (Tortricidae) and leaf rollers in western Europe. However, in areas where modern synthetic chemicals are used less regularly, *Y. malinellus* remains the second most important pest to apples behind the codling moth (e.g., former U.S.S.R., Nosyreva 1981). In the absence of control by natural enemies, *Y. malinellus* represents a significant threat to the development of a pheromone-based pest management program for apple pests (particularly codling moth) in North America.

Yponomeuta malinellus has been the target of a biological control program from 1988–1991, the complete details of which will be reported at another time. Herein we summarize the status of the recent introduction, provide measures of the impact of natural enemies endemic to northwestern Washington on this exotic species, and discuss the prospects for its control by endemic and introduced natural enemies. Parasitism by one introduced species, *Ageniaspis fuscicollis* Dalman (Encyrtidae), is reported.

Materials and Methods

Seasonal Biology.—*Yponomeuta malinellus* larvae were collected weekly from May to June 1988 and on selected dates in 1989. Specimens were collected from 10 unsprayed *Malus* trees in a suburban setting (two larval aggregations/tree) on each date and killed in 70% EtOH. Head capsule widths were measured under a binocular microscope equipped with an ocular micrometer. Head capsule widths were used to infer larval instar and, together with field observations of other life stages and collections in 1989–1991, to outline seasonal phenology.

Pheromone Survey Trapping.—Since 1985, *Y. malinellus* distribution in Washington state has been monitored by the Washington Department of Agriculture (WSDA), in cooperation with USDA-APHIS, to determine counties to be quarantined for nursery tree export restrictions. Originally, surveys were visual (1986–1988), but recent identification of the *Y. malinellus* sex pheromone (McDonough et al. 1990) has enabled monitoring with synthetic pheromone lures. Pherocon 1-C traps (Trece Incorporated, Salinas, California), baited with rubber septa impregnated with a two component lure (200 micrograms of Z11-14:OH and Z9-12:Ac in a ratio of 200:3; McDonough et al. 1990) were used in most cases in 1989 and exclusively in 1990. In 1989, some traps placed by USDA-ARS were baited with a three component lure (100 micrograms of Z11-14:OH, E11-14:OH, Z9-12:Ac, in a ratio of 100:30:1); both formulations had similar attractiveness (McDonough et al. 1990; Unruh, unpublished data). Traps were placed in residential or feral *Malus* trees from early to mid-July and removed from mid-August to early September. Some trap transects, such as those south and east of Puget Sound in 1989, were monitored semimonthly and, if several traps caught *Y. malinellus,* the transect was moved farther south to discern the southern edge of the distribution. For these transects, intertrap distances were from 1.6–16 km (1–10 mi). Other transects were examined at the end of the flight season. Results of similar surveys in British Columbia (1990) and in Oregon (1991) have been supplied to us and are also reported (D. J. Hilburn, personal communication).

Parasitism Surveys.—Collections and rearing of *Y. malinellus* larvae and pupae

showed that parasitism rates could be accurately assessed from cocooned larvae and pupae because no parasitoids emerged from earlier life stages. In 1988, cocoons were collected from unsprayed *Malus* trees in suburban and rural settings of Whatcom County, Washington on 28 Jun to 2 Jul. These were individually placed into 4 dram glass vials with a cork stopper and were allowed to develop at 22° (± 2°) C and 50 (± 10) %RH with 16:8 photophase : scotophase. In 1989, cocoon collections were made from unsprayed *Malus* in San Juan and Whatcom Counties on 16 Jun to 14 Jul and were either individually isolated or pupal clusters were placed in resealable sandwich bags. In 1990, cocoons were collected from Whatcom County on 28 Jun to 17 Jul and cocoon clusters were placed in either plastic vials (40 dram) or sandwich bags. After parasitoid emergence ceased, the remaining host cocoons were dissected under a binocular microscope. Percentage parasitism for all 3 years was based on the number of cocoons from which a parasitoid emerged, divided by the total number of cocoons from which insects emerged, or which died, as pupae. Adult *Y. malinellus* found dead within the pupal cases were considered emerged adults. A few fly puparia dissected from *Y. malinellus* pupae that did not eclose are reported as Tachinidae. All other unemerged host cocoons, whether due to predation or unknown causes, are reported as unknown mortality.

Predator Exclusion Studies.—Two forms of exclusion cages were used to determine the impact of endemic predators on the second through fifth larval stadia in 1989. Complete exclusion cages, designed to exclude both insect and bird predators, consisted of a 30 cm diameter by 1–1.5 m long cylinder of white, nylon, organdy screen (300 Denier Nylon, 39 strands/cm [100/inch]) secured at each end with tightened wire bands over a branch containing a larval colony. Bird exclusion cages consisted of two or more layers of plastic bird netting (0.64 cm [0.25 inch] mesh) wrapped around a branch containing larvae and held in place with staples. Marked, uncaged branches containing a single larval brood were used as experimental controls (= natural mortality).

Unsprayed, residential *Malus* trees were inoculated with larvae to artificially establish colonies for predator exclusion studies; thus, the number of larvae present at the beginning of the experiment was known. The day before inoculating, the trees were pruned to minimize larval movement and to accommodate exclusion cages. Within 8 hours of collection, larvae of each colony were counted and moved to clean, excised apple leaves in 15 cm diameter plastic petri plates that were covered and left overnight at room temperature. The following morning all colonies had established tents on the excised leaves. These artificial colonies (ACs) were returned to their collection sites and randomly assigned to prepared branches and covered with an exclusion cage or, for the controls, left uncovered. ACs were attached to a vigorous cluster of leaves by stapling a thin (2–3 cm) strip of paper around the cluster and the infested leaf.

ACs were visually inspected each week after inoculation and those that failed to establish or were contaminated from naturally occurring colonies (as evinced by the copious webbing left by larval colonies and the increased number of larvae in the AC) were excluded from the study. ACs were established at two sites in Bellingham, Washington on 12, 17, 24 and 31 May and removed on 6 to 7 Jun. The ACs setup on the first two dates consisted of small larvae (second, third and small fourth instar) and were pooled for statistical analyses. Those on the third

and fourth dates were relatively larger (large fourth and fifth instar) and were also pooled.

A similar experiment was done with pupal clusters, except that leaves to which clusters adhered were carefully removed, cocoons enumerated, and then stapled through extra webbing directly to undamaged leaves. Cocoon clusters were then covered with one of the two exclusion cages used for larvae or left exposed. Forty pupal clusters were set up on 6 Jun (20 exposed, 10 with bird exclusion and 10 with complete exclusion; half of each type in each study site) and removed on 28 Jun. Intact pupae and those from which moths successfully emerged were counted as survivors; missing larvae or pupae and dead ones with feeding damage (yellow hemolymph stains, etc.) were scored as dead.

Finally, two exclusion treatments were used to measure egg mass predation: (1) all predators were excluded with close-fitting organdy sleeves, and (2) walking predators were excluded with a 1 cm wide band of Stickem®, 2–5 cm proximal and distal to the egg mass. Eighty naturally occurring egg masses were monitored (40 exposed and 20 for each exclusion treatment) at each of two sites on 6 and 7 Aug 1989. A census of egg masses was taken on 12 Sep 1989. A census of a subset of surviving hibernacula (= egg case with diapausing/quiescent larvae) was taken again on 15 Mar and 9 May 1990.

Differences among exclusion treatments for the two larval size classes and cocoons were analyzed separately using factorial analysis of variance (ANOVA) of untransformed survival proportions, with exclusion treatment and site as crossed factors. (Arcsine transformation gave qualitatively similar results, but because a few cases had more larvae at the end of exposure than counted at the onset and because the arcsine transform is undefined for values greater than one, it was not used.) The initial number of larvae or pupae in each AC was treated as a covariate. Comparisons between means employed Tukey's Studentized (HSD) range test (Proc GLM: SAS 1988). Differences in the frequency of intact egg masses versus those empty or missing at the census intervals were analyzed using Chi square.

Population Density Estimates.—In 1989–1992, samples consisting of 30 vigorous branches (with developed terminal bud) were taken from five trees at each of four sites early each year prior to bud burst and larval exit from hibernacula. All hibernacula on the terminal two seasons of wood growth were counted under a binocular microscope. The same five trees were sampled at each site each year, minimizing year to year variance.

Adult population trends were also monitored using pheromone traps baited with the two component lure as described for survey trapping. Four sites were monitored in 1988 and nine were monitored during 1989–1991 flight seasons. Traps (Pherocon 1-C, Trece) were changed approximately every two weeks (range 10–20 days) and traps at all sites were replaced on the same day. Only the second half of the flight season for 1988 was trapped because that is when the pheromone became available. The numbers of traps deployed at each site were two in 1988, three to 14 in 1989, and three in 1990 and 1991. *Yponomeuta malinellus* males are typically caught within 10 m of their release site in mark recapture studies (Menken et al. 1992; Unruh, unpublished data) and intertrap distances exceeded 10 m at all sites. Data were expressed as the number of males/trap/day for each trapping interval. Mean trap catch for the trapping interval with highest capture rate in each year at each site is reported.

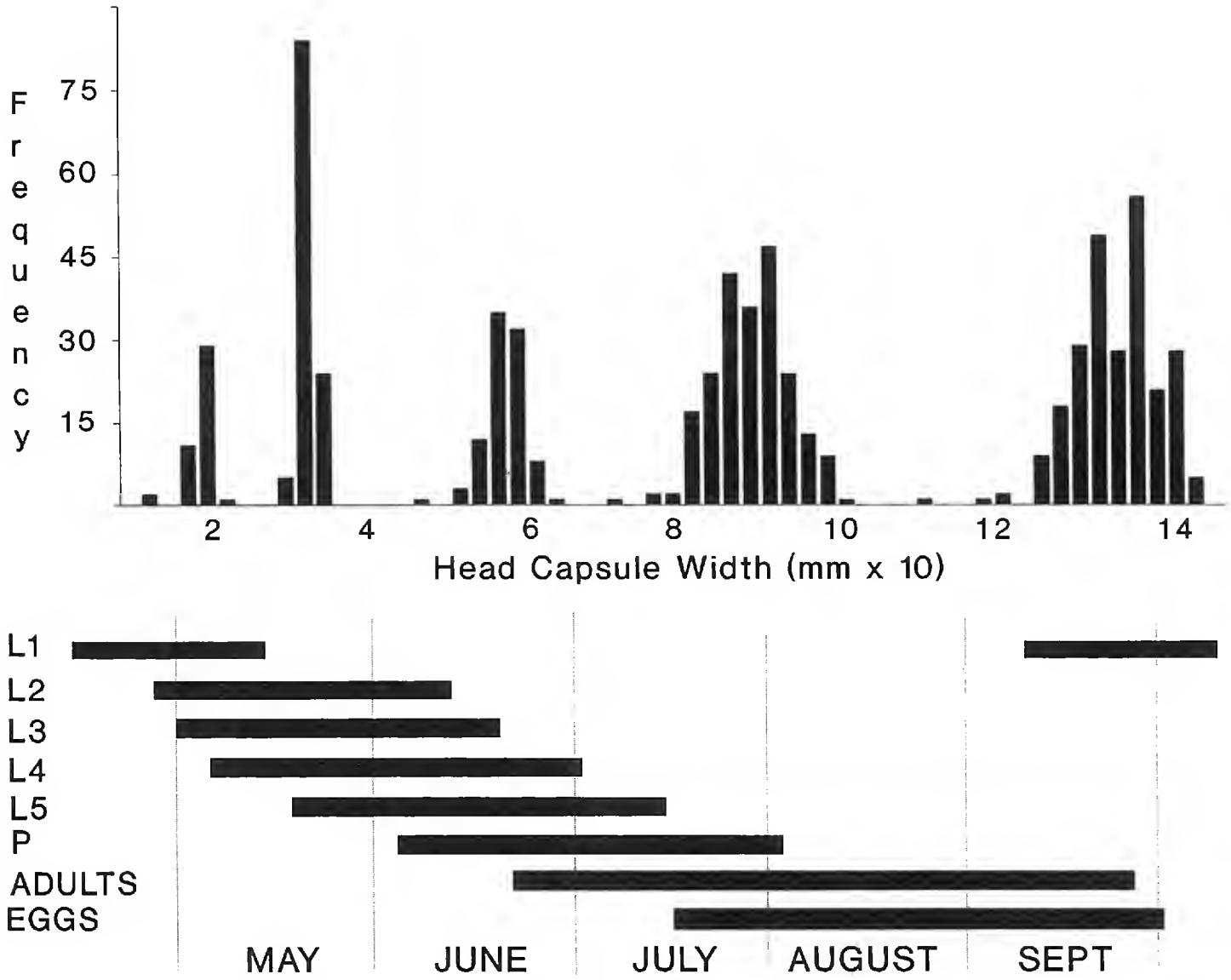

Figure 1. Head capsule widths for five larval instars of *Y. malinellus* and approximate duration of all life stages in the field in Whatcom County, Washington. Based on 20 tents collected weekly from early May to late Jun 1988 and on selected dates in 1989.

Results and Discussion

Life History.—The frequency distribution of head capsule widths of *Y. malinellus* larvae fell in five discrete groups (Fig. 1); based on inspection of the distributions we chose 0.25, 0.4, 0.7 and 1.15 mm as head capsule growth intervals between instars. Given these intervals, head capsule widths averaged [SEM] 0.1891 mm [.0023], 0.3317 mm [.0011], 0.5828 mm [.0028], 0.8998 mm [.0035] and 1.373 mm [.0033] for first through fifth instars, respectively.

The seasonal biology of *Y. malinellus* in northwestern Washington is also diagrammed in Fig. 1 and is similar to that reported for the Palaearctic (e.g., Beirne 1943, Junnikkala 1960). Eggs were laid in an overlapping pattern in an irregular mass about 5 mm in diameter; egg laying commenced in mid-summer (earliest observed 6 Jun 1987). In Washington, egg masses consisted of about 50 eggs ($\bar{x}$ = 45.7, S.D. = 14.2, range 16–82, n = 58; 1988). From cage studies in Sweden, Junnikkala (1960) found that females lay an average of 1.37 egg masses. Egg masses were typically found on one to three year old wood, rarely on the growth of the current season. The eggs hatched about three weeks after oviposition and first instar larvae remained under the hibernaculum, which consists of upper surface of the egg mass, through winter until early spring.

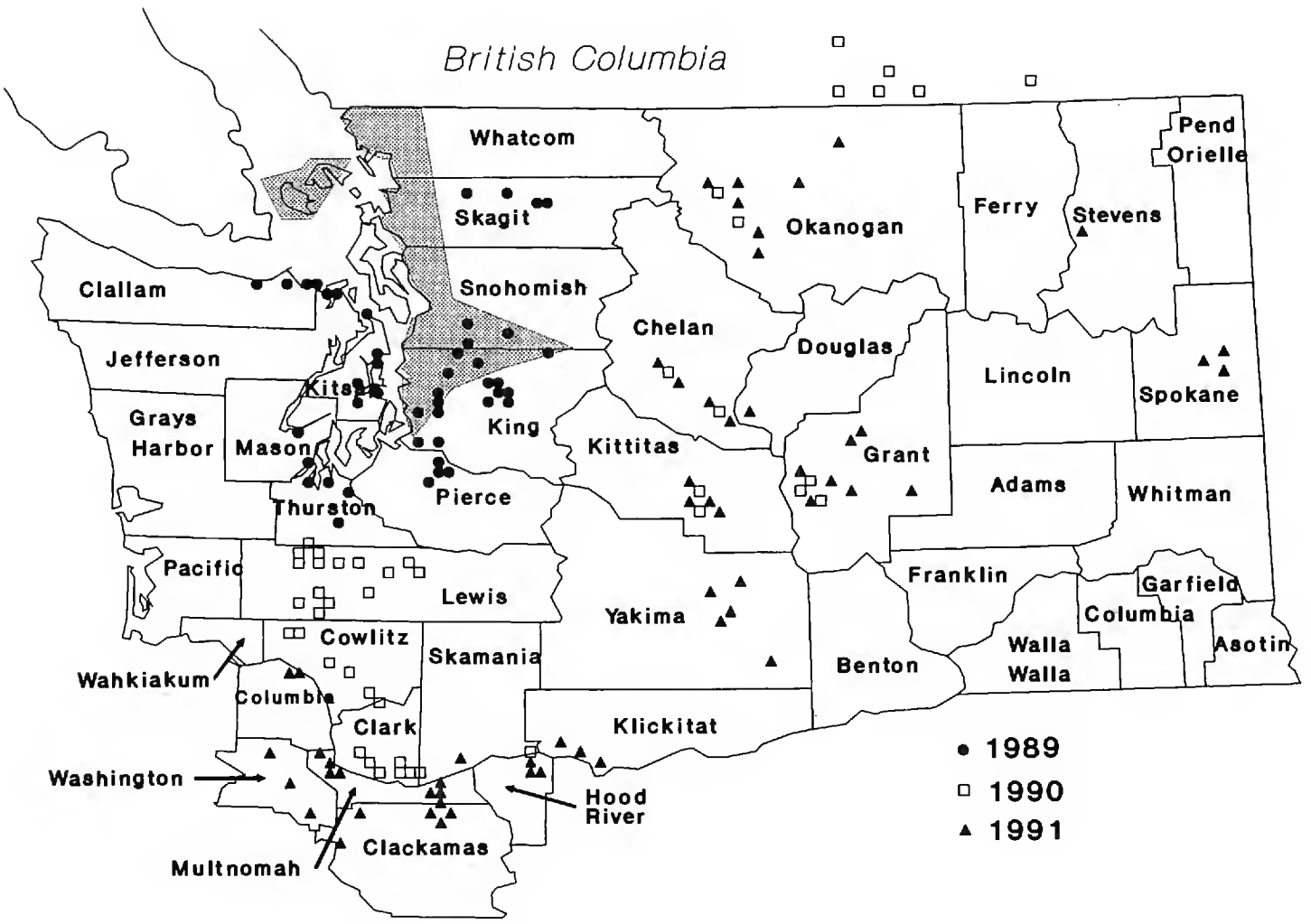

Figure 2. Geographic pattern of pheromone trap catch for 1989–1991 in Washington, five Oregon counties and the area bordering Washington in southern British Columbia. Infestation boundaries based on visual surveys in 1988 are also depicted as a shaded area.

Larvae abandoned hibernacula and began leaf mining in early April with the first sign of leaf tissue on apple. Newly established mines, always on young leaves, were observed until late May. The second through fifth instars fed externally on leaves and spun loose white-grey webbing (tents) around and near attacked leaves. All larval stages formed aggregations, presumably of the siblings from the same egg-mass. High population densities and disturbance by predators appeared to cause confluence of aggregations or their partial dissolution into smaller groups, respectively.

Cocoon spinning and pupation also occurred gregariously, beginning as early as late May but normally in mid June in western Washington. In high density infestations, where trees were largely or entirely defoliated, cocooning occurred in irregularly shaped super aggregations (composed of multiple sibships) in the crotches of tree branches, below branches, under large bark flakes, in holes in the trunk, etc., and large masses reached 10 cm in diameter. In moderate to light infestations, cocoons were typically found as isolated clusters on the underside of undamaged leaves.

Adult eclosion was first observed about 2 weeks after cocooning; emergence of adults in the laboratory was spanandrous with the bulk of the males emerging about 3 days before the females. First male trap catch followed first observed eclosion by 1–2 weeks and first observations of oviposition or of egg masses were 2–3 weeks after the onset of eclosion. This timing is consistent with observation in Europe—that adults are not sexually mature at eclosion, that mating occurs

about one week later, and oviposition commences 2 weeks after eclosion (Junikkala 1960, Menken et al. 1992).

Distribution.—Figure 2 shows the geographic distribution of *Y. malinellus* in Washington based on pheromone trap catches from mid Jul through mid Sep 1989 to 1991. Also displayed are the distributions as determined by visual surveys in 1988, representative positive sites for southern British Columbia east of the Cascade Mountains, and positive traps for northern Oregon in 1991.

For Washington, we refer to two regions, east and west, separated by the crest of the Cascade Mountains and seen in Fig. 2 as the eastern borders of Whatcom, Skagit, King, Pierce, Lewis, and Skamania Counties. In 1989, 312 traps placed in nine western counties produced 81 positive trap sites and 500 moths. In contrast, no moths were captured in 58 traps arrayed in four eastern counties (Chelan, Douglas, Kittitas, Yakima). In 1990, 480 traps placed in four southwestern counties produced 53 positives and 117 moths, demonstrating the moth had reached the Columbia River in western Washington. Fourteen counties in eastern Washington were added to the survey in 1990 (Asotin, Benton, Columbia, Ferry, Franklin, Garfield, Grant, Kickittat, Okanogan, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman). Of 825 traps placed in 18 eastern counties, 21 were positives with 34 moths in four counties. These four counties included two (Chelan and Kittitas) that were trapped with no captures in 1989, with traps placed in the same areas, if not the same trees, in both years. In 1991, survey trapping was restricted to eastern Washington and two counties along the Columbia River Gorge (Skamania and Klickitat). Columbia, Pend Oreille, and Whitman Counties were not trapped in 1991. Of 1130 traps in the remaining 15 counties, 62 caught 145 moths with new records in Douglas, Klickitat, Spokane, Stevens and Yakima Counties. Because these areas were trapped the previous year, the results suggest trap catch was contemporaneous with colonization of these counties.

Also in 1991, the Oregon Department of Agriculture trapped in 25 counties; including counties bordering the Columbia River, counties surrounding the greater Portland area, and in most areas of high human density; including down the Willamette Valley and in towns along Interstate Highway 5 to the California border. Captures, 51 moths in 34 traps of 1329 deployed, were restricted to the five counties depicted in Fig. 2 (Columbia, Washington, Multnomah, Clackamas and Hood River; D. J. Hilburn, personal communication). These results indicate that the southern edge of the distribution was the northernmost extent of western Oregon in 1991.

In summary, all pheromone trap transects west of the Cascade Mountains caught males in 1989, including those extending up the western slope along the three major trans-Cascadian mountain passes in Washington (Baker, Stevens and Snoqualamie). These were followed by moth catches on the eastern slopes of the Cascades east of the same mountain passes in Chelan, Okanagon and Kittitas Counties in 1990. However, only Chelan and Kittitas were trapped in 1989; hence, only there can we have some confidence that the colonization was recent. A similar expansion eastward up the Columbia Gorge was evident. Because these mountain passes and the foothills on either side are not heavily populated, we infer that the spread of *Y. malinellus* through the Cascade Mountains was unaided by man.

The surveys for *Y. malinellus* in British Columbia (H. Nichols, personal communication) revealed a similar pattern of spread from the original infestation area

Table 1. Parasitism rates of *Yponomeuta malinellus* Zeller for 1988-1990 by parasitoid species.

Year	Number sites	N_1[a]	% *Y.m.*	*C.c.*	Tach	*H.p.*	*I.q.*	*D.c.*	Unk	*A.f.*	N_2
1988	5	857	78.9	0.93	—	0.58	0.70	0	18.9	—	—
1989	35	13,478	96.12	0.13	0.32	0.12	0.49	0.04	2.7	0.35	12,026
1990	16	6430	90.87	1.30	0.40	0.33	1.24	0.02	5.4	0.48	6290

[a] N_1, number of cocoons reared; % *Y.m.*, percent emerged as *Y. malinellus* or died in pupal case as fully formed adults; *C.c.*, percent emerged *Compsilura concinnata* (Meigen); Tach, percent of undetermined tachinids that were probably either *C.c.* or *H.p.* but deteriorated, or remained as puparia; *H.p.*, percent *Hemisturmia parva* (Bigot); *I.q.*, percent *Itoplectis quadricingulata* (Provancher); *D.c.*, percent *Dibrachys cavus* (Walker); Unk, percent unknown mortality of cocooned larvae and pupae; *A.f.*, percent *Ageniaspis fuscicollis* Dalman; N_2, the subset of N_1 taken from sites where *A.f.* was released and used for calculating *A.f.* parasitism rates.

in the Fraser River delta (Anonymous 1985). In 1989, limited trapping surveys showed the Fraser River Canyon to be generally infested up to Lillooet and east of the Cascade crest near Kamloops and Sicamous. The infestation also extended south into the Canadian Okanogan to Kelowna and to the United States border near Grand Forks, British Columbia. Only the southern edge of this distribution is depicted in Fig. 2. It is likely that *Y. malinellus* in eastern British Columbia also arrived by dispersing through the low pass(es) in the Canadian Cascades.

Parasitism and Predation.—Parasitism of *Y. malinellus,* based on cocoon collections from 1988 to 1990, is summarized in Table 1. No parasitoids were discovered emerging from earlier life stages. Combined parasitism by two tachinid species, *Compsilura concinnata* (Meigen) and *Hemisturmia parva* (Bigot), was about equal to that by the ichneumonid *Itoplectis quadricingulata* (Provancher) and was about 2–3% altogether. All three of these parasitoids are polyphagous. *Compsilura concinnata* is of exotic origin and was introduced in large numbers in several biological control programs, notably against the satin moth, *Stilpnotia salicis* (L.) (Lymantriidae), in Washington between 1928 and 1935 (Clausen 1978). *Itoplectis quadricingulata* has a host range that includes many microlepidoptera and sawflies (Carlson 1979) and is common in the forests of the northwest (Ryan 1971). *Hemisturmia parva* has a more narrow host range that includes seven families of Lepidoptera (as *H. tortricis* Coquillett: Arnaud 1978). The gregarious parasitoid *Dibrachys cavus* (Walker) (Pteromalidae) was uncommon and may have acted as either a primary or, more likely, a hyperparasitoid. Total parasitism by these four "endemic" parasitoids was quite low and never exceeded 4% in any year. A trend of increasing parasitism rates, which would suggest adaptation to this exotic host, was not evident.

In 1989, the exotic egg parasitoid, *A. fuscicollis,* was detected at nine of 33 sites at which we had released it in 1988 (release details to be presented elsewhere). Recoveries in 1990 at four sites where *A. fuscicollis* was released in 1988 but not in 1989 showed that this parasitoid is established. Introductions into British Columbia, beginning in 1987 by Agriculture Canada in conjunction with the Commonwealth Institute of Biological Control, CAB, have also resulted in successful establishment of this parasitoid (Frazer 1989). Through 1990, *A. fuscicollis* had not added significantly to parasitism rates of *Y. malinellus* in Washington.

Exclusion Cage Studies.—Exclusion cage experiments demonstrated significant

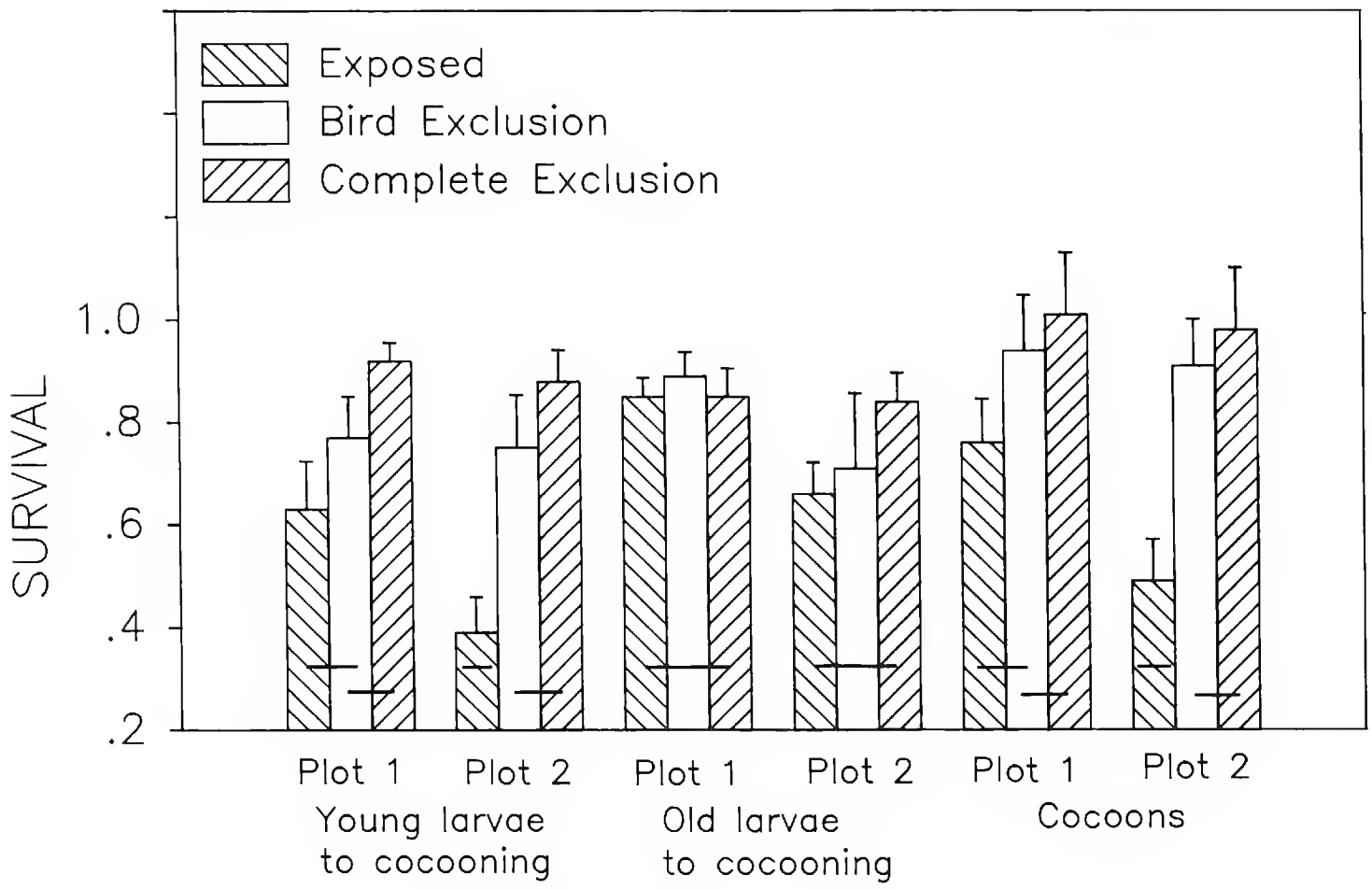

Figure 3. The proportion survival of *Y. malinellus* larvae and cocooned larvae or pupae in exclusion cage experiments of 1989. See text for details of treatments. Within groups, significantly different treatments do not share heavy crossbars (Tukey's HSD, alpha = 0.05).

levels of predation in three life stages of *Y. malinellus*: free living larvae, cocooned larvae and egg masses (Fig. 3). Survivorship from small through large larval stages (early May through early June) was significantly increased by predator exclusion at both study plots. An ANOVA model that included study plot, exclusion treatment, and their interaction as factors, with the number of larvae in each AC at the start of the experiment as a covariate, explained 48% of the variation in survivorship proportions and was highly significant ($P = 0.0001$). Exclusion treatments were significant ($P = 0.0001$) as was the covariate (number of larvae setup, $P = 0.03$); all other effects were insignificant. Bird exclusion gave survivorship intermediate (plot 1) or equal (plot 2) to that provided by complete exclusion (Fig. 3). For the second experiment with large larvae (late May to early June) the ANOVA model explained only 14% of the variation in survival proportions and was not significant ($P = 0.1$). However, plot differences caused a significant effect ($P = 0.03$) and modest, nonsignificant differences in survivorship associated with exclusion treatments were evident at plot 2 (Fig. 3).

In the experimental exclusions with pupae, the ANOVA model explained 44% of the variation in survival and was significant ($P = 0.005$); exclusion treatments were the only significant effect ($P = 0.005$). Exposed pupal clusters had lower survivorship than those under bird exclusion or complete exclusion. The pattern observed for the young larvae to cocooning was again evident for cocoons; bird predation accounted for most mortality, especially at plot 2 (Fig. 3).

Qualitative observations at other study sites showed the diversity of insect predators (e.g., wasps and ants) was abundant and they often fed on both large

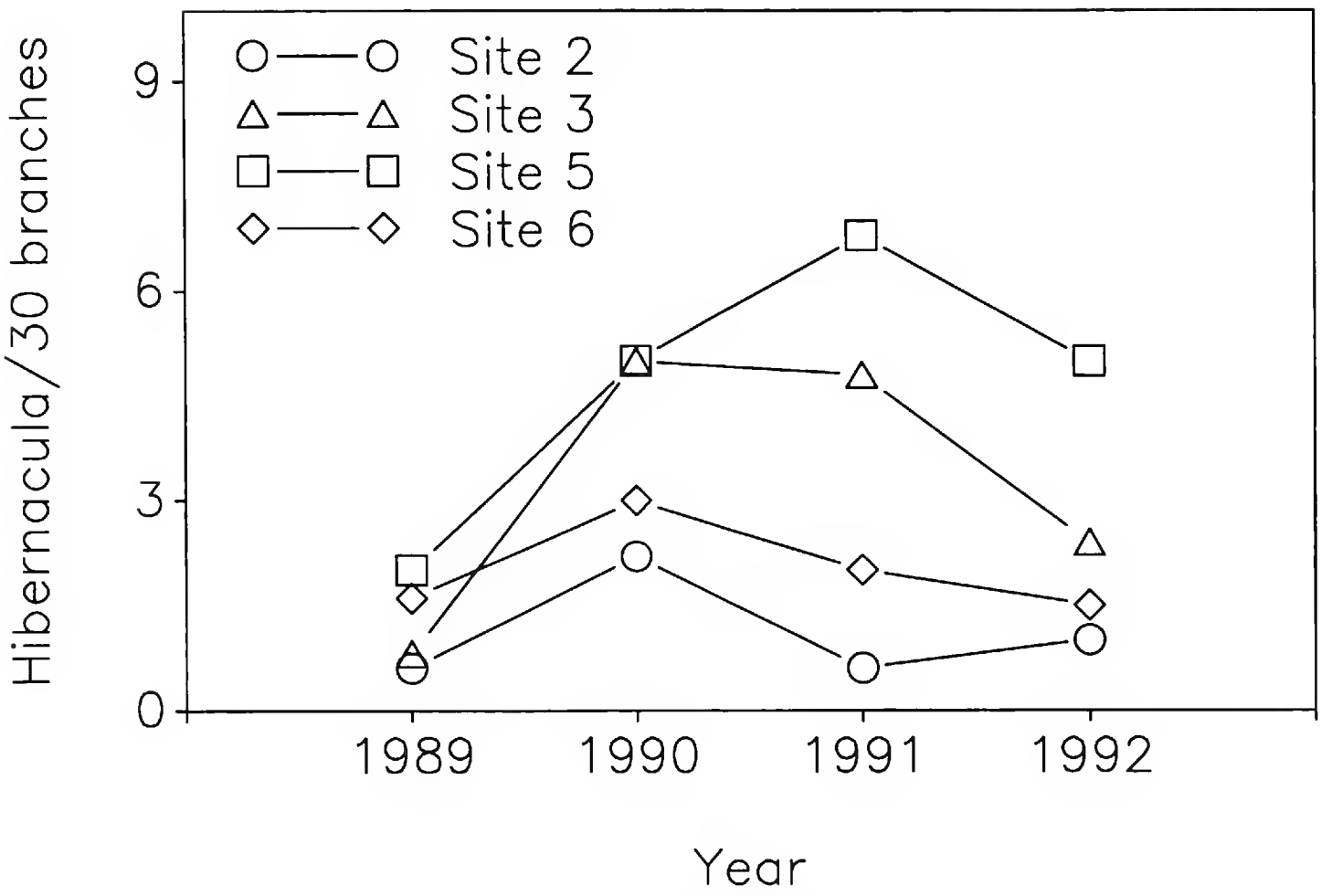

Figure 4. Egg mass (= hibernacula) densities per 30 branch sample (per tree) for *Y. malinellus* at 4 sites in Whatcom County, Washington. Standard errors are not shown but averaged 44% of the mean (range 25% to 66%).

and small *Y. malinellus* larvae. Large numbers of a common hornet, *Vespula* sp., were seen taking larvae at one site. In our exclusion studies, experimental variation was large for bird exclusion treatments because several ACs were excluded from analyses when larval aggregations moved outside of the bird netting enclosures. This suggests that bird netting allowed free access for insect predators. However, this may be true only for predators that forage by walking; flying foragers, such as *Vespula,* would likely be impeded by bird netting. Indirect evidence of bird activity (i.e., droppings) was also commonly observed and starlings (*Sturnus*) were often seen foraging in infested trees. Beirne (1943) claimed birds were significant mortality agents of *Y. malinellus* in Ireland, and Affolter & Carl (1986) reported records of starlings feeding on *Y. malinellus.*

Only 1% of egg masses under exclusion treatments ($n = 79$) were destroyed from 7 Aug to 12 Sep 1989 at both study sites. However, 36% of exposed egg masses ($n = 80$) perished over the same interval. Most of this mortality occurred at site 1 (25 of 40 exposed egg masses), producing statistical significance of exclusion treatments (site 1: Chi-Square, df = 2, $n = 80$, $P = 0.0001$). Because tanglefoot barriers excluded virtually all mortality one may infer the mortality agents were small and approached egg masses by walking. We made no systematic search for the organism(s) responsible for this mortality but Smith (R. B. Smith, personal communication) found that a mite, *Balaustium* sp. (Erythraeidae), caused similar levels of mortality in nearby British Columbia. Census of a subset of hibernacula (= egg masses with hatched larvae in diapause/quiescence) on 15 Mar 1990 showed mortality was 9% in exposed hibernacula ($n = 33$) and was not

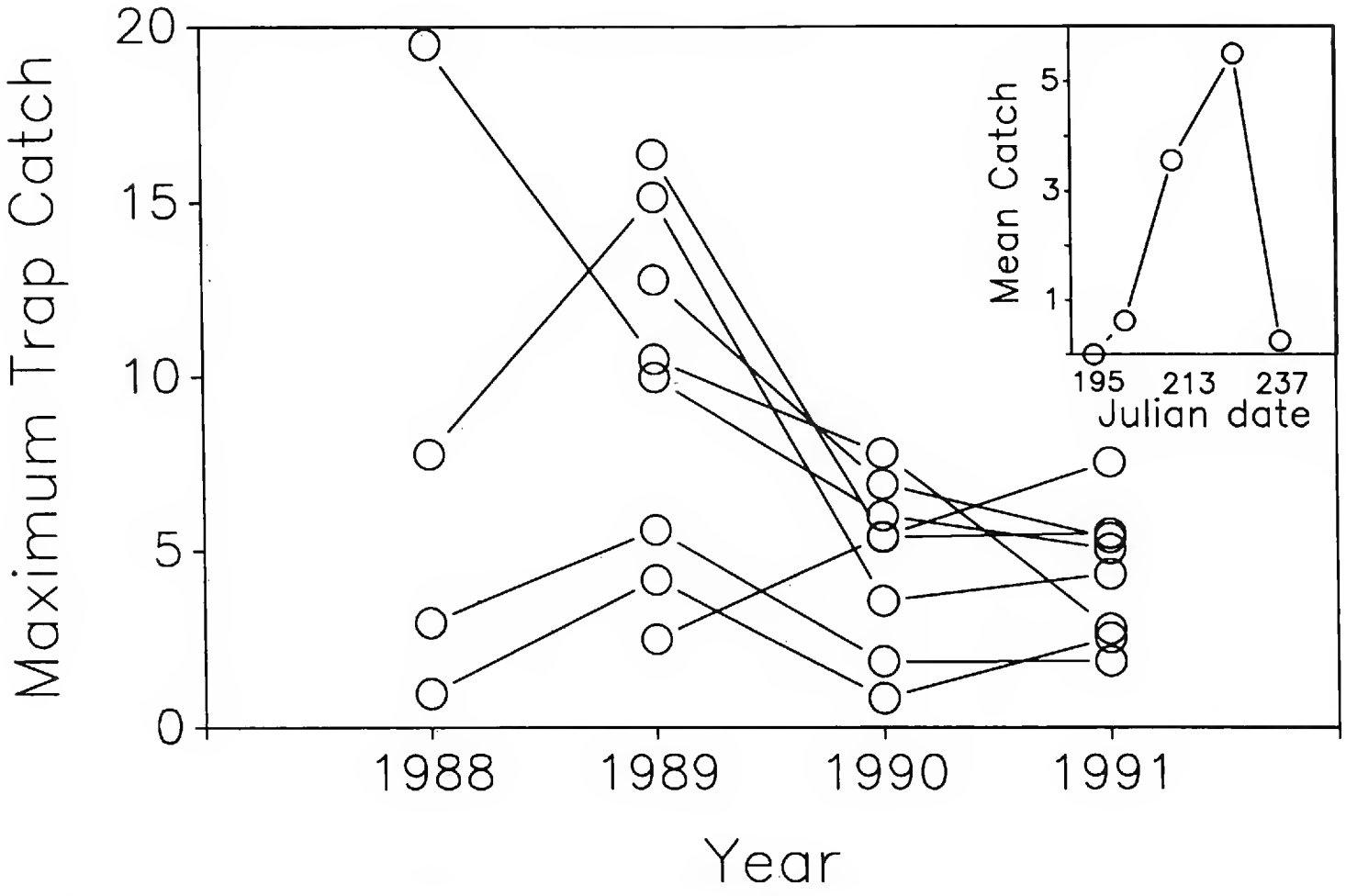

Figure 5. Maximum pheromone trap catch (male moths/trap/day) for 1988–1991 at 4 to 9 sites in Whatcom County, Washington. Traps were changed every 2 weeks from the beginning of flight season (except for 1988; see text). Inset shows a representative flight curve monitored at one study site in 1991. The maximum value, 5.5 males/trap/day, represents a single datum in the body of the figure.

statistically different from cage (0%, $n = 37$) or sticky barrier (6%, $n = 16$) exclusion treatments ($P > 0.3$ at each site). Similarly, census on 9 May showed 100% of exposed ($n = 32$) hibernacula and hibernacula protected by sticky barriers ($n = 15$) survived to larval egress as did 96% of hibernacula in cages ($n = 22$).

Population Trends.—Egg mass samples over 4 years showed similar population trends at four study sites (Fig. 4). The average number of egg masses per 30 branch sample (five trees/site) increased two to five fold from 1989 to 1990 and generally decreased from 1990 through 1992.

The maximum trap catch (mean number of males/trap/day) taken from the seasonal flight curve at each study site (5.5 in inset) was used to summarize flight each year at nine study sites and is depicted in Fig. 5. Generally higher trap catches in 1989 were consistent with the pattern observed for hibernacula densities, although there were exceptions. Maximum daily trap catch varied only 2.5 fold, at most, over years within each site.

Both egg mass densities and pheromone trap catches indicate that *Y. malinellus* populations have been relatively stable over the last 4 years in Whatcom County. High trap catches at sites where infestations were visually obvious (the main infestation areas in Whatcom County) versus low trap catches in newly infested southern counties where densities were too low to be detected visually during pest surveys suggest that pheromone traps will provide some measure of regional population trends across years. Thus, traps should be valuable to assess the long-term effect of introduced biological agents on regional population densities.

However, we do not suggest that pheromone trap catch or egg mass sampling, as employed here, provide resolution adequate to study site-specific population dynamics. We have observed striking year-to-year variation in apparent densities of larvae and cocoons (stages for which we have been unable to develop an objective sampling method). For example, we observed *Y. malinellus* larval populations extirpated in April 1989 at several sites in Whatcom County when trees were completely defoliated by the winter moth, *Operophtera brumata* (L.) (Geometridae), prior to the completion of larval development of *Y. malinellus*. At one of these sites, we monitored male trap catch before and after this event. A decline of only 50% in peak trap catch was evident in the flight following larval extirpation (10 in 1989 versus 20 in 1988), suggesting that a significant percentage of trap catch are males from off site.

Conclusion

Our observations of *Yponomeuta malinellus* in Washington show its phenology is similar with that reported throughout the Palaearctic. From survey trapping, we infer that the moth is capable of colonizing new areas over mountain passes that may provide no suitable hosts for 50 to 100 km. Populations appear to be regionally stable in the original infestation area of Whatcom County and ongoing monitoring will determine how long it will take for newly colonized areas (e.g., Yakima County) to reach the high levels that now are characteristic of northwestern Washington.

In pesticide-free settings in its native range, *Y. malinellus* is host to a large complex of natural enemies that are well known and produce high parasitism rate (20–90%) (e.g., Beirne 1943, Junnikkala 1960, Friese 1963, Dijkerman 1987). These authors and a host of others (reviewed in Affolter & Carl 1986) consider *Y. malinellus* to be regulated by its parasitoid complex, together with generalist predators, throughout the Palaearctic. Prior to use of synthetic insecticides, *Y. malinellus* was a significant pest of apples, second in importance to the codling moth, *C. pomonella,* especially in central and northern Europe (Faes 1928, Jancke 1933, Affolter & Carl 1986). In countries where economic development has lagged and synthetic pesticide use has remained restricted, *Y. malinellus* has continued to show periodic outbreaks that can cause severe, region-wide crop damage (e.g., Vaclav 1958, cited by Affolter & Carl 1986; Nosyreva 1981).

Yponomeuta malinellus does not pose a serious threat to conventional apple producers in North America if an early cover spray of organophosphate insecticide is used for codling moth control. However, if orchardists substitute sex pheromone based mating disruption for codling moth control (Howell et al. 1992) and other pesticide applications are made based on need, then *Y. malinellus* may become one cause for periodic pesticide applications.

The prognosis for control of populations infesting feral and residential *Malus* is uncertain. The constant low levels of parasitism by generalist "endemic" species indicate that they will not control *Y. malinellus*. However, our data suggest that endemic predators do produce significant mortality that may be largely responsible for preventing even more damaging levels of *Y. malinellus* in the western U.S.A. Also, increasing parasitism rates by the introduced parasitoid *A. fuscicollis* in 1991 (Unruh, unpublished data) suggest that this species may eventually contribute to lowering populations to densities more closely approximating those in Europe.

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EFFECTS OF TEMPERATURE ON DEVELOPMENT OF *BACTROCERA ZONATA* (SAUNDERS) (DIPTERA: TEPHRITIDAE)

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Abstract.—We measured the developmental times and survivorship of the immature stages of *Bactrocera zonata* (Saunders) and the longevity, preovipositional period and fecundity of adult flies at five temperatures between 15° C and 35° C. Egg hatch significantly increased with temperature from 15° C (51%) to 25° C (91.3%), and then decreased to zero at 35° C. No larvae completed development at 15° C or 35° C. Larval and pupal survival were greatest at 25° C, as were female fecundity (eggs laid) and fertility (% egg hatch). Developmental times for all stages were inversely related to temperature. Egg development was fastest at 25° C and 30° C, although larval, pupal and ovarian development were fastest at 30° C.

Key Words.—Insecta, *Bactrocera zonata,* temperature dependent development, immature survival, adult preovipositional period, fecundity and fertility

Temperature has been shown to be an important factor influencing the development of immature stages and ovaries of a number of economically important fruit flies (Tephritidae) (Moore 1960, Tsiropoulos 1972, Saeki et al. 1980, Okumura et al. 1981). Models describing the influence of temperature on developmental rate have been used to determine when to apply fruit fly control and eradication measures, and to determine the possible geographic distribution of various fruit fly species (Saeki et al. 1980, Meats 1981, Tassen et al. 1983).

Bactrocera zonata (Saunders), the peach fruit fly, is found in Egypt, Pakistan, Burma, India, Thailand, and Indonesia (Kapoor et al. 1980), where it attacks a range of fruit, including apple, guava, peach and pear (Nair 1975, Kapoor et al. 1980, Kapoor & Agarwal 1983). In India, it is as, or more, important a pest of commercial and dooryard crops than its better known cogenor *B. dorsalis* (Hendel), the oriental fruit fly (Kapoor & Agarwal 1983).

The recent discovery and successful eradication of several isolated infestations of *B. zonata* in California (Dowell 1988; Dowell & Gill 1989; RVD, unpublished data) have highlighted the need for data on the biology of this important fruit pest. Reported here are the effects of temperature on the development and survival of life stages of *B. zonata.*

MATERIALS AND METHODS

Rearing of Test Insect.—Guava infested with *Bactrocera zonata* were placed in wooden trays on sterilized sand moistened with distilled water until the larvae emerged. The resulting pupae were isolated and kept in wire cages (45 × 45 ×

55 cm) until adult emergence. This colony was reared through one generation to increase the number of flies before the experiments started. The rearing conditions were 25 ± 2° C, 65 ± 5% RH and a 14:10 LD cycle. The adults were provided water, protein hydrolysate (enzymatic) and sugar.

The larval diet was 100 g wheat shorts, 17 g brewer's yeast, 33 g sugar, 3.5 g agar, 0.5 g Nipagin, 20 ml HCl and 400 ml water. The wheat shorts, brewer's yeast, sugar and Nipagin were mixed together. The agar was dissolved in boiling water, and after cooling to 15° C it was mixed with the other ingredients, with the HCl added last. The mixture was blended for 2–3 minutes to a smooth consistency. The prepared medium had a pH of 4.5. The medium was poured into 15 petri dishes (9 cm diameter). Tissue paper was placed on the diet for seeding larvae (100 larvae per petri dish).

Temperature Studies.—We studied the effect of temperature on the life stages of *B. zonata* in Hotpack® programmable refrigerated incubators, each equipped with two 20 watt fluorescent lights and set at a 14:10 LD cycle. Test temperatures ranged from 15° C to 35° C in 5° increments. Fluctuation at each temperature was ±1° C. The procedures followed for testing the different stages are given in seriatum. Each test was replicated three times.

Eggs.—One hundred eggs obtained from the colony were placed on filter paper moistened with distilled water at each test temperature. After 24 h, each petri dish was examined hourly for egg hatch. After hatch was completed, unhatched eggs were counted and hatch percentage determined.

Larvae and Pupae.—One hundred neonate larvae were divided among three petri dishes kept at each test temperature. When the larvae reached third instar, the petri dishes were placed on sterilized sand in a covered enamel tray for pupation. Pupae were removed daily from the sand and kept in petri dishes until adult eclosion. Larval and pupal survival were computed from pupal recovery and adult emergence data respectively.

Adults.—The adults were sexed and 30 pairs were confined in each of three screen cages (25 × 25 × 35 cm) at each test temperature. Water, sugar and protein hydrolysate (enzymatic) were provided as food and mortality was recorded daily. An egging receptacle, a yellow plastic glass with fine holes in its sides and smeared internally with guava juice, was placed in each cage. The egging receptacle was replaced daily until all females had died. Eggs were removed daily from the receptacles and kept on moistened filter paper to determine percent hatch.

Following the above procedures, the effects of temperature on *B. zonata* development and survival were evaluated in four sets of experiments: (1) egg to adult stage, (2) larva to adult, (3) pupa to adult and (4) adults alone. This procedure allowed us to determine whether the flies acclimated to the colony rearing temperature. Analysis of variance tests were used to determine differences between developmental time, percent survival (arcsine squareroot of percent transformed) and adult fecundity data within and among experiments.

Results

Egg to Adult.—The effects of temperature on survival of *B. zonata* life stages are shown in Table 1. Egg hatch significantly increased with temperature from 15° C (51%) to 25° C (91.3%) and then decreased to zero at 35° C. No larvae completed development at 15° C or 35° C. Larval and pupal survival, and male

Table 1. Effect of temperature on survival of egg, larval, and pupal stages of *Bactrocera zonata* that were reared on artificial diet.

Test	°C	Stage specific survival (%)[a]		
		Egg	Larvae	Pupae
Egg to adult	15	51.00 [A]	—	—
	20	76.67 [B]	71.28 [C]	93.9 [B]
	25	91.33 [C]	93.78 [A]	97.66 [A]
	30	55.67 [C]	79.66 [B]	81.94 [C]
Larvae to adult[b]	20		62.67 [C]	88.86 [B]
	25		89.00 [A]	95.50 [A]
	30		72.33 [B]	88.93 [B]
Pupae to adult[b]	15			78.67 [C]
	20			92.33 [B]
	25			97.67 [A]
	30			95.00 [A]
	35			5.00 [D]

[a] Means followed in square brackets by different capital letters within each test differ at $P \leq 0.05$; $n = 100$ individuals per replicate, with three replicates conducted.

[b] Immature stages reared at 25° C prior to exposure to test temperature in latter two tests.

longevity were greatest at 25° C. Female longevity was the same at 20° C and 25° C. Longevity of both sexes was reduced by 59 to 74 days as the rearing temperature was increased from 25° C to 30° C. Female fecundity (eggs laid) and fertility (% egg hatch) were greatest at 25° C (Table 2).

Developmental times for all stages were inversely related to temperature (Table 3). Egg development was fastest at 25° C and 30° C, and larval, pupal and ovarian development were fastest at 30° C.

Larva to Adult.—With one exception, the trends described previously were seen when starting with neonate larvae instead of eggs: larval and pupal survival, and female fecundity and fertility were greatest at 25° C, no larvae completed development at 15° C or 35° C, no adults laid eggs at 30° C, adult longevity decreased between 25° C and 30° C, and developmental times were inversely related to temperature. In this test, however, adult longevity was inversely related to temperature with significant decreases at 25° C for both sexes (Tables 1–3).

Pupa to Adult.—Pupal survival was greatest at 25° C and 30° C but decreased at 35° C. No females laid eggs at 15° C, 30° C or 35° C and both fecundity and fertility were greatest at 25° C. Adult longevity significantly increased from 15° C to 25° C and then significantly decreased. As before, adult longevity decreased between 25° C and 30° C. Pupae completed development at all temperatures and developmental time was inversely related to temperature (Tables 1–3).

Adults.—The results starting with colony reared adults at each test temperature are similar to those starting with pupae: maximum female fecundity and fertility, and male longevity at 25° C. Female longevity was greatest at 20° C (Table 2). The preoviposition period ranged from 23.8 days at 20° C to 8.4 days at 30° C (Table 3).

Cross Test Comparisons.—Female fecundity and fertility were significantly reduced ($P < 0.01$) when pupae or adults were removed from the 25° C rearing colony and placed at 20° C when compared to females reared at 20° C starting as eggs or larvae. Adult survival at 30° C was significantly increased ($P < 0.01$) in

Table 2. Effect of temperature on female fecundity and fertility, and adult longevity of *Bactrocera zonata*.

Test	°C	Eggs per female	Percent egg hatch	Adult longevity (days)[a]	
				Female	Male
Egg to adult	20	177.62 [B]	53.33 [B]	78.94 [A]	62.26 [B]
	25	215.93 [A]	81.67 [A]	76.14 [A]	70.33 [A]
	30	—	—	4.70 [B]	3.77 [C]
Larvae to adult	20	175.58 [B]	57.00 [B]	70.08 [A]	61.56 [A]
	25	195.23 [A]	82.00 [A]	59.83 [B]	45.80 [B]
	30	—	—	3.10 [C]	2.97 [C]
Pupae to adult	15	—	—	19.33 [C]	17.33 [C]
	20	111.53 [B]	48.33 [B]	57.03 [B]	49.8 [B]
	25	202.7 [A]	81.30 [A]	72.80 [A]	62.7 [A]
	30	—	—	16.70 [C]	12.60 [D]
	35	—	—	8.60 [D]	6.37 [E]
Adult	15	—	—	12.30 [C]	9.80 [C]
	20	80.82 [B]	34.33 [B]	76.67 [A]	62.63 [A]
	25	172.27 [A]	89.67 [A]	67.6 [B]	66.10 [B]
	30	—	—	11.50 [C]	10.40 [B]
	35	—	—	5.03 [D]	4.30 [C]

[a] Means followed in square brackets by different capital letters within each test differ at $P \leq 0.05$; $n = 30$ pairs of flies per replicate with three replicates conducted.

flies held at 25° C until they were pupae or adults compared to those reared at 30° C starting as eggs or larvae.

Holding the previous developmental stages at 25° C had no effect on the developmental times or survival for *B. zonata* larvae or pupae held at 20° C or 30°

Table 3. Effect of temperature on duration of developmental stages of *Bactrocera zonata* that were reared on artificial diet.

Test	°C	Stage duration (days)[a]			
		Egg	Larvae	Pupae	Preoviposition
Egg to adult	15	2.90 [A]	—	—	
	20	1.79 [B]	13.5 [A]	18.7 [A]	
	25	1.02 [C]	6.1 [B]	11.6 [B]	
	30	1.02 [C]	5.4 [B]	6.2 [C]	
Larvae to adult	20		12.2 [A]	21.4 [A]	
	25		6.2 [B]	11.5 [B]	
	30		5.8 [C]	8.3 [C]	
Pupae to adult	15			30.0 [A]	
	20			18.0 [B]	
	25			10.3 [C]	
	30			7.4 [D]	
	35			4.1 [E]	
Adult	15				never
	20				23.8 [A]
	25				14.4 [B]
	30				8.4 [C]
	35				never

[a]Means followed in square brackets by different capital letters within each test differ at $P \leq 0.05$; $n = 100$ individuals per replicate, with three replicates conducted.

C (Table 1). This indicates that rearing the flies in colony at 25° C for the duration of this experiment caused no acclimation of the insects.

Discussion

Rearing temperature had a significant effect on the rate of *B. zonata* development. Like other fruit flies (Messenger & Flitters 1958, Pritchard 1978, Saeki et al. 1980, Fletcher & Kapatos 1981, Okumura et al. 1981), development is sigmoid up to a maximum of 26° C to 30° C and decreases thereafter. Although other factors including fruit moisture, ripeness, and variety, and larval crowding (Smith 1977, Tsitsipis & Abatzis 1980, Ibrahim & Rahman 1982, Carey et al. 1985) influence fruit fly developmental rate, temperature is the key factor in the field (Fletcher & Comins 1985).

Our data indicate that *B. zonata* can complete three to nine generations per year in the various parts of its range. This estimate compares favorably with other polyphagous fruit flies including *B. dorsalis* and *B. tryoni* (Froggatt) which have three to eight generations per year in various parts of their ranges (Saeki et al. 1980, Meats 1981).

Our results provide useful information for better handling of *B. zonata* in the laboratory. Mass rearing of fruit flies requires optimizing the rearing conditions for each stage to maximize turnover of production and quality of insect produced. Our data indicate that the optimum temperature for larval (25° C to 27° C) and pupal (20° C to 25° C) rearing are different because, aside from faster development, other parameters such as percent pupation, complete adult emergence from the puparia, and larval and pupal survival should also be considered. Temperature limits in a mass rearing system should be kept lower than optimum to avoid accidental overheating either from malfunctioning cooling systems or the build-up of metabolic heat.

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BEE FAUNA ASSOCIATED WITH SHRUBS IN TWO CALIFORNIA CHAPARRAL COMMUNITIES

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Abstract.—The bee faunas visiting spring-blooming shrubs in the chaparral of northern California were compared between two localities having similar plant species but different climatic regimes. Bees were collected from mid-March to mid-July during two consecutive years that were characterized by different rainfall. In the Inner Coast Ranges of Napa County, with a mediterranean climate, 73 bee species from six families were recorded on 11 shrub species; Megachilidae was the most species-rich family, followed by Andrenidae and Halictidae. Immediately inland from the coast in Marin County, where the frequently cool, foggy conditions are unfavorable for many solitary bees, the bee fauna had only half the number of species and a third the number of individuals; there were very few Megachilidae and a relatively high abundance of bumble bees. Of the 81 total species at both sites, close to one-third were shared between sites; the introduced honey bee was ubiquitous. A greater number of species were collected during the year of normal rainfall, most species were recorded in low abundance, and females comprised two-thirds of the collected specimens. Shrubs of the genus *Ceanothus* attracted the greatest diversity of bees. Comparison with other regional bee surveys shows the inland site here to be most typical of other areas with chaparral.

Key Words.—Insecta, Apoidea, Hymenoptera, faunal survey, chaparral, pollination, California

Surveys of pollinators in different plant communities of California show the chaparral community to have the largest diversity of bee species per area, as well as comparatively high diversities of other flower-visiting insects (Moldenke 1976a). Furthermore, these studies indicate that bees are the most species-rich group of pollinators throughout California, with the exception of subalpine marsh meadows. Bees are typically most diverse in warm temperate xeric climates (Michener 1979). Within California, the southern deserts and mediterranean-climate regions have the highest number of species, with up to three-fold more than alpine, Great Basin, and immediate-coastal areas (Moldenke 1976a, 1979a). This concentration in arid regions may be attributed, in part, to the generally high diversity of plants blooming during the short flight season of bees, and to the tendency of most solitary bees to nest in the ground, where risk of mortality from fungus attacks is decreased in dry climates (Linsley 1958, Michener 1979). In the chaparral community, bees are the most significant pollinators; in terms of abundance, they outnumber all other flower-visiting insects except beetles, whose greatest impact is, however, as flower herbivores (Moldenke 1976a).

The chaparral vegetation covers large areas of California and occurs inland from the coast, mainly within the Coast Ranges and at low- to mid-elevations bordering the Central Valley, especially on dry rocky slopes with thin soil (Munz & Keck 1959, Keeley & Keeley 1988). These regions are characterized by a prevailingly mediterranean-type climate with hot dry summers and cool wet winters, but chaparral may also extend into areas with more moderate climatic regimes. Chap-

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arral is dominated by evergreen sclerophyllous, fire-adapted shrubs, which commonly include *Adenostoma fasciculatum* Hooker & Arnott (chamise), *Ceanothus* spp., and *Arctostaphylos* spp. (manzanita); the herbaceous cover is generally sparse except during the first years following fire (Hanes 1977, Keeley & Keeley 1988). In mature chaparral, flowering shrubs comprise the major food source for bees, although herbaceous plants growing in shrub openings or neighboring grassland appear to play a role in maintaining populations of certain bee species (Dobson 1980). The principal blooming season follows the winter rains, with most shrub species flowering between March and June (Moldenke 1979b). This corresponds to the period in spring when both soil moisture is still plentiful and ambient temperatures have increased to levels favorable for insect activity, but before the hot, dry summer begins; this is also the time when most insects, including flower visitors, reach peak numbers (Force 1990).

This paper compares the species composition and relative abundance of bees collected on the flowers of spring-blooming shrubs in two chaparral sites in northern California. The sites were chosen for their ease of accessibility and generally similar shrubby flora; they differed in climate, with the site closer to the coast being cooler and subject to frequent fog. Data on the bee fauna were gathered for two consecutive years characterized by sharply different amounts of rainfall. The results here represent part of a broader study of the pollinator and flower-visiting insect fauna associated with chaparral shrubs (Dobson 1980). In addition to increasing our understanding of insect-plant interactions in the chaparral, this study had the goal of providing baseline data for future faunal surveys and to serve in efforts to preserve the California chaparral community.

Methods and Materials

The study was carried out at two chaparral sites, 50 airline km apart, in northern California. The first site was located in the Inner Coast Ranges of Napa County, on the upper east-facing slope of Mt. Veeder at 550 m elevation. The vegetation consisted principally of mature impenetrable chaparral, interspersed with stands of mixed evergreen forest, but within the study plot (approximately 200 m^2) the chaparral was more open, having been cleared mechanically 4 years previously; herbaceous plants were sparse. The second site was situated in the Outer Coast Ranges in Marin County, at the foot of Pine Mountain at 335 m elevation, facing south over Alpine Lake. Due to the closer proximity of the ocean (within 12 airline km), the spring-summer climate is cooler and windier than on Mt. Veeder, with frequent fog, especially in the mornings. The study plot, of similar size as the previous, was in an area where the strongly serpentine character of the soil yielded an open plant cover comprised of low-growing shrubs, which included serpentine-endemic species.

Bees visiting the flowering shrubs were censused at each site 1 day per week during the spring-summer months, from mid-March to mid-July in 1977 and 1978, using sweep-net collection methods. Collecting was concentrated on selected shrubs of each species, which were sampled in succession over 30 min periods every 2–3 h, from 08:30 h to 16:30 h, thus spanning the daytime hours of bee activity. Hourly recordings of ambient temperature were taken during each sampling day in 1978. Based on the collected specimens, bee faunas were compared between sites with respect to the numbers and kinds of species, relative abun-

dances, sex ratios, and Shannon-Wiener diversity indexes of individual families, temporal activities, and shrub associations. Some species, particularly fast-flying bees (e.g., large Anthophoridae), were difficult to collect and, therefore, are underrepresented in the samples. The introduced honey bee, which was very common on certain shrubs, was not collected in proportion to its abundance and was censused mainly for its presence. Bee specimens were identified by specialists and vouchers deposited in the R. M. Bohart Museum of Entomology, University of California, Davis.

Results

Habitat Resources.—During the study a total of 13 shrub species from seven families bloomed at the two sites: 11 at Mt. Veeder and eight at Pine Mountain; six of the species occurred at both sites. Following the nomenclature of Munz & Keck (1959), shrubs common to the sites were *Eriodictyon californicum* (Hooker & Arnott) Torrey (Hydrophyllaceae), *Pickeringia montana* Nuttall (Leguminosae), *Rhamnus californica* Eschscholtz (Rhamnaceae), *Adenostoma fasciculatum* and *Heteromeles arbutifolia* M. Roemer (Rosaceae), and *Mimulus* (*Diplacus*) *aurantiacus* Curtis (Scrophulariaceae); only at Mt. Veeder: *Arctostaphylos viscida* Parry (Ericaceae), *Dendromecon rigida* Bentham (Papaveraceae), *Ceanothus foliosus* Parry, *C. parryi* Trelease, and *C. sonomensis* J. T. Howell (Rhamnaceae); and only at Pine Mountain: *Arctostaphylos pungens* var. *montana* (Eastwood) Munz and *Ceanothus jepsonii* Greene. With the exception of *Dendromecon,* all genera were represented at both sites. Thus, any taxonomic differences between sites were at the species level.

Blooming phenologies of the shrubs were generally similar both years, but flower density was less in 1977. This was especially marked for *R. californica, P. montana,* and *A. fasciculatum* (produced no flowers); *C. parryi* on Mt. Veeder was unusual in producing a denser bloom in 1977. The two study years differed markedly in rainfall, and this was most pronounced in the more inland site on Mt. Veeder. During 1977, which was the second of two consecutive years with severe drought, precipitation was several fold less than in 1978, which received slightly above normal rainfall. For each weather year (1 Jul–30 Jun), rainfall at Mt. Veeder was 32.94 cm (1977) and 117.07 cm (1978), with an average over 33 years of 82.96 cm (data from Oakville, Napa Co., National Weather Service 1948–1981); at Pine Mt., rainfall was 56.74 cm (1977) and 170.21 cm (1978), with an average over 113 years of 131.47 cm (data from Lake Lagunitas, Marin Co.; Roxon 1992).

Bee Species.—A total of 81 bee species, representing six families, were collected on the 13 shrubs at the two sites (Appendix 1). Mt. Veeder had 73 species, and thus twice as many as Pine Mountain, with only 36 species (Table 1). With the exception of Halictidae, which had an equal number of species at both sites, species numbers within each family were greater at Mt. Veeder; this was most pronounced in Megachilidae, where differences between sites reached ten-fold.

Approximately one-third of the species were collected at both sites (Table 1 and Appendix 1). This shared bee fauna constituted a high proportion (78%) of the species at Pine Mountain, but only a third (38%) of those at Mt. Veeder; Halictidae, which was the most species-rich family at Pine Mountain, contributed the largest number (10 of 28 species). Of the 53 species collected exclusively at

Table 1. Number of bee species collected at each site and number shared by (common to) both sites.

Family	Mt. Veeder				Pine Mtn.				Shared
	Only 1977	Only 1978	Both 1977/1978	Total 1977 + 1978	Only 1977	Only 1978	Both 1977/1978	Total 1977 + 1978	
Andrenidae	3	4	8	15	3	5	1	9	6
Anthophoridae	0	4	4	8	1	0	2	3	2
Apidae	0	2	4	6	0	0	4	4	4
Colletidae	0	4	5	9	0	3	2	5	5
Halictidae	0	7	6	13	2	7	4	13	10
Megachilidae	3	7	12	22	1	1	0	2	1
Sum	6	28	39	73	7	16	13	36	28
%	8.4	38.4	53.4	100.0	19.4	44.4	36.1	100.0	

one site, 45 were at Mt. Veeder and, among these, close to 50% were Megachilidae and 20% Andrenidae.

A larger number of bee species were collected in 1978, when rainfall was normal, than in 1977, a year of drought (Table 1). Both sites showed relative increases of close to 50% from 1977 to 1978. Species exclusive to 1978 included a large proportion of the small and mainly late-spring active bees (e.g., Colletidae, Halictidae, and *Ceratina* in Anthophoridae). The majority of species collected in 1977 were recorded both years. These more constant bees, which represented the most stable component of the fauna, comprised approximately half the species at Mt. Veeder and a third of those at Pine Mountain.

Bee Relative Abundance.—During the two years, 799 bee specimens were collected at Mt. Veeder and 205 at Pine Mountain (Table 2). Most species were low in abundance (Appendix 1). Based on apparent breaks in the numbers of species distributed in function of their abundance, 54% of species at Mt. Veeder can be classified as rare (1–4 specimens each), 26% occasional (5–15 specimens), 14% common (20–32 specimens), and 6% abundant (48–96 specimens). Abundant species consisted of *Andrena chlorura* Cockerell and *A. vandykei* Cockerell (Andrenidae), *Bombus edwardsii* Cresson (Apidae), and *Hylaeus polifolii* (Cockerell) (Colletidae). The pattern at Pine Mountain was very similar, with 57% of species rare (1–2 specimens), 23% occasional (3–6 specimens), 14% common (8–14 specimens), and 6% abundant (21–37 specimens). The latter included *Panurginus nigrellus* Crawford (Andrenidae) and *H. polifolii.*

Table 2. Bee abundance (number of specimens collected) at each site over both years.

Family	Mt. Veeder				Pine Mtn.			
	♀	♂	Total	% ♂	♀	♂	Total	% ♂
Andrenidae	219	26	245	10.6	18	24	42	57.1
Anthophoridae	37	20	57	35.1	5	0	5	0.0
Apidae	101	42	143	29.4	50	5	55	9.1
Colletidae	40	113	153	73.9	14	37	51	72.5
Halictidae	83	7	90	7.8	30	20	50	40.0
Megachilidae	76	35	111	31.5	1	1	2	50.0
Total	556	243	799	30.4	118	87	205	42.4

Table 3. Representation of each family in terms of species and specimen numbers, and family diversity index H′.

Family	Mt. Veeder			Pine Mtn.		
	% total species	% total specimens	H′[a]	% total species	% total specimens	H′[a]
Andrenidae	20.5	30.7	1.88	25.0	20.5	1.60
Anthophoridae	11.0	7.1	1.63	8.3	2.4	1.05
Apidae	8.2	17.9	0.92[b]	11.1	26.8	0.99[b]
Colletidae	12.3	19.1	1.71	13.9	24.9	0.88
Halictidae	17.8	11.3	2.06	36.1	24.4	2.18
Megachilidae	30.1	13.9	2.77	5.6	1.0	0.69

[a] Shannon-Wiener diversity index, where $H' = -\sum p_i \ln p_i$, and p_i = proportion of total specimens in a family that belong to the ith species (Whittaker 1972).

[b] Excluding the introduced honey bee, *Apis mellifera*.

The proportion of males collected varied among families and between sites (Table 2). Colletidae had an exceptionally high percentage of males (over 70%) at both sites, whereas most other families had a marked predominance of females. In Andrenidae and Halictidae, males and females tended to be more equally represented at Pine Mountain.

Bee Faunal Composition.—In terms of species numbers, each site was dominated by a single family (Table 3). Megachilidae (with 30% of the species) were dominant at Mt. Veeder and Halictidae (36%) at Pine Mountain. Figures for other families were generally similar between sites, with Andrenidae occupying second place. Pine Mountain had a striking paucity of Megachilidae (5.6%).

With respect to relative abundance (Table 3), Andrenidae were clearly the most abundant bees at Mt. Veeder, whereas no family predominated at Pine Mountain. Anthophoridae were few at both sites. Overall, the sites differed in the comparatively high relative abundance of Andrenidae at Mt. Veeder and the low abundance of Megachilidae at Pine Mountain.

The Shannon-Wiener diversity index of each family, which is based on both the number of species and the relative abundance of each species (Whittaker 1972), provides a measure of how equitably the species are represented within each site (Table 3). Megachilidae had the highest diversity at Mt. Veeder, followed by Halictidae, whereas at Pine Mountain Halictidae was highest. Index values at Mt. Veeder clearly exceeded those at Pine Mountain for Megachilidae, Colletidae, and Anthophoridae.

Temporal Activity of Bees.—Daily activity levels, based on the number of specimens collected at bihourly intervals, were generally uniform among families and between sexes. At Mt. Veeder, bee activity showed a normal distribution, with a maximum around midday. This corresponded with, or slightly preceded, the time of highest daily ambient temperature between 13:00 and 15:00 h. Diverging activity patterns were evident in four cases: (1) female Megachilidae, with a generally high activity over the morning hours; (2) female Andrenidae, with peak activity during mid-morning; (3) male Colletidae, with maximum activity extending broadly from mid-morning to mid-afternoon; and (4) male Apidae (*Bombus*) and Anthophoridae (excluding *Ceratina*), with a bimodal activity curve showing a small peak in early morning and a principal peak at midday.

Seasonal activity patterns of bee families, measured by the number of species collected over the course of the study, were in general similar at the two sites. As exemplified by Mt. Veeder (Fig. 1), Andrenidae flew almost exclusively during the early part of the spring, Megachilidae reached peak activity during the middle period, and Colletidae, with initially very low activity, increased across the season; Halictidae, Apidae, and Anthophoridae maintained relatively constant levels throughout the study. Considering all families together, the total number of species was quite uniform and showed only a moderate peak in early spring, associated primarily with the blooming of *Ceanothus,* and a smaller one at the end of the season, on *Heteromeles.*

Bee-shrub Associations.—A list of bee species collected on each shrub genus at each site is provided in Appendix 1; bee-shrub associations at Mt. Veeder are broken down by bee family in Fig. 1. The number of bee species per shrub genus ranged from 4–33 at Mt. Veeder and 2–16 at Pine Mountain. At Mt. Veeder, *Ceanothus* (33 species) received the greatest number, followed by *Heteromeles* (27 species), *Eriodictyon* and *Pickeringia* (each 23 species); *Dendromecon* (four species), which is nectarless, received the fewest. A major contrast between sites was the paucity of bees on *Mimulus* and *Pickeringia* at Pine Mountain, whereas at Mt. Veeder these shrubs attracted numerous species, especially Megachilidae. At Mt. Veeder each shrub genus was visited by at least three of the six bee families; all families were represented on *Ceanothus* and *Eriodictyon.*

Bee-shrub associations showed greater diversity at Mt. Veeder. Bees recorded at both sites generally visited more shrub taxa at Mt. Veeder and most bee-shrub associations at Pine Mountain were likewise observed at Mt. Veeder. At the bee family level, Halictidae and Apidae showed the broadest associations, which spanned all shrub genera, and Andrenidae exhibited the most restricted visitation. At the bee species level, Andrenidae tended to visit principally *Arctostaphylos* and *Ceanothus* shrubs. The majority of species in other families showed more generalist foraging patterns, with several host shrubs each. Flower and pollen specificity at Mt. Veeder are discussed in greater detail in Dobson (1980).

The Introduced Honey Bee.—Honey bees were frequent at both sites and foraged throughout the day from early morning to late afternoon, utilizing floral resources over longer daily periods than most native bees except *Bombus.* At Mt. Veeder, they visited all shrubs except *Mimulus*; they were the most abundant bees on *Arctostaphylos* and the tree *Arbutus menziesii* Pursh (madrone, Ericaceae), both of which bloomed in early spring during the major population growth of honey bee colonies, and on *Rhamnus* and *Heteromeles,* which were the last nectar-providing shrubs to bloom. At Pine Mountain, honey bees accounted for the majority of visitors on five of the seven shrub species and seemed to occupy a foraging niche generally similar to that of bumble bees.

Although no remarkable interferences in foraging were observed among any of the native bees, several instances of negative interactions were recorded between honey bees and native bees, especially at Mt. Veeder where solitary bees were most abundant. During these encounters, which occurred mainly on *Rhamnus* and *Heteromeles,* honey bees either actively chased small bees away from flowers or caused them to fly off upon landing on the same flower or inflorescence. Individual shrubs heavily frequented by honey bees appeared to have distinctly

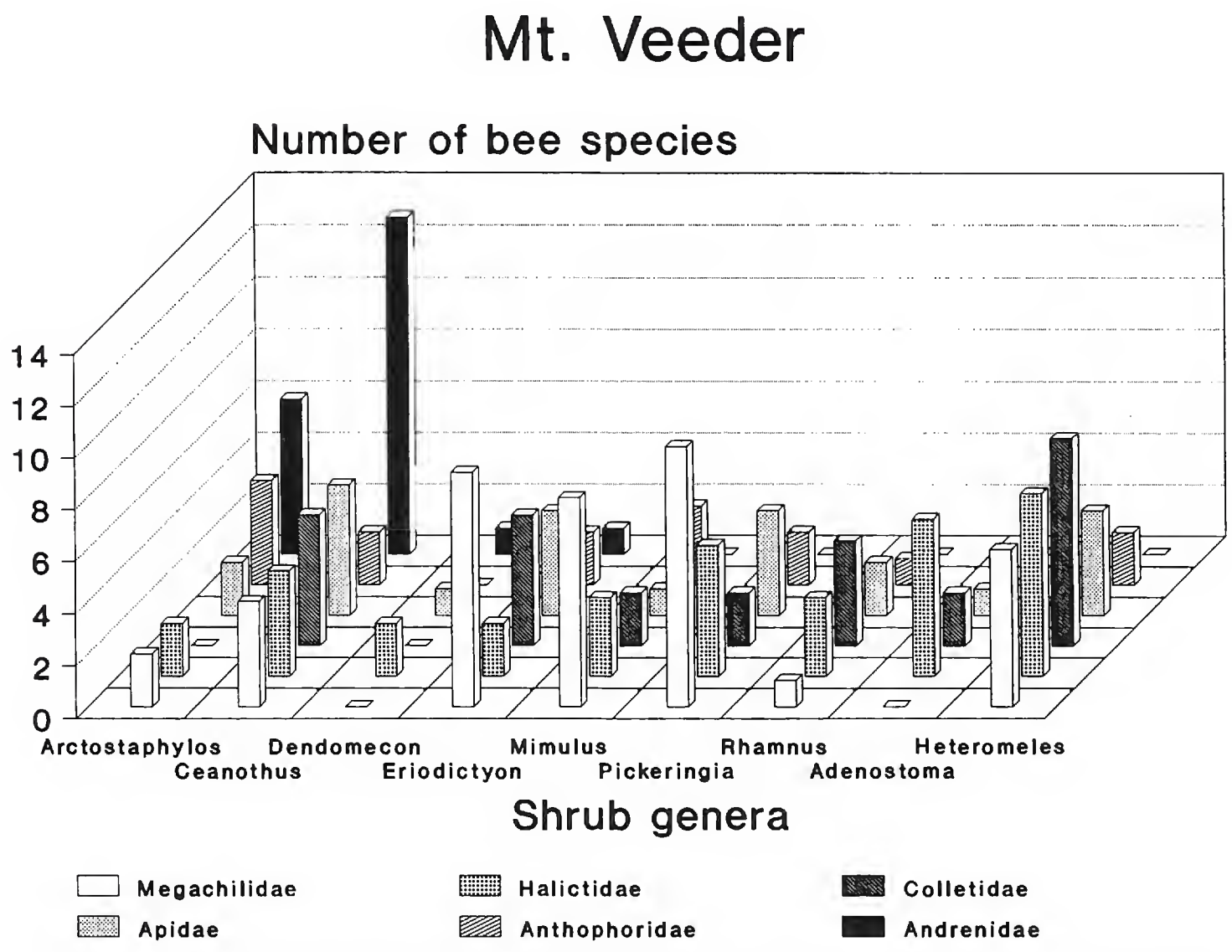

Figure 1. Number of bee species in each family that were collected on the different shrub genera, Mt. Veeder, 1977 and 1978. Shrubs are arranged according to the seasonal chronology of their peak blooming periods.

fewer solitary bees compared to other shrubs, but no count data were collected to verify this impression.

Discussion

The two chaparral sites were found to have bee faunas that differed sharply in both numbers of species and abundance, even though the shrub floras were similar. With twice as many species of bees and over three-fold more bee specimens, the Mt. Veeder site, situated in the warm and dry Inner Coast Ranges, had a much more diverse bee fauna, as is also reflected in the higher diversity indexes within its bee families. The cooler and more coastal climatic conditions (frequent fog and winds) at the Pine Mountain site, located just inland from the coast, appeared to be a major factor limiting its bee fauna, thereby overriding intersite similarities in the composition of bee host-plants. Likewise, the presence in northern California of comparatively few flower-visiting insects on the immediate coast at Point Reyes, compared to a chaparral site at Jasper Ridge, has also been attributed to the restrictions imposed by the foggy, cool, and windy coastal climate (Moldenke 1975).

Parallel decreases in bee fauna associated with proximity to the coast have been documented in other areas. In California, reductions of 50% in bee species, as well as in total pollinator diversity, may occur in coastal communities compared

to adjacent chaparral (Moldenke 1976a), and differences of the same magnitude have been recorded between vegetationally similar (but floristically different) coastal and inland sites in scrubby mediterranean-climate areas of southern Spain (Herrera 1988) and Chile (Moldenke 1979b, c). These changes in bee species are, however, not surprising, given the general tendency of bee numbers to increase as one moves into comparatively warmer, more xeric habitats (Linsley 1958, Michener 1979, Dylewska 1988, Armbruster & Guinn 1989).

Moldenke's (1976a) observations that the pollinator fauna of northern coastal scrub shifts to a depauperate chaparral fauna inland of the immediate coast are corroborated here, where almost 80% of the species at Pine Mountain were also found at Mt. Veeder. Nevertheless, of the total species at Mt. Veeder, only 23% included the chaparral community among their list of characteristic habitats (Moldenke & Neff 1974a); the majority belonged to Andrenidae and Megachilidae, the two most species-rich families at the site. The corresponding figure at Pine Mountain was 22%, with the species distributed among several families. According to geographic and habitat distributions listed for 66 of the 81 species at the two sites (Moldenke & Neff 1974a), 61 species are wide-ranging and occur mainly in montane regions of both northern and southern California, and five are principally southern Californian species.

In terms of bee faunal compositions, the most striking contrast between sites was the high percentage of Megachilidae species at Mt. Veeder, which supports reports that this family is generally well represented in the scrubby vegetations of California but is less prevalent in other habitats, including coastal areas (Moldenke 1976a). A second contrast was the high percentage of Halictidae at Pine Mountain. Comparison with bee faunas in other chaparral and coastal communities in California (Table 4) shows that both sites resemble others in their percentage of species in Andrenidae (high), but are distinctive in having figures that are higher for Colletidae and lower for Anthophoridae. These differences may arise partly from the study being restricted in time (i.e., to spring-summer months) and in habitat (i.e., to shrubby plants). Similarly affected was the total number of recorded species: at Mt. Veeder this was very low compared to other chaparral sites; at Pine Mountain it was somewhat lower compared to the other coastal areas. Discrepancies specifically in the number of Anthophoridae may result from the under-collection of fast-flying species as well as the lack of revisionary studies of *Nomada* (resulting in many undescribed species) which, while accounting for the largest proportion of Anthophoridae species in Moldenke (1976b), were collected in only low numbers here. Comparisons in the Apidae, Halictidae, and Megachilidae, however, suggest that Mt. Veeder is more typical of chaparral and Pine Mountain of coastal habitats. Indeed, Mt. Veeder resembled the chaparral regions in its unusually high percentage of Megachilidae (around 30%) and somewhat low percentage of Halictidae (under 20%), whereas Pine Mountain displayed in extreme the coastal sites' opposite trends and a moderate tendency for higher proportions of Apidae.

Relative abundance of each family did not closely follow patterns in species numbers, and the greatest deviations occurred at Mt. Veeder in Apidae, with few species but high abundances, and Megachilidae, with many species comprised of few individuals each. The distribution of specimen numbers across the species was very similar at the two sites; the majority of species (80%) had low relative

Table 4. Family representations of bee faunas (% total species) at various localities with chaparral or coastal vegetation in California.

	Chaparral vegetation						Mixed	Coastal vegetation			
Family	Mt. Veeder	Pine Mtn.	N. coast range[a]	Mather[b]	Echo Valley[c]	Japatul Valley[d]	Channel Islands[e]	N. coast[f]	Bodega[g]	Humboldt[h]	S. coast[i]
Andrenidae	20.5	25.0	18.3	21.5	20.1	18.5	20.3	20.4	17.0	9.3	28.4
Anthophoridae	11.0	8.3	28.1	22.2	28.4	20.5	32.0	25.3	25.5	11.6	32.1
Apidae	8.2	11.1	2.9	4.2	1.2	1.3	4.6	6.2	17.0	25.6	2.4
Colletidae	12.3	13.9	4.2	7.6	5.3	2.0	1.3	6.2	4.3	7.0	1.2
Halictidae	17.8	36.1	16.2	15.3	19.5	19.2	24.8	26.5	21.3	23.3	22.2
Megachilidae	30.1	5.6	30.2	29.2	24.9	37.7	17.0	14.8	14.9	23.3	11.1
Melittidae	0	0	0	0	0.6	0.7	0	0.6	0	0	2.4
No. species	73	36	377	144	169	151	153	162	47	43	81

[a] Jasper Ridge, San Mateo Co. (Moldenke 1976a).
[b] Sierra Nevada foothills, Tuolumne Co. (Moldenke & Neff 1974b).
[c] San Diego Co. (Moldenke & Neff 1974b).
[d] Post-fire (mainly annual flora), San Diego Co. (Moldenke & Neff 1974b).
[e] Mainly chaparral and coastal scrub/prairie (Rust et al. 1985).
[f] Coastal scrub, Point Reyes, Marin Co. and Pescadero, San Mateo Co. (Moldenke 1976a).
[g] Dunes and prairie, Sonoma Co. (Thorp & Gordon 1992).
[h] Dunes, Humboldt Co. (Thorp & Gordon 1992).
[i] Coastal scrub, Torrey Pines, San Diego Co. (Moldenke & Neff 1974b).

abundances, and only 6% were exceptionally numerous. The patterns corroborate general trends of plant and animal surveys, in which species-abundance curves typically show logarithmic distributions (Preston 1948, Tepedino & Stanton 1981).

Bees were most numerous, in both species and individuals, during the year of normal rainfall, when plant bloom was denser and all shrub species flowered. The substantial increases in species numbers that occurred at both sites from the year of drought (1977) to the year of normal rainfall (1978), amounting to almost half of the total species recorded, indicates that bee diversity during a given year is not simply a function of the previous year's bee fauna. Indeed, it suggests that some bee species are parsivoltine, in which individuals of a single species require different numbers of years to complete development or emerge from the nest. Parsivoltinism has been documented in several bees, especially Megachilidae, and studies of *Osmia* species suggest that this polymorphism in emergence time is genetically controlled (Torchio & Tepedino 1982). However, it cannot be excluded that in other cases emergence may be cued to rainfall patterns and that during unfavorable years bees may remain dormant in their nests until a more favorable season (Linsley 1958). This may apply to Mt. Veeder, where most of the bees collected exclusively during the year of normal rainfall were species that fly in mid-spring to summer when any water shortage effects might critically restrict bee activity. The triggering of bee emergence by moisture levels has been proposed especially in relation to desert bees that were observed to fly only when water was sufficient for their primarily annual host plants to germinate and bloom (e.g., Linsley 1978).

The few bee species recorded exclusively during the drought year may represent bees that extended their foraging ranges into neighboring habitats or onto alternate host plants (i.e., chaparral shrubs) to supplement the decreased availability of

their usual food plants. The yearly variation in floral resources observed in this study does not appear to be very unusual in plant communities (e.g., Rotenberry 1990, Tepedino & Stanton 1980). Furthermore, the corresponding changes in the bee fauna lend support to Tepedino & Stanton's (1981) contention that a large proportion of the occasional bees within a fauna may be opportunistic fugitives that respond to the spatiotemporal unpredictability of floral resources by dispersing among patchily distributed food sources. Given the comparatively great variance in annual rainfall, common occurrence of drought, and year-to-year variation in flower production within the chaparral (Keeley & Keeley 1988), the differences in bee faunal compositions obtained over the 2 years here could be viewed as typical of chaparral communities.

The differing composition and abundance of bee species at the two sites probably stemmed primarily from the influence of climatic conditions on bee activity, although availability of nesting sites and density of host-plant bloom may have also played a role. The warmer, drier, and more constant spring-summer weather at Mt. Veeder provided more hours during the day and days during the season that were favorable for bee activity than at Pine Mountain and thereby allowed for a larger number of solitary bees. Most of the species collected exclusively at Mt. Veeder were small-bodied or metallic-colored bees (e.g., *Hylaeus, Osmia, Ceratina*), which generally require higher ambient temperatures for flight than do larger-sized bees (Stone & Willmer 1989). Unsurprisingly, in the changing climate at Pine Mountain the abundance and diversity of bees on the shrubs fluctuated often hourly in relation to the weather. During the frequent, cool periods of fog and winds, activity decreased sharply and only honey bees and bumble bees continued to forage. These large hairy bees, particularly *Bombus,* can generate and maintain higher body temperatures under adverse ambient conditions (Heinrich 1979, Stone & Willmer 1989) and were the most abundant bees at this site. In addition, the cool moist climate at Pine Mountain may have limited the survival of larvae in many bee species by increasing the susceptibility of nest provisions to mold and by slowing bee development, thereby lengthening the mold-sensitive period (Linsley 1958).

The tendency for most bees to reach peak numbers on the shrubs around midday may reflect primarily their need to restrict their flower-visiting activity to daytime hours when temperature and insolation are appropriately high (Linsley 1958, 1978; Käpylä 1974; Willmer 1983) and secondarily the temporal pattern of nectar and pollen availability in the flowers. Depletion of food rewards was probably the main cause behind the sharp decrease in bees after early afternoon. The unimodal pattern of daily activity was strongest among the smaller bees; in progressively larger and more hairy bees, this pattern became less pronounced and eventually bimodal (*Bombus* and large Anthophoridae). Similar observations of bees visiting *Lavendula* were shown to relate to differences in body size and were correlated with the bees' differing temperature requirements for flight and nectar-water needs (Herrera 1990). It has certainly been repeatedly noted that the composition of bee species at a flower source changes during the day, with the most energetically demanding bees arriving first (Roubik 1989). On a seasonal level, in mediterranean Israel the body sizes of bees are reported to correlate negatively with the seasonal increase in air temperature (Shmida & Dukas 1990), but such trends were not evident in the present study with the possible exception of *Hylaeus,*

which, unlike other small-sized bee groups, showed a general increase in numbers of species over the course of the study.

The relatively open vegetation of both shrubs and trees in the area at Pine Mountain contrasted with the more dense and heterogeneous woody vegetation at Mt. Veeder, and although availability of nesting locations for ground-nesting bees was probably comparable at the two sites, conditions for twig- and cavity-nesting bees may have been more limiting at Pine Mountain. Potentially vulnerable bees included Megachilidae, as well as wood-nesting species in Anthophoridae (*Ceratina* and *Xylocopa*) and Colletidae (*Hylaeus*) (Stephen et al. 1969). However, even in these cases, climate may have been the most restricting factor (P. F. Torchio, personal communication).

Flowering shrubs were the principal food source for the bees collected at both sites, based on field observations and on analysis of female pollen loads, although some bees at Mt. Veeder did visit other plants in low frequency (Dobson 1980). The shrub floras were similar between sites, and differed mainly in their respective species of *Arctostaphylos* and *Ceanothus,* making it unlikely that shrub composition was a major determinant of the sites' different bee faunas. However, shrub cover and consequently food density, which has been shown to influence levels of bee foraging activity (Moldenke 1975, Ginsberg 1983, Sih & Baltus 1987), was less at Pine Mountain and probably contributed to the lower abundance of bees. The effect of shrub cover on bee species richness is less clear, but the marked increases in bee species during 1978 when shrub bloom was denser (particularly at Mt. Veeder) suggests that it too may have been a factor in the disparate number of bee species between sites.

The diversity of bees visiting the different shrubs underscores the importance of all shrub species in providing food for the resident bees. In turn, most chaparral shrub species are self-incompatible and depend upon insects for pollination (Keeley & Keeley 1988). Each shrub was visited by a distinctive spectrum of bee species from different families. *Ceanothus* species and *H. arbutifolia,* covering the beginning and end of the spring season respectively, attracted the greatest diversity. Both genera have bowl-shaped flowers where the nectar and pollen are easily accessible to a variety of insects. Curiously, *A. fasciculatum,* which has small bowl-shaped flowers and is the most common shrub in the California chaparral, received very low visitation. These patterns are not, however, consistent across chaparral sites in California (Moldenke & Neff 1974c; A. R. Moldenke, personal communication). At some locations, high bee diversities have been observed on additional shrubs, including *Arctostaphylos* species, which were not fully sampled in the present study; and although the paucity of bees on *A. fasciculatum* corroborates observations in other northern California sites (i.e., at Jasper Ridge and Mather), in certain areas, particularly southern California, bee diversity may reach very high levels. *Ceanothus* species, however, number regularly among the chaparral shrubs attracting the greatest diversity of bees.

Certain bee families showed definite seasonal patterns in their numbers of species and were consequently more frequent visitors on some shrubs than on others, although shrub-choice was undoubtedly also influenced by accessibility and quantity of food rewards. Thus, the early-season Andrenidae visited almost exclusively *Arctostaphylos* and *Ceanothus,* as reported in other chaparral areas (Moldenke & Neff 1974b), whereas Megachilidae, which reached peak numbers

at mid-season and are relatively long-tongued, foraged mainly on *Eriodictyon, Mimulus,* and *Pickeringia.*

Reasons behind the differing proportions of male bees at Pine Mountain compared to Mt. Veeder are not clear, although sex ratios can vary considerably both inter- and intraspecifically (Stephen et al. 1969, Michener 1974, Roubik 1989). One factor possibly involved is the phenomenon of protandry, in which males emerge up to a week or more prior to females (and females generally outlive males). Although Linsley (1958) points out that some reports of protandry may in fact reflect the earlier activity of males on flowers rather than any actual earlier emergence, protandry appears to be prevalent in most families of bees except Halictidae and Apidae (social species), which tend to produce males at the end of the season (Robertson 1918, 1930). The remarkably low proportion of male Andrenidae at Mt. Veeder may thus have resulted from the study being initiated after the emergence of males but during the peak activity time of females. Indeed, flower visitors on the early-blooming *Arctostaphylos* shrubs, which males appeared to use as their principal food source, were not sampled throughout their entire bloom period. At Pine Mountain, where the spring season was a little later, the *Arctostaphylos* bloom was fully included in the study and the proportion of Andrenidae males reached much higher levels, close to 50%. In the case of bumble bees, however, it is the factor of early-season nest establishment that underlies the higher proportion of *Bombus* males at Mt. Veeder, most of which were *B. edwardsii.* This species, which was poorly represented at Pine Mountain, as well as *B. vosnesenskii* may establish nests in winter and produce males in early spring (Linsley 1944, Thorp et al. 1983).

Besides timing of flight activity, several other factors may have influenced the variation in sex ratios of collected bees, both within and between sites. First, males and females may differ in the flowers they visit and thus in their tendency to frequent shrubby species. Second, species-specific mating strategies and the associated sites for mate location (e.g., at food sources, near nests, or elsewhere) may result in differing abundances of males and females on the blooming shrubs. Finally, males and females may vary in their wariness of any disturbance created by the collector near the flowers (D. M. Gordon, personal communication) and in the ease with which they are collected; these last factors may also create a bias in the relative abundances of species based on collection data.

Observations of negative interactions between honey bees and solitary bees on selected shrubs suggest that honey bees may substantially influence the foraging activities of native chaparral bees and that they may be competing with them for floral resources. The aggressive chasing away of smaller bees by honey bees was similar to that reported in other bees (e.g., Frankie 1976) and did not appear to reach the high levels of aggression described in eusocial bees (Roubik 1989). The less aggressive displacement of solitary bees through their avoidance of honey bees landing on their flowers may be a relatively common behavior in encounters involving social bees of differing size or aggressivity (Johnson & Hubbell 1975, Morse 1977, Roubik 1989). Although effects of honey bees are difficult to quantify, data gathered by Schaffer et al. (1983) suggest that honey bees compete with native bees (including bumble bees) by reducing the available nectar and evidence from other studies imply that they can have a major impact on the population dynamics and foraging activities of solitary bees (Eickwort & Ginsberg 1980, Ginsberg 1983).

The present study points to the variation in bee faunas that can occur in similar plant communities lying within short distances of each other and to the apparently strong influence that climatic conditions may have in shaping bee diversity and abundance. Given the compositional differences in bee faunas between the 2 years, extension of the study over a broader seasonal span would provide further insight in the population dynamics of native bees in these chaparral areas. In addition to contributing to our understanding of chaparral insects (Force 1990), the data herein could serve as a baseline for future sampling of chaparral bee faunas. From the perspective of biological conservation, insect faunal monitoring is of prime importance if we wish to evaluate any changes in a community incurred from habitat (vegetation) changes, human disturbance, or introduced species. Yet, insects have been generally underrepresented in biotic inventories and local insect surveys are wanting (Disney 1986, Wilson 1987). The paucity of attention given to native bees, which are important pollinators of indigenous plants and thus key components of communities, needs to be redressed (Osborne et al. 1991). With this goal in mind, the information here could assist in the effective protection and preservation of the California chaparral and its associated insect fauna.

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Appendix 1. Bee species collected on the flowers of chaparral shrubs at the Mt. Veeder (V) and Pine Mountain (P) sites, 1977 and 1978, with total number of specimens collected (males and females).

Bee species	Host-shrub genera[a]									No. bees[b]	
	Arct	Cean	Dend	Erio	Mimu	Pick	Rham	Aden	Hete	V	P
ANDRENIDAE											
Andrena angustitarsata Viereck	V	V					P			11C	1A
Andrena astragali Viereck & Cockerell		P								–	1A
Andrena auricoma Smith		V								1A	–
Andrena candidiformis Viereck & Cockerell	V	VP								27C	1A
Andrena chlorogaster Viereck		V								4C	–
Andrena chlorura Cockerell	VP	VP		V			P			49C	4B
Andrena cristata Viereck	V									2B	–
Andrena fuscicauda (Viereck)		V					P			4A	1B
Andrena obscuripostica Viereck		V								3B	–
Andrena orthocarpi Timberlake		V								6C	–
Andrena prolixa LaBerge		VP								3A	2B
Andrena salicifloris Cockerell		V								1B	–
Andrena transnigra Viereck	V									1B	–
Andrena vandykei Cockerell	VP	VP								96C	6C
Andrena w-scripta Viereck		V								10C	–
Panurginus atriceps (Cresson)		V	V							28C	–
Panurginus gracilis Michener		P								–	5B
Panurginus nigrellus Crawford	P									–	21B
ANTHOPHORIDAE											
Anthophora pacifica Cresson	V									1B	–
Anthophora urbana Cresson						V				2B	–
Ceratina acantha Provancher				V	V					13C	–
Ceratina arizonensis Cockerell									V	1B	–
Ceratina nanula Cockerell		P							V	–	1A
Ceratina punctigena Cockerell					V					1B	–
Emphoropsis depressa (Fowler)	VP	VP		VP						9C	2C
Nomada undet.	VP	VP					V			20C	2C
Xylocopa tabaniformis var *orpifex* (Smith)	V				V	V				10C	–

Appendix 1. Continued.

Bee species	Host-shrub genera[a]									No. bees[b]	
	Arct	Cean	Dend	Erio	Mimu	Pick	Rham	Aden	Hete	V	P
APIDAE											
Apis mellifera (Linnaeus)	VP	VP		V		V	VP	VP	VP	C[c]	C
Bombus californicus Smith									V	2B	—
Bombus caliginosus (Frison)	P	V		VP	V	V		V	V	22C	14C
Bombus edwardsii Cresson	V	VP		VP		V				70C	4C
Bombus flavifrons (Ashmead)		V								1B	—
Bombus vosnesenskii Radoszkowski		V		VP		VP	P		VP	9C	12C
COLLETIDAE											
Hylaeus calvus (Metz)		V		V			VP		V	22C	8C
Hylaeus episcopalis (Cockerell)				V		V	VP	V	V	28C	1B
Hylaeus modestus citrinifrons (Cockerell)								VP		1B	1B
Nylaeus nevadensis (Cockerell)									V	1B	—
Hylaeus nunenmacheri Bridwell		V		V						21C	—
Hylaeus (*Paraprosopis*) undet.									V	1B	—
Hylaeus polifolii (Cockerell)		VP		VP	V		VP	VP	VP	48C	37C
Hylaeus rudbeckiae (Cockerell & Casad)									VP	3B	4B
Hylaeus verticalis (Cockerell)		V		V	V	V	V		V	32C	—
HALICTIDAE											
Dialictus sp. 20	P			VP	V	V	V			12C	2B
Dialictus incompletus (Crawford)	V		V				P		P	2B	4C
Dialictus nevadensis (Crawford)		VP	V	P	V		V	VP	VP	21C	6C
Dialictus punctatoventris Crawford							V		V	4C	—
Dialictus tegulariformis (Crawford)	P			P				P		—	3B
Dialictus undet.									VP	2B	2A
Evylaeus argemonis (Cockerell)	V					V	P	VP		4B	2B
Evylaeus nigrescens (Crawford)	P	V		P			P	VP	VP	9C	14C
Evylaeus near *synthyridis*	P	V				V				3C	2B
Evylaeus undet.						V		V	P	3B	1B
Halictus tripartitus Cockerell	P	VP		VP		V		V	VP	26C	10C
Halictus (*Seladonia*) undet.									P	—	1A
Lasioglossum mellipes (Crawford)					V				P	2B	2B

Appendix 1. Continued.

Bee species	Host-shrub genera[a]									No. bees[b]	
	Arct	Cean	Dend	Erio	Mimu	Pick	Rham	Aden	Hete	V	P
Lasioglossum sisymbrii (Cockerell)							P			—	1B
Sphecodes sp. 1									V	2B	—
Sphecodes sp. 2								V		1B	—
MEGACHILIDAE											
Callanthidium illustre (Cresson)						V				1B	—
Chelostomopsis rubifloris (Cockerell)	P	V		V	V	V				15C	1B
Dianthidium plenum Timberlake						P				—	1A
Heriades occidentalis Michener									V	5C	—
Hoplitis producta gracilis (Michener)				V						1B	—
Hoplitis sambuci Titus				V		V			V	13C	—
Megachile b. brevis Say									V	1A	—
Megachile gemula (Cresson)						V				1B	—
Megachile gentilis Cresson									V	1B	—
Megachile (*Leptorachis*) undet.									V	1A	—
Osmia a. albolateralis Cockerell						V				3B	—
Osmia b. brevis Cresson						V				4A	—
Osmia bruneri Cockerell				V						6C	—
Osmia cobaltina Cresson					V	V				8C	—
Osmia cyanella Cockerell					V	V	V			12B	—
Osmia exigua Cresson				V	V					2C	—
Osmia gabrielis Cockerell					V	V				7C	—
Osmia juxta Cockerell				V	V					3B	—
Osmia lignaria propinqua Cresson	V	V		V						9C	—
Osmia ribifloris biedermannii Michener	V									2B	—
Osmia tristella Cockerell		V		V	V				V	6C	—
Osmia (*Chenosmia*) undet.		V		V	V					5C	—
Trachusa gummifera Thorp						V				4B	—

[a] Shrub genera; Arct = *Arctostaphylos,* Cean = *Ceanothus,* Erio = *Eriodictyon,* Dend = *Dendromecon,* Mimu = *Mimulus,* Pick = *Pickeringia,* Aden = *Adenostoma,* Hete = *Heteromeles.* See text for species names.

[b] Year of collection: A = 1977 only, B = 1978 only, C = both 1977 and 1978.

[c] Specimen number not specified, since bees not collected in representation of abundance.

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FLOWER-VISITING INSECTS OF THE GALAPAGOS ISLANDS

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Abstract.—A list of known flower-visiting insects found in the Galapagos Islands is presented. This information, compiled from the literature and direct observations, represents the first step toward understanding how angiosperms interact with insects in the Galapagos archipelago.

Key Words.—Insecta, angiosperms, pollination, flower visitation, Galapagos Islands, Ecuador

The taxonomic composition of the Galapagos Islands flora and insect fauna has been the subject of numerous investigations (Linsley & Usinger 1966, Wiggins & Porter 1971, Rindge 1973, Hayes 1975, Linsley 1977, Froeschner 1985, Lawesson et al. 1987, Peck & Kukalova-Peck 1990, Peck 1991). However, relatively little is known about the relationships that exist between the insects that inhabit these islands and the reproductive processes of their flowering neighbors.

One of the first steps taken when attempting to describe an angiosperm's breeding strategy is to determine what insects regularly visit its blossoms. Direct field observations of the plant in question are normally preceded by a review of previous work on the subject. Unfortunately, the difficulty in obtaining and interpreting such literature often dissuades workers from continuing. In an effort to expedite future studies, I have assembled all available records of insect flower-visitation in the Galapagos Islands, and added to these my most recent field observations from 14 Jun–11 Aug 1990.

Scientific literature from the first part of this century reveals little of substance on the topic of insect pollination in this archipelago. Most of what can be found are casual observations of flower visitors that were made during the many collecting expeditions to the Galapagos Islands that characterized these early years (Williams 1911; Beebe 1923, 1924; Wheeler 1924). For example, Williams (1911) mentioned that *Agrius cingulatus* Fabr. (Lepidoptera, Sphingidae) (recorded as *Phlegathontius cingulata* Fabr.) was commonly seen at flowers during the day, and *Enyo lugubris delanoi* Kernbach (Lepidoptera, Sphingidae) (recorded as *Triptogon lugubris* L.) was observed visiting a "convolvalaceous" flower on Santa Cruz Island. Beebe (1923) reported seeing *Agraulis vanillae galapagensis* Holland (Lepidoptera, Nymphalidae) "flying slowly from flower to flower" on Santiago Island, and *Hyles lineata florilega* Kernbach (Lepidoptera, Sphingidae) (recorded as *Deilephila lineata* Fabr.) was observed "hovering before small blossoms" during the day on Baltra Island.

It was not until 1966 that detailed reports were presented on the possible roles insects played in the ecology and evolution of the Galapagos flora (Linsley 1966, Linsley et al. 1966). These essays summarized what was then known about the distribution of potential insect pollinators in the islands, and the plants they were known to visit. Linsley emphasized the relative dearth of insects in the archipelago, compared to mainland areas, by pointing out that only one species of bee inhabited

the islands. This was an endemic carpenter bee, *Xylocopa darwini* Cockerell (Hymenoptera, Apidae), which was known to visit 60 angiosperm species (Linsley et al. 1966).

Rick (1963, 1966), Eliasson (1974), Grant & Grant (1981), Aide (1986), and Elisens (1989) have also contributed to the growing knowledge of pollination ecology in the Galapagos Islands. In addition, McMullen (1985, 1986, 1987, 1989, 1990) has discussed the interactions between plants and insects in this archipelago.

Methods and Materials

Fieldwork was conducted on Pinta Island from 23 Jun–26 Jul 1990. During this period, breeding studies were performed on six angiosperm species. These included *Justicia galapagana* Lindau (Acanthaceae), *Darwiniothamnus tenuifolius* (Hooker f.) Harling (Asteraceae), *Scalesia baurii* Robinson & Greenman ssp. *hopkinsii* (Robinson) Eliasson (Asteraceae), *Tournefortia rufo-sericea* Hooker f. (Boraginaceae), *Plumbago scandens* L. (Plumbaginaceae), and *Lycopersicon cheesmanii* Riley var. *minor* (Hooker f.) Porter (Solanaceae). Study sites were established at a variety of locations on the southern slope of Pinta ranging from approximately 15 m to 580 m in altitude.

Observations were undertaken to determine what insects, if any, were common visitors to the flowers of these species and might act as pollinators. In addition, flower visitors of plants not involved in the breeding studies were also noted and recorded.

Similar studies took place on Santa Cruz from 27 Jul–10 Aug 1990. However, *Scalesia baurii* was not included since it does not inhabit this island, and *Lycopersicon cheesmanii* Riley var. *cheesmanii* was substituted for var. *minor*. Study sites on the southern slope ranged from approximately 90 m to 632 m in altitude but centered around the area known as Los Gemelos (632 m).

Voucher specimens of each plant species studied were collected in the conventional manner and deposited in the herbarium of the Charles Darwin Research Station on Santa Cruz Island, the Galapagos Islands. Specimens of flower visitors were also obtained and placed in the Station's research collection. Some duplicate insect specimens are housed at the Systematic Entomology Laboratory, United States Department of Agriculture in Beltsville, Maryland; and at Carleton University, Ottawa, Ontario.

Results and Discussion

Table 1 lists insect flower-visitation records for the Galapagos Islands found in the literature, as well as those obtained by direct observations during the summer of 1990. Angiosperms are listed alphabetically by family, genus, and species. Following each name, in parentheses, is a letter representing the plant's resident status.

Insect visitors to the flowers of each plant are listed alphabetically by genus and species, or by common name if the genus is not known. Authorities, orders, and families are listed the first time an insect name appears in the table, but not afterwards. Following the insect's name, in parentheses, is the island on which the visit was recorded, and the article in which the visit was published. For example, *Justicia galapagana* Lindau is reported as having been visited by *Xylocopa darwini* Cockerell on Santa Cruz Island in references 8, 9, 12, and 14. If

Table 1. Flower-visiting insects of the Galapagos Islands. Plant status, island, and references follow the taxa as abbreviations within square brackets. Plant resident status: E, endemic; N, native; C, cultivated escape; I, introduced. Island names: B, Baltra; D, Daphne Major; E, Espanola; F, Floreana; G, Genovesa; I, Isabela; P, Pinta; R, Rabida; SCRI, San Cristobal; SC, Santa Cruz; SF, Santa Fe; STG, Santiago. References: 1, Aide (1986); 2, Beebe (1923); 3, Beebe (1924); 4, Eliasson (1974); 5, Elisens (1989); 6, Grant & Grant (1981); 7, Hayes (1975); 8, Linsley et al. (1966); 9, McMullen (1985); 10, McMullen (1986); 11, McMullen (1989); 12, McMullen (1990); 13, Rick (1963); 14, Rick (1966); 15, Wheeler (1924); 16, Williams (1911). Numbers for alternative names also refer to references. Italicized years indicate my summer observations.

ACANTHACEAE

Justicia galapagana Lindau [E][a]
Damsel bug nymph (Hemiptera, Nabidae) [P—*1990*][b]
Leptotes parrhasioides Wallengren (Lepidoptera, Lycaenidae) [SC—10, 12]
Phoebis sennae L. (Lepidoptera, Pieridae) [SC—*1990*]
Short-horned grasshopper nymph (Orthoptera, Acrididae) [SC—*1990*][b]
Toxomerus crockeri Curran (Diptera, Syrphidae) [SC—*1990*]
Urbanus dorantes galapagensis Williams (Lepidoptera, Hesperiidae) [SC—*1990*][b]
Wasmannia auropunctata Roger (Hymenoptera, Formicidae) [SC—10, 12]
Xylocopa darwini Cockerell (Hymenoptera: Apidae) [SC—8, 9, 12, 14]
Tetramerium nervosum Nees (recorded as *T. hispidium* in 8) [N]
Xylocopa darwini [SC—8]

AIZOACEAE

Sesuvium portulacastrum L. (N)[c,d]
Xylocopa darwini [SC—*1990*]

APOCYNACEAE

Catharanthus roseus (L.) George Don [C][c]
Phoebis sennae [SC—*1990*]
Vallesia glabra (Cavara) Link
Xylocopa darwini [SC—8]

ASTERACEAE

Ageratum conyzoides L. (recorded as *A. conyzoides* subsp. *conyzoides* in 12) [N]
Toxomerus crockeri [SC—10, 12]
Bidens pilosa L. [N][a]
Phoebis sennae [SC—*1990*]
Xylocopa darwini [F—8]
Darwiniothamnus tenuifolius Hooker f. Harling [E][c,d]
Atteva hysginiella Wallengren (Lepidoptera, Yponomeutidae) [P—*1990*][e]
Darwinysius marginalis Dallas (Hemiptera, Lygaeidae) [SC—*1990*][b]
Goniozus sp. (Hymenoptera, Bethylidae) [P—*1990*][b]
Lepidanthrax tinctus Thomas (Diptera, Bombyliidae) [P—*1990*][b]
Moth (Lepidoptera, Gelechioidea, probably Scythrididae) [SC—*1990*][b]
Moth (Lepidoptera, Tortricidae, Olethreutinae) [SC—*1990*][b]
Olcella sp. (Diptera, Chloropidae) [P—*1990*][b]
Orthoperus sp. (Coleoptera, Corylophidae) [P—*1990*][b]
Toxomerus crockeri [SC—*1990*]
Urbanus dorantes galapagensis [SC—*1990*][b]
Xylocopa darwini [SC—*1990*]
Encelia hispida Andersson [E]
Heliothis cystiphora Wallengren (Lepidoptera, Noctuidae) [SF—7]
Jaegeria gracilis Hooker f. [E]
Toxomerus crockeri [SC—10, 12]
Macraea laricifolia Hooker f. [E]
Xylocopa darwini [F—8]

Table 1. Continued.

Scalesia affinis Hooker f. [E]
Xylocopa darwini [F—8; SC—4, 8, 14]
Scalesia baurii Robinson & Greenman ssp. *hopkinsii* (Robinson) Eliasson [E][c]
Atteva hysginiella [P—*1990*][e]
Lepidanthrax tinctus [P—*1990*][b]
Mythenteles sp. (Diptera, Bombyliidae) [P—*1990*][b]
Pyralid moth (Lepidoptera, Pyralidae) [P—*1990*][e]
Rhinacloa sp. (Hemiptera, Miridae) [P—*1990*][b]
Scalesia helleri Robinson [E]
Xylocopa darwini [SC—8, 14; SF—8]
Scalesia pedunculata Hooker f. (recorded as *S. pedunculata* var. *parviflora* in 9) [E]
Xylocopa darwini [F—8; SC—8, 9, 12]
Scalesia sp. (probably *retroflexa* Hemsley) [E]
Xylocopa darwini [SC—8]
Sonchus oleraceus L. [I]
Xylocopa darwini [SC—11]

AVICENNIACEAE

Avicennia germinans (L.) L. [N]
Paratrechina longicornis Latreille (Hymenoptera, Formicidae) [SC—10, 12]
Tapinoma melanocephalum Fabr. (Hymenoptera, Formicidae) [SC—10, 12]

BORAGINACEAE

Cordia leucophlyctis Hooker f. [E][a]
Atteva hysginiella [SC—*1990*][f]
Disclisioprocta stellata Guenee (Lepidoptera, Geometridae) [SC—10, 12]
Xylocopa darwini [SC—9, 12]
Cordia lutea Lamarck [N][a]
Amblycerus piurae Pierce (Coleoptera, Bruchidae) [SC—*1990*][b]
Atteva hysginiella [B—3] [2]
Beetles [15]
Camponotus planus Wheeler (Hymenoptera, Formicidae) [15]
Chrysopa spp. (Neuroptera, Chrysopidae) [B—3] [15]
Enyo lugubris delanoi Kernbach (Lepidoptera, Sphingidae) (recorded as *Triptogon lugubris* L. in 16) [I—16]
Euchrombius ocellus Haworth (Lepidopetra: Pyralidae) (recorded as *Eromene ocellea* Haworth in 2) [2]
Green winged hemerobiid (probably *Megalomus darwini* Banks) (Neuroptera, Hemerobiidae) [2]
Hypasclera collenettei Blair (Coleoptera, Oedemeridae) [SC—*1990*][b]
Hypasclera sp. (recorded as *Asclera* sp. in 3) [B—3]
Manduca rustica calapagensis Holland (Lepidoptera, Sphingidae) (recorded as *Phlegathontius rustica calapagensis* Holland in 16) [I—16]
Melipotis indomita Walker (Lepidoptera, Noctuidae) [SC—*1990*][f]
Metacanthus galapagensis Barber (Hemiptera, Berytidae) [SC—10, 12]
Monomorium floricola Jerdon (Hymenoptera, Formicidae) [G—15]
Oxacis sp. (Coleoptera, Oedemeridae) [2]
Paratrechina longicornis [SC—*1990*]
Paratrechina vaga (Hymenoptera, Formicidae) [SC—10, 12]
Perepitragus fascipes Latr. (Coleoptera, Tenebrionidae) [SC—*1990*][b]
Phoebis sennae (recorded as *Callidryas eubele* L. in 2, 3, 16) [B—3; I—16; SC—*1990*; SCRI—2) [2]
Urbanus dorantes galapagensis [SC—*1990*][b]
Utetheisa galapagensis Wallengren (Lepidoptera, Arctiidae) [SC—*1990*][b]
Wasmannia auropunctata [SC—10, 12]
Xylocopa darwini [SC—1, 8, 9, 11, 12, 14, *1990*] [15]

Table 1. Continued.

Cordia spp.
Pseudoplusia includens Walker (Lepidoptera, Noctuidae) [7]
Tournefortia psilostachya Humboldt, Bonpland, Kunth [N]
Leptotes parrhasioides [SC—10, 12]
Pyralid moth (Lepidoptera, Pyralidae) [SC—10, 12]
Tournefortia rufo-sericea Hooker f. [E][c]
Disclisioprocta stellata [SC—*1990*]
Frankliniella sp. (Thysanoptera, Thripidae) [P—*1990*; SC—*1990*][b]
Leafhopper (Homoptera, Cicadellidae) [P—*1990*; SC—*1990*][b]
Mordellistena galapagoensis Van Dyke (Coleoptera, Mordellidae) [SC—*1990*][b]
Phoebis sennae [SC—*1990*]
Utetheisa galapagensis [SC—*1990*][b]
Wasmannia auropunctata [SC—*1990*]

BRASSICACEAE
Brassica campestris L. [C]
Xylocopa darwini [F—8]

BURSERACEAE
Bursera graveolens Triana & Planchon [N]
Xylocopa darwini [F—8; SC—8]

CACTACEAE
Opuntia echios Howell var. *echios* [E]
Ammophorus sp. (Coleoptera, Tenebrionidae) [D—6]
Xylocopa darwini [D—6]
Opuntia echios Howell (probably var. *gigantea* (Howell) Porter) [E]
Xylocopa darwini [S—8, 14]
Opuntia helleri K. Schumann [E]
Caterpillar [G—6]
Cricket [G—6]
Diptera [G—6]
Manduca rustica calapagensis (recorded as *Protoparce rustica galapagoensis* Holland in 6) [G—6]
Monomorium floricola [G—15]
Tetramorium guineense (Fabr.) Wheeler (Hymenoptera, Formicidae) [G—6]
Opuntia megasperma Howell [E]
Xylocopa darwini [SCRI—8]
Opuntia sp. (probably *insularis* Stewart) [E]
Phoebis sennae (recorded as *Callidryas eubele* in 16) [I—16]
Opuntia sp. [E]
Agrius cingulatus Fabr. (Lepidoptera, Sphingidae) [7]

CAESALPINIACEAE
Caesalpinia pulcherrima (L.) Swartz [C][c,d]
Xylocopa darwini [SC—*1990*]
Cassia occidentalis L. [N]
Xylocopa darwini [SC—8, 9, 12]
Cassia picta George Don [N][a]
Phoebis sennae [SC—*1990*]
Xylocopa darwini [SC—11]
Cassia sp.
Atteva hysginiella [2]
Euchrombius ocellus (recorded as *Eromene ocellea* in 2) [2]
Green winged hemerobiid (probably *Megalomus darwini*) [2]

Table 1. Continued.

Oxacis sp. [2]
Phoebis sennae (recorded as *Callidryas eubele* in 2) [2]
Parkinsonia aculeata L. [N]
Xylocopa darwini [E—8; F—8; SC—8, 9, 11, 12, *1990*]

CANNACEAE
Canna sp. [Not Endemic]
Xylocopa darwini [SC—8]

CARICACEAE
Carica papaya L. [C]
Agrius cingulatus [SC—10]

CONVOLVULACEAE
Ipomoea linearifolia Hooker f. [E]
Xylocopa darwini [SC—11]
Ipomoea pes-caprae (L.) R. Brown [N]
Xylocopa darwini [SC—8]
Ipomoea sp.
Agrius cingulatus [7]

CUCURBITACEAE
Cucurbita pepo [C]
Xylocopa darwini [SC—8]
Mormordica charantia L. (recorded as *M. indica* in 8) [C]
Leptotes parrhasioides [SC—10]
Wasmannia auropunctata [SC—10]
Xylocopa darwini [SC—8, 13]

EUPHORBIACEAE
Croton scouleri Hooker f. var. *scouleri* [E][a]
Atteva hysginiella [P—*1990*][c] (male flowers)
Caterpillar [G—6]
Moth [SC—14]
Euphorbia cyathophora J. A. Murray [C][c,d]
Xylocopa darwini [SC—*1990*]

FABACEAE
Crotalaria incana L. (recorded as *Crotolaria setifera* in 8) [N]
Xylocopa darwini [SC—8]
Galactea striata (Jacquin) Urban (recorded as *G. jussiana* var. *volubilis* in 8) [N]
Xylocopa darwini [SC—8]
Geoffroea spinosa Jacquin (recorded as *G. striata* in 8) [N]
Xylocopa darwini [F—8]
Piscidia carthagenesis Jacquin (recorded as *P. erythrina* in 13) [N]
Xylocopa darwini [SC—13]
Rhynchosia minima (L.) de Candolle [N]
Xylocopa darwini [SC—8]
Vigna luteola (Jacquin) Bentham [N][a]
Leptotes parrhasioides [SC—10, 12]
Utetheisa ornatrix L. (Lepidoptera, Arctiidae) [SC—*1990*][b]
Xylocopa darwini [SC—9, 12, *1990*]

GOODENIACEAE
Scaveola plumieri (L.) M. Vahl [N]
Xylocopa darwini [F—8]

Table 1. Continued.

Inga edulis Martius [C]
Xylocopa darwini [F—8; SC—8]
Prosopis juliflora (Swartz) de Candolle (recorded as *P. dulcis* in 8) [N]
Tapinoma melanocephalum [SC—10, 12]
Xylocopa darwini [F—8; SC—8, 9, 12]

MYRTACEAE

Psidium guajava L. (recorded as *P. guayava* in 8) [C]
Xylocopa darwini [F—8; SCRI—8]

NOLANACEAE

Nolana galapagensis Johnston (recorded as *Periloba galapagensis* in 8, 14) [E]
Xylocopa darwini [SC—8, 14]

NYCTAGINACEAE

Bougainvillea spectabilis Willdenow [C][c]
Phoebis sennae [SC—*1990*]
Commicarpus tuberosus (Lamarck) Standley (recorded as *Boerhaavia scandens* in 8) [N]
Leptotes parrhasioides [SC—10, 12]
Xylocopa darwini [SC—8, 11]
Cryptocarpus pyriformis Humboldt, Bonpland, Kunth [N][a]
Camponotus sp. (Hymenoptera, Formicidae) [SC—*1990*]
Xylocopa darwini [SC—13]
Mirabilis jalapa L. [C]
Xylocopa darwini [SC—8]

PASSIFLORACEAE

Passiflora foetida L. var. *galapagensis* Killip (recorded as *P. foetida* in 1, 8) [E]
Xylocopa darwini [SC—1, 8, 9, 11, 12, *1990*]

PLUMBAGINACEAE

Plumbago scandens L. [N][a,d]
Cardiocondyla nuda Mayr (Hymenoptera, Formicidae) [P—*1990*][b]
Naucles sp. (Coleoptera, Scraptiidae) [P—*1990*][b]
Lepidanthrax tinctus [P—*1990*][b]
Leptotes parrhasioides [P—*1990*; SC—10, 12, *1990*][e]
Ornebius erraticus Schudder (Orthoptera, Gryllidae) [P—*1990*][b]
Paratrechina sp. [P—*1990*][e]
Phoebis sennae [SC—10, 12, *1990*]
Urbanus dorantes galapagensis [SC—*1990*][b]
Wasmannia auropunctata [SC—*1990*]
Xylocopa darwini [SC—*1990*]

POACEAE

Setaria geniculta (Lamarck) Beauvois [N]
Wasmannia auropunctata [SC—10, 12]

POLYGONACEAE

Polygonum opelousanum Small [N]
Toxomerus crockeri [SC—10, 12]

PORTULACACEAE

Portulaca oleracea L. [N]
Xylocopa darwini [SC—8]

RUBIACEAE

Borreria sp.
Diptera [SC—14]

Table 1. Continued.

LAURACEAE

Persea americana Miller (recorded as *P. gratissima* in 8) [C]
Xylocopa darwini [SC—8]

LOASACEAE

Mentzelia aspera L. [N]
Xylocopa darwini [SC—1, 8]

LYTHRACEAE

Cuphea racemosa (L. f.) Sprengel [I][a,d]
Leptotes parrhasioides [SC—10, 12]
Toxomerus crockeri [SC—10, 12]
Xylocopa darwini [SC—*1990*]

MALVACEAE

Abelmoschus manihot (L.) Medicus (recorded as *Hibiscus manihot* in 8) [I]
Xylocopa darwini [SC—8]
Abutilon depauperatum (Hooker f.) Robinson [E]
Xylocopa darwini [SC—1, 8]
Bastardia viscosa (L.) Humboldt, Bonpland, Kunth [N]
Xylocopa darwini [SC—8, 9, 11, 12]
Gossypium barbadense L. var. *darwinii* (Watt) J. B. Hutchinson [E]
Phoebis sennae (recorded as *Callidryas eubele* in 2) [SC—10, 12; SCRI—2]
Xylocopa darwini [I—8]
Gossypium sp. [E]
Atteva hysginiella [2]
Euchrombius ocellus (recorded as *Eromene ocellea* in 2) [2]
Green winged hemerobiid (probably *Megalomus darwini*) [2]
Oxacis sp. [2]
Phoebis sennae (recorded as *Callidryas eubele* in 2, 16) [I—16] [2]
Hibiscus tiliaceus L. [N]
Xylocopa darwini [SC—8, 11, *1990*]
Malvastrum coromandelianum (L.) Garcke [I]
Xylocopa darwini [SC—8]
Sida acuta Burman f. [I]
Xylocopa darwini [SC—8]
Sida paniculata L. [I]
Xylocopa darwini [F—8]
Sida rhombifolia L. [I][a]
Leptotes parrhasioides [SC—10, 12]
Phoebis sennae [SC—*1990*]
Utetheisa ornatrix [SC—*1990*][b]
Xylocopa darwini [F—8; SC—8, 9, 12, *1990*]
Sida spinosa L. (recorded as *S. angustifolia* in 8) [N]
Xylocopa darwini [F—8; SC—8]

MELASTOMATACEAE

Miconia robinsoniana Cogniau [E]
Xylocopa darwini [SC—8]

MIMOSACEAE

Acacia insulae-iacobi Riley (recorded as *A. tortuosa* in 8) [N][a]
Urbanus dorantes galapagensis [SC—*1990*][b]
Xylocopa darwini [SC—8, 11]
Acacia macracantha Willdenow [N]
Xylocopa darwini [F—8; SC—8]

Table 1. Continued.

Chiococca alba (L.) A. S. Hitchcock [N]
Xylocopa darwini [SC—8]
Coffea arabica L. [C]
Xylocopa darwini [SC—8, 9]
Diodia radula Chamisso & Schlechter [I][a]
Phoebis sennae [SC—*1990*]
Toxomerus crockeri [SC—10, 12, *1990*]
Urbanus dorantes galapagensis [SC—*1990*][b]
Psychotria rufipes Hooker f. [E]
Xylocopa darwini [SC—8]

SAPINDACEAE

Cardiospermum galapageium Robinson & Greenman (recorded as *C. galapageum* in 8) [E]
Xylocopa darwini [SC—8, 18]

SCROPHULARIACEAE

Bacopa monniera [Not Endemic]
Xylocopa darwini [SC—8]
Galvezia leucantha Wiggins var. *leucantha* [E]
Xylocopa darwini [I—5]
Galvezia leucantha Wiggins var. *pubescens* Wiggins [E]
Xylocopa darwini [R—5]

SIMAROUBACEAE

Castela galapageia Hooker f. [E]
Xylocopa darwini [SC—8, 14, *1990*]

SOLANACEAE

Cacabus miersii (Wellstein f.) D'Arcy [E]
Agrius cingulatus [7]
Capsicum frutescens L. [C]
Wasmannia auropunctata [SC—10, 12]
Lycopersicon cheesmanii Riley var. *cheesmanii* (recorded as *L. pimpinellifolium* in 13, 14) [E][a]
Leptotes parrhasioides [SC—*1990*]
Urbanus dorantes galapagensis [SC—*1990*][b]
Xylocopa darwini [SC—11, 13, 14, *1990*]
Lycopersicon cheesmanii Riley var. *minor* (Hooker f.) Porter [E][c]
Leaf bug (Hemiptera, Miridae) [P—*1990*][b]
Physalis pubescens L. [N]
Xylocopa darwini [SC—8]
Solanum americanum Miller [N][a]
Toxomerus crockeri [SC—*1990*]
Xylocopa darwini [SC—11]

STERCULIACEAE

Waltheria ovata Cavanilles (recorded as *W. reticulata* in 8) [N][a]
Atteva hysginiella [P—*1990*][c]
Xylocopa darwini [SC—8, 11, *1990*]

VERBENACEAE

Clerodendrum molle Humboldt, Bonpland, Kunth var. *glabrescens* Svenson [E]
Xylocopa darwini [SC—11]
Clerodendrum molle Humboldt, Bonpland, Kunth var. *molle* [N]
Ant (Hymenoptera, Formicidae) [SC—10, 12]
Hawk moth (Lepidoptera, Sphingidae) [SC—10, 12]
Xylocopa darwini [SC—9, 11, 12, *1990*]

Table 1. Continued.

Clerodendrum molle Humboldt, Bonpland, Kunth (variety not known)
Manduca rustica calapagensis (recorded as *Phlegathontius rustica calapagensis* in 16) [I—16]
Pseudoplusia includens [7]
Xylocopa darwini [SC—8]
Lantana peduncularis Andersson [E]
Xylocopa darwini [SC—8, 11]
Phyla sp. [Not Endemic][c]
Leptotes parrhasioides [SC—*1990*]
Stachytarpheta cayennensis (Richard) M. Vahl (recorded as *S. cayannensis* in 8) [I]
Xylocopa darwini [F—8]
ZYGOPHYLLACEAE
Tribulus cistoides L. [N]
Leptotes parrhasioides [SC—10, 12]
Xylocopa darwini [SC—8, 9, 12]

[a] Flowers reported as visited by new insects.
[b] Insect reported for the first time as a flower visitor in the Galapagos Islands.
[c] Flowers reported for the first time as visited by insects in the Galapagos Islands.
[d] Flowers reported for the first time as visited by *Xylocopa darwini.*
[e] Insect reported for the first time as a flower visitor on Pinta Island.
[f] Insect reported for the first time as a flower visitor on Santa Cruz Island.

the island is not known, the reference number appears alone in square brackets. The designation "*1990*" represents an observation by me during the summer of that year.

The observations from 1990 provide several new records. Ten angiosperms, representing nine families, are reported for the first time as having their flowers visited by insects in the Galapagos Islands. In addition, new insect visitors are reported for 16 angiosperms from 14 families. Six flowering plants are reported for the first time as having their blossoms visited by *Xylocopa darwini.*

Twenty-four insects, representing eight orders, are reported for the first time as flower visitors in the Galapagos; four insects are reported as flower visitors for the first time on Pinta Island, and two are reported for the first time on Santa Cruz Island. Although no other references than mine are listed in the table for *Melipotis indomita* Walker (Lepidoptera, Noctuidae), it is not listed as a first time flower visitor in the Galapagos because Hayes (1975) mentions that "adults come to flowers at dusk in the rainy season."

Table 1 indicates that *Xylocopa darwini* is the primary flower visitor on the islands that it inhabits. The vast majority of these visits have been made by female bees. In fact, all but two of the carpenter bee records from 1990 refer exclusively to female visitors. Only *Cordia lutea* Lamarck (Boraginaceae) and *Waltheria ovata* Cavanilles (Sterculiaceae) were observed being visited by both male and female bees.

A total of 79 plant taxa, from 35 families, are listed that have been visited by this polytropic bee, with 25 of these being endemics. Apparently, the more recent arrivals to the Galapagos Islands are favored as sources of pollen and nectar. Although members of several different families are visited, the legumes, mallows, and composites are especially well represented.

Among the other flower visitors observed in 1990, an *Olcella* sp. (Diptera: Chloropidae), a *Goniozus* sp. (Hymenoptera: Bethylidae), and a *Leptotes parrhasioides* Wallengren (Lepidoptera: Lycaenidae) appeared to be most common on Pinta Island. On Santa Cruz, *Toxomerus crockeri* Curran (Diptera: Syrphidae) and *Phoebis sennae* L. (Lepidoptera: Pieridae) were extremely active.

In summary, this paper represents the first phase of a study designed to understand the reproductive relationships that exist between the plant and insect coinhabitants of the Galapagos Islands. It should be noted that this listing does not assign any particular value to each flower visitor. Undoubtedly, some of these insects are more important pollen vectors than others. Details can be found in the literature cited, or in the case of the 1990 observations, in future publications.

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Scientific Note

NEW HOST RECORD FOR *ACANTHOSCELIDES CLANDESTINUS* (MOTSCHULSKY) (COLEOPTERA: BRUCHIDAE) FROM BRAZIL

Acanthoscelides clandestinus (Motschulsky) was recently reared from the seeds of *Phaseolus uleanus* Harms (Fig. 1) from Brazil by G. P. Lewis and S. M. M. de Andrade in the state of Bahia, c. 4 km along estrada de terra, from Livramento do Brumado to Rio de Contas, c. 41°51′ W, 13°38′ S, on 28 Mar 1991. This is the first record of a bruchid feeding in the seeds of this plant. The only valid host for this bruchid had been *Phaseolus vulgaris* L. (Johnson, C. D. 1983. Misc. Publ. Entomol. Soc. Am., 56). It has also been reported to feed in *Cajanus cajan* (L.) Millspaugh (Johnson, C. D. 1990. Trans. Am. Entomol. Soc., 116: 297–618), a record that must be verified.

Phaseolus uleanus (Fig. 2) was described in 1909, but as recently as 1977 it was still only known by the type-specimen, E. Ule 7215. Maréchal et al. (Maréchal, R., J.-M. Mascherpa & F. Stainier. 1978. Boissiera, 28: 150–151) found the plant difficult to place taxonomically due to a lack of information about seedlings, fruits (Fig. 3) and seeds. They suggested a close relationship with *Ramirezella* and *Vigna* subgenus *Sigmoidotropis*. Since 1977, several new collections of *P. uleanus* have been made in Bahia, Brazil and recently seeds have been germinated and chro-

Figure 1. Mature seeds and pods (fruits) of *Phaseolus uleanus*.

Figure 2. Growth habit of *Phaseolus uleanus.*

mosomes counted. The current view is that the plant requires a new generic name and GPL is preparing a paper to formalize this.

Two species closely related to *A. clandestinus* have updated host names. *Acanthoscelides caracallae* Kingsolver feeds in *Vigna caracalla* (L.) Verdcourt (= *Phaseolus caracalla* L.) and *A. comptus* Kingsolver in *Vigna* aff. *peduncularis* (Kunth) Fawcett & Rendle (= *P.* aff. *peduncularis* Kunth). *Acanthoscelides caracallae* has been recorded from Argentina and Paraguay, but *A. comptus* has only been found in Argentina. *Acanthoscelides clandestinus* has a much wider distribution that includes Mexico, Guatemala, Honduras, Panama, Colombia, Venezuela, Surinam, Brazil and Peru (Johnson 1990). All are of potential economic importance because all feed in species of beans in the genera *Phaseolus* and *Vigna.*

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Figure 3. Mature and immature flowers and immature pods (fruits) of *Phaseolus uleanus.*

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Scientific Note

NEST CONSTRUCTION PLASTICITY IN *OSMIA RIBIFLORIS BIEDERMANNII* MICHENER (HYMENOPTERA: MEGACHILIDAE)

Cavity-nesting wasps and bees use a variety of materials in the construction of cell partitions and nest plugs (Malyshev, S. I. 1935. Eos, 11: 210–309; Linsley, E. G. 1958. Hilgardia, 27: 543–599; Krombein, K. V. 1967. Trap-Nesting Wasps and Bees. Smithsonian Press, Washington, D.C.). The choice of materials is ordinarily species specific and usually constant (numerous individual species accounts). Here, I report on the use of a new material in the construction of cell partitions and nest plugs in the bee *Osmia ribifloris beidermannii* Michener. This use was not from an isolated nest, but from several nests and from two different nesting seasons.

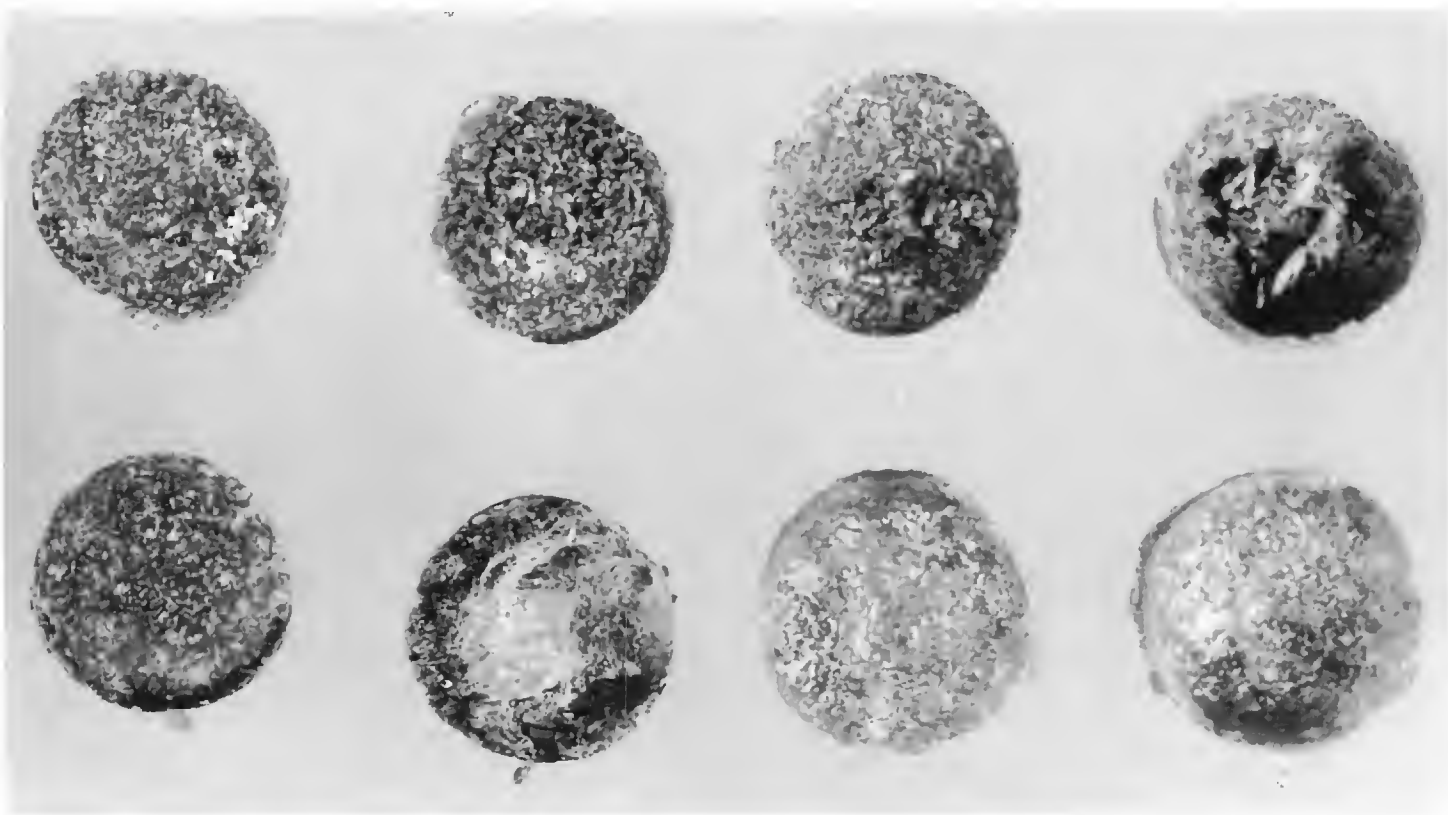

Figure 1. Cell partitions from *Osmia ribifloris biedermannii* nests. Top row are masticated leaf material partitions (most likely *Taraxacum officinale* leaves) from a 7 mm nest and the bottom row shows the inner most partition of masticated leaf (left), the next partition with threshold of masticated leaf but filled with pine resin, and two complete resin partitions from outer cells of the nest.

Osmia r. biedermannii uses masticated leaf material in cell partition and nest plug construction, most likely dandelion (*Taraxacum officinale* Wiggers) in field populations and *Oenothera hookeri* T. & G. in a greenhouse population (Rust, R. W. 1986. J. Kansas Entomol. Soc., 59: 89–94). Trap-nests (pine blocks 1.9 × 1.9 × 15 cm and drilled with 5–9 mm holes) from Reno, Nevada from 1990 (32), 1991 (75) and 1992 (23) contained nests (3 or 9.4% in 1990, 6 or 8.0% in 1991 and 3 or 30% in 1992) in which the bee had used pine resin in both partition and nest plug construction (Fig. 1). The resin partitions were the same thickness as those of masticated leaf from similar diameter holes. However, they were statistically heavier ($t = 13.56$, df = 12, $P > 0.001$, masticated leaf mean 17.8 ± 3.5 mg (SD) and resin mean 55.2 ± 6.0 mg) in 7 mm diameter holes. Nest plugs were also heavier (109.8 to 29.2 mg) in the resin nests of similar diameter. All nests in which resin was substituted for masticated plant material were from trap-nest bundles attached to pine trees (*Pinus* spp.). Also, the inner most partitions were of masticated plant material with the resin partitions and plugs completing the with the resin partitions and plugs completing the nest structure (Fig. 1).

The appearance of resin in partition and plug construction in a nest could be considered an error or mistake by one individual. However, its appearance in several nests and in several different nesting seasons suggests that the ability to substitute construction materials is a behavioral plasticity, at least in the population of *O. r. biedermannii* from the Reno, Nevada area. Because all nests were opened in the laboratory, it is not known if the progeny in resin nests can effectively chew through the resin partitions and plugs during their spring emergence.

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Scientific Note

THE FORMOSAN SUBTERRANEAN TERMITE, *COPTOTERMES FORMOSANUS* SHIRAKI (ISOPTERA: RHINOTERMITIDAE), ESTABLISHED IN CALIFORNIA

The Formosan subterranean termite, *Coptotermes formosanus* Shiraki, which has been introduced into subtropical, coastal areas throughout the world (including Hawaii, Louisiana, Alabama, Mississippi, Florida, Texas, and South Carolina), is native to mainland China. Although it is primarily known as a structural pest, it can be an agricultural pest because of its habit of consuming the heartwood of living trees (Su, N.-Y. & M. Tamashiro. 1987. pp. 3–14. *In* Tamashiro, M. & N.-Y. Su (eds.). Biology and control of the formosan subterranean termite. Hawaii Inst. Agric. Human Resources Research Extension Ser., 83). In the United States, it has become the major economic pest of structures in areas where it has been introduced because of its destructiveness and control problems. In mid-February 1992, a pest control operator in the San Diego area submitted a sample of several termite soldiers from a residential property in La Mesa at which he had experienced difficulty in achieving satisfactory control. The soldiers were identified as *Coptotermes* species by comparison with voucher material. Definitive identification was made by Dr. Rudolf Scheffrahn (University of Florida, Fort Lauderdale, Florida) on the basis of dried alates collected in the attic of the home at a later collected in the attic of the home at a later date.

We visited the site on 5 Mar 1992 to look for evidence of termite activity. The house (built in the late 1940s) is situated on a moist hillside in a former vegetable farm with abundant fruit trees. The property is heavily irrigated with a combination of drip and sprinkler systems. Numerous dead bodies of termite soldiers and workers were observed inside the house under the carpet along a previously treated wall. In the attic, we found many cadavers inside the eaves above the wall where termite activity had been noted. There had been no live termites or corpses in this area several weeks previously when the same area had been inspected by the pest control operator. The dead termites observed in the attic probably had died as a result of the chlorpyrifos treatment, either from direct intoxication or as a consequence of the termites inside the structure being cut off from the soil. We noted numerous shed wings of *Coptotermes* alates in the attic. These shed wings might have been overlooked during initial inspections or confused with those of drywood termites, which were known to occur there. Several intact, desiccated alates were found in spider webs.

Inspection of the property revealed *Coptotermes* activity in wood that was buried or in contact with the soil (steps, tree stumps, raised borders of beds, fences), planters made from oak barrels cut in half, and a raised wooden deck. Active termite foraging was observed up to the property lines on three sides of the property (the fourth side faces the street). The large numbers of workers and

soldiers, their large size, and the amount of damaged wood on the site were remarkable. We found no live termites inside the house or indications of active structural infestation on 5 Mar, indicating that contact between the termite colony and the structure had been broken. Live soldiers and workers were again noted on 28 Mar, suggesting that the termites had found an untreated access route to the wall. On that date, neighboring properties were inspected for evidence of Formosan subterranean termite activity. Live termites were found on a total of four adjacent properties, but not in others on either side of these.

Although *C. formosanus* has been intercepted in California on several occasions, this is the first case in which it has become established. The presence of wings in the structure indicates that there is at least one mature colony in the area, because alates are not produced by young colonies. A neighbor indicated that he had observed termite swarms in the early evening during the past several years. These were probably *C. formosanus* because native subterranean and drywood termite species typically swarm during daylight hours. Laboratory colonies have produced alates within 10 years, although it is believed that alates would be produced in less time (5–6 years) under field conditions (Su & Tamashiro 1987). The large size of the workers (4.27 ± 0.09 mg, average of five groups of 10 workers) and soldiers is typical of mature colonies, probably greater than 10 years old (Rudolf Scheffrahn, personal communication). We have no indication of how many colonies might be involved. The total area in which we observed live termites is within the foraging range of a single colony (the maximum distance between sites of observed activity across the four properties was approximately 100 m) (Su, N.-Y. & R. H. Scheffrahn. 1988. Sociobiology, 14: 353–359). Swarming alates may have established new colonies that were not detected in our preliminary surveys.

Because most introductions of the Formosan subterranean termite have been in seaports in tropical and subtropical areas of the world, regulatory attention has focused on port areas. The La Mesa infestation, however, is over 9.4 km (15 miles) inland. The source of the original colony may have been neighbors who moved into the area with all of their personal belongings in June of 1976 from an infested part of Hawaii. This scenario could easily be repeated with the extensive contacts between California and Hawaii and countries of the Pacific Rim. The possibility of overland introduction of colonies cannot be ruled out, as this termite is now well established in many areas of the southeastern United States. A mated pair of alates could be transported under conditions suitable for their survival and placed in an appropriate setting on arrival. This could be in potted plants, nursery material, outdoor furniture, among other possibilities. Although the climate of most parts of California is much drier than that of many areas where the Formosan subterranean termite has become established, properties that are heavily shaded and irrigated, such as the one at La Mesa, provide a suitable microhabitat for establishment and subsequent colony growth.

Material Examined.—CALIFORNIA. *SAN DIEGO Co.:* La Mesa, 5 Mar 1992, T. H. Atkinson, M. K. Rust & J. M. Smith.

Acknowledgment.—Mike Cole, Algon Exterminating, El Cajon, was the local pest control operator who first detected the problem. Steve Fleming, DowElanco, San Diego, submitted the first specimens for identification. David Kellum, San

Diego Co. Agricultural Commisioner's Office, obtained permission from neighboring homeowners for the follow-up survey on 28 Mar.

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Editorial Notice

Pan-Pacific Entomologist
Additions to the Editorial Staff

The editorial staff of the *Pan-Pacific Entomologist* has increased, with appointment of Dr. Robert V. Dowell as Associate Editor, effective with volume 69. The staff now includes: an Editor (John T. Sorensen), Associate Editor (Robert V. Dowell), Book Review Editor (Ronald E. Somerby) and Editorial Assistant (Susan M. Sawyer).

Although Dr. Dowell will handle non-taxonomic manuscripts, please continue to send *all correspondence and submissions* directly to the Editor for handling efficiency. This staff increase was necessitated by the State of California's 1993–94 budget restrictions, and resulting additions to the regular workload of its employees.

PAN-PACIFIC ENTOMOLOGIST
Information for Contributors

See volume 66 (1): 1–8, January 1990, for detailed format information and the issues thereafter for examples. Manuscripts must be in English, but foreign language summaries are permitted. Manuscripts not meeting the format guidelines may be returned. Please maintain a copy of the article on a word-processor because revisions are usually necessary before acceptance, pending review and copy-editing.

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The PAN-PACIFIC ENTOMOLOGIST

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A NEW *LEPTOCONOPS* (*HOLOCONOPS*) FROM BAJA CALIFORNIA, MEXICO (DIPTERA: CERATOPOGONIDAE)

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Abstract.—*Leptoconops* (*Holoconops*) *doyeni* NEW SPECIES from Baja California, Mexico, is described and male specimens are illustrated. It is compared with its closely related congeners, *L.* (*H.*) *bequaerti* (Kieffer) and *L.* (*H.*) *linleyi* Wirth & Atchley.

Key Words.—Insecta, Ceratopogonidae, *Leptoconops* (*Holoconops*), Baja California

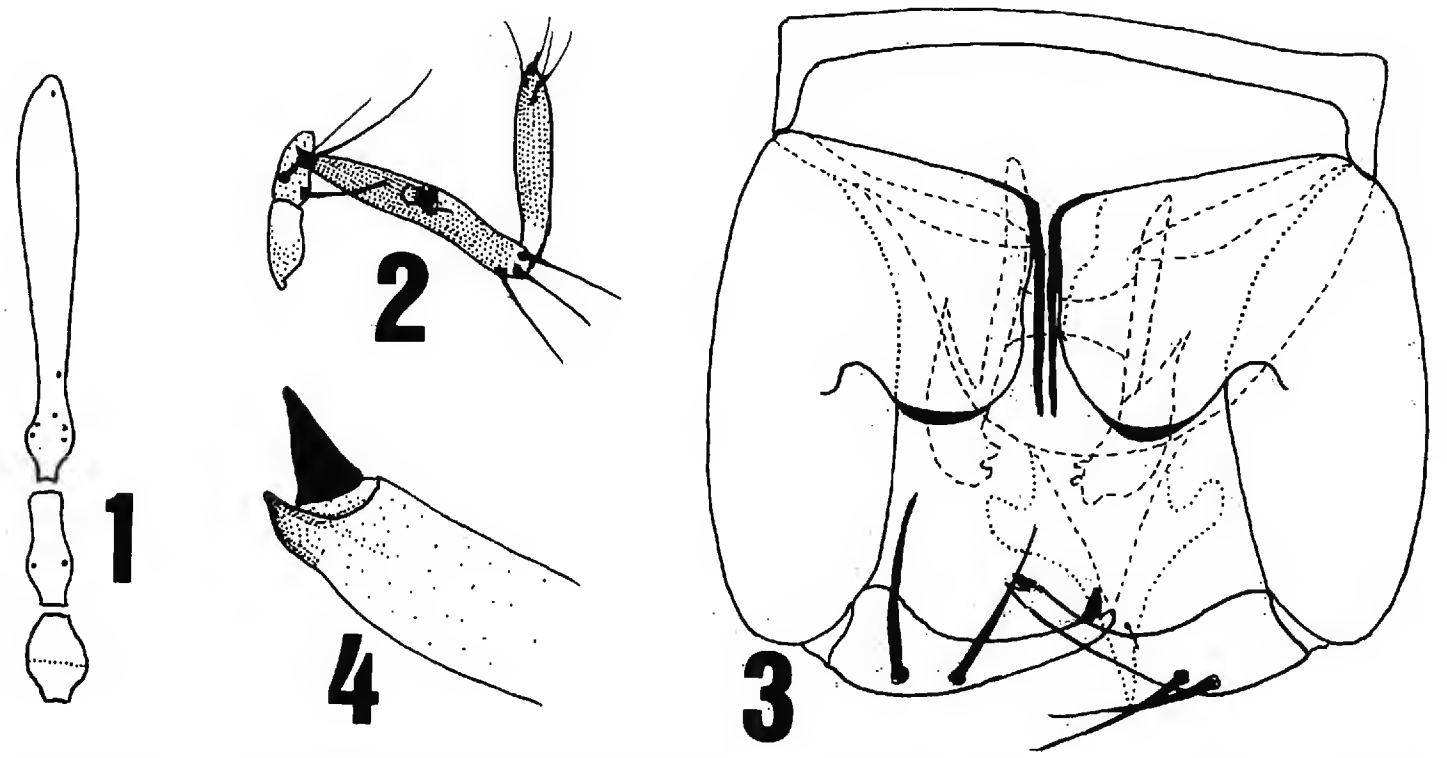
Biting midges of the genus *Leptoconops* Skuse are often extremely annoying, bloodsucking pests in coastal or desert regions (Clastrier & Wirth 1978). Wirth & Atchley (1973) reviewed the North American species of *Leptoconops.* They provided a historical review and systematic accounts of the genus, as well as diagnoses and key for recognition of the New World subgenera. They also recognized 13 species, including the following five in the subgenus *Holoconops* Kieffer: *L.* (*H.*) *belkini* Wirth & Atchley, *L.* (*H.*) *bequaerti* (Kieffer), *L.* (*H.*) *catawbae* (Boesel), *L.* (*H.*) *kerteszi* Kieffer, and *L.* (*H.*) *linleyi* Wirth & Atchley. Clastrier & Wirth (1978), using new morphological characters in both males and females, excluded *L. kerteszi* from the North American fauna and recognized 11 species in a group that they named by custom the "*kerteszi complex.*"

In this paper, we describe and illustrate male specimens of *L.* (*Holoconops*) *doyeni* NEW SPECIES, from Baja California, Mexico, which closely resembles the Circum-Caribbean species *L. bequaerti* and the Florida species *L. linleyi.* For terminology see Clastrier & Wirth (1978).

LEPTOCONOPS (*HOLOCONOPS*) *DOYENI,* NEW SPECIES
(Figs. 1–4)

Types.—Holotype, male, and one male paratype deposited in the California Academy of Sciences, San Francisco, data: MEXICO. *BAJA CALIFORNIA NORTE:* Bahia de Los Angeles, 18 Apr 1974, J. T. Doyen. Paratype, data: same as holotype, 1 male deposited U.S. National Museum of Natural History, Washington, D.C. Paratype, data: same as holotype, 1 male deposited in the Museo de La Plata, Argentina.

Description.—*Adult Male.* Wing length 1.38 (1.27–1.50) mm, breadth 0.43 (0.39–0.47) mm (n = 3). *Head.* Dark brown. Antenna with dense plume; lengths of flagellomeres 11–13 in proportion of 9-16-53 (Fig. 1); pubescence present on flagellomeres 12–13. Palpus (Fig. 2) dark brown, segments 1–2 paler; lengths of segments in proportion of 10-8-25-21; third segment with median sensory pit not very deep containing small pore; sensory setae apparently absent. *Thorax.* Dark brown; 3 posterolateral setae. Legs dark brown, tarsi pale brown; basitarsi of fore leg with (2-4-2) × 4 dark spines; mid leg (2-2-2) × 2, (2-3-2) × 1; hind leg (0-4-1) × 4; basal setae of fifth tarsomere erect or erect curved; tarsal claws mixed in fore and mid legs, simple in hind leg. Wing with membrane infuscated; costal setae short (23–25), leaving a few voids at base of wing. Halter dark brown. *Genitalia* (Fig. 3). Ninth tergum slightly broader than long, tapering posteriorly with marked caudal modification into trilobed structure; single visible subapical seta. Gonocoxite stout, with conspicuous ventromedian lobe that is



Figures 1–4. *Leptoconops* (*H.*) *doyeni* NEW SPECIES, male. Figure 1. Flagellomeres 11–13. Figure 2. Palpus. Figure 3. Genitalia. Figure 4. Tip of gonostylus.

darkly pigmented posteriorly; gonostylus 0.7 × length of gonocoxite, basal one-half broad with pair of strong setae, distal one-half narrowed to sclerotized pointed apex, subterminal spine stout (Fig. 4). Aedeagus represented by pair of narrow, separated, strongly sclerotized sclerites located between swollen basal portion of gonocoxites, not extending beyond them. Parameres with stout, strongly sclerotized basal arms; distal portion fused in H-shaped piece, distal ends stout, each pointed anteriorly and with 2 mesally directed teeth.

Female.—Unknown.

Diagnosis.—*Leptoconops doyeni* NEW SPECIES is a dark brown species that is very similar to *L. bequaerti* and *L. linleyi,* from which it can be distinguished by its larger size, infuscated wing membrane, gonostylus with stronger setae, and aedeagus represented by two separated pieces (distally fused in *L. bequaerti* and *L. linleyi*).

Distribution.—Restricted to the type-locality.

Etymology.—This species is named in honor of John T. Doyen, who collected the type-series.

Material Examined.—See types.

Acknowledgment

We thank Willis W. Wirth for the critical review and suggestions on the manuscript.

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GROUP FORAGING FACILITATES FOOD FINDING IN A SEMI-AQUATIC HEMIPTERAN, *MICROVELIA AUSTRINA* BUENO (HEMIPTERA: VELIIDAE)

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Abstract.—Group living may evolve as a result of individuals finding food more quickly when in the presence of others versus when alone. Food location by individuals may facilitate food location by others in the group, and may increase mean search rate (food patches found/time) relative to solitary foraging. I experimentally addressed the influence of group foraging on the mean and variance in food-finding time (inverse of search rate) of a semiaquatic bug, *Microvelia austrina* Bueno. Focal males and females were observed in the lab in two contexts: alone versus in the presence of seven conspecifics. Food-finding time and movement rate were calculated for 29 focal animals in each context. Both the mean and variance in food-finding time decreased significantly when focal animals foraged in groups versus alone. Faster microveliids had shorter food-finding times. However, the decrease in food-finding times in groups is most likely due to foraging animals being attracted to conspecifics that have located food, rather than movement rate differences between foraging contexts. This is the first study to show search rate benefits to group living in an insect.

Key Words.—Insecta, Hemiptera, Veliidae, group living, facilitation, foraging behavior

Group living can affect individual feeding rates (Pulliam & Caraco 1984). The influence of group living on the mean and variance in the rate at which food, or food patches, are found has received much experimental attention. If group living has evolved in some species as a result of foraging advantages, then individuals are expected to locate food less frequently when foraging alone versus in a group. Individuals in groups often have higher mean and/or lower variance in search rate (food patches found per unit time) than solitary individuals. These patterns have been demonstrated experimentally in birds (Krebs et al. 1972, Brown 1988) and fish (Pitcher et al. 1982). However, very few experimental studies have examined the effects of group living on search rate in invertebrates (but see Rypstra 1989, Uetz 1988).

The semi-aquatic insect *Microvelia austrina* Bueno (Veliidae) is commonly found clustered in groups of up to 100 individuals (Travers & Sih 1991) on the surface of stream pools. They are opportunistic feeders on floating soft-bodied organisms, such as anopheline larvae and muscid flies (Anderson 1982), and will collectively feed on large items (personal observation). I conducted an experiment on field-caught microveliids to test the predictions that: (1) foraging in groups, versus alone, decreases both the mean and variance in time until a food item is found (hereafter food-finding time); and (2) the food-finding time of an individual is a function of the individual's movement rate (number of moves per unit time).

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Materials and Methods

Adult *M. austrina* were collected from a second order stream, 30 km south of Lexington, Kentucky, and maintained in the laboratory for four days prior to experimental trials. All animals were fed frozen fruit flies (*Drosophila melanogaster* Meigen) *ad libitum* up until 48 hours prior to the experiment. Twenty-four hours prior to the experiment, focal males and females were isolated and marked on the pronotum with a fine, red powder.

I measured the food-finding times of focal individual microveliids foraging in two separate contexts: alone and in the presence of seven conspecifics of the same sex. The sexes were tested separately to prevent mating, which would reduce the number of animals searching for food. Fifteen focal males and fourteen focal females were monitored in both treatments (solitary and group). Seven of the males and females were monitored in the solitary treatment first (SG). The other eight males and seven females were monitored in the group treatment first (GS). Individuals were randomly assigned to GS or SG sequences.

All experimental trials were conducted in a plastic tub (19 × 30 cm) filled to a depth of 4 cm with tap water. To prevent microveliids from detecting surface vibrations that are associated with the introduction of food, all experimental animals were placed on one side of an aluminum foil barrier while two frozen, adult fruit flies were placed 7 cm apart on the other side of the barrier. Trials began when I lifted the barrier. The following information was recorded with a hand-held tape recorder during a trial: (1) time of trial initiation, (2) time of food location by the focal individual, and (3) the number of movements by the focal individual (microveliids move in a saltatory fashion with discrete starts and stops). Trials were terminated after the focal animal found the first fly. I then calculated: (1) the time required for each focal individual to find food when in a group versus when alone, (2) the overall movement rate (number of moves per second) of focal individuals while foraging alone, and (3) movement rates before and after food discovery by a conspecific in group trials.

To compare food-finding times in solitary and group treatments, I used a one-tailed paired *t*-test because I had the *a priori* expectation that food-finding times for individuals in groups would be lower than that of the same individuals when alone. The variance in food-finding time was compared between treatments using a *F*-ratio test. To test for effects of gender or trial sequence (SG or GS), I conducted two-way analysis of variance (ANOVA) on food-finding times and movement rates of focal animals (when alone, in a group, before versus after food discovery by a conspecific). All values for ANOVAs were log-transformed to reduce heteroscedasticity.

Individuals varied considerably in food-finding time. To test the hypothesis that more active foragers find food sooner, I regressed food-finding time against movement rate in the same trial. I pooled the data for all analyses because in most cases there were no significant gender or sequence effects (although after food discovery females moved more frequently than males: $F = 8.96$, $P = 0.009$).

Results

Group foraging significantly reduced the food-finding time of focal animals by, on average, 55.7% ($\bar{x} \pm$ SD: solitary trials = 243.8 ± 58.3 sec, group trials = 107.9 ± 14.7 sec; paired *t*-test: $t = 2.21$, $P = 0.02$). Movement rate was signifi-

cantly, negatively related to food-finding time when animals foraged alone (r^2 = 0.59, df = 28, P = 0.0007) and in groups (r^2 = 0.372, df = 28, P = 0.047); i.e., less active animals took longer to find food. Focal animals also showed significantly lower variances in food-finding time when foraging in groups versus alone (F-ratio test: F = 15.7, P = 0.0001).

Foragers were significantly more active when foraging alone than when foraging in a group (mean moves/sec ± SD: solitary trials = 0.66 ± 0.1, group trials = 0.50 ± 0.02; paired t-test: t = 3.02, P = 0.005). Male movement rate did not differ significantly before versus after food discovery (paired t-test: t = 0.13, P = 0.90). Females showed a nearly significant tendency to move faster following food discovery (t = 2.20, P = 0.06).

Discussion

This study is the first to address the effects of group foraging on foraging success in an insect. As has been the case for many vertebrates, the mean and variance in food-finding time were lower for foragers in groups. On average, *M. austrina* thus enjoyed group benefits in search rate.

The search rate of microveliids depends in part on the rate at which they are moving. Interestingly, despite a negative relationship between an individual's movement rate and food-finding time within both group and solitary treatments, focal animals (1) had lower movement rates when in groups than when alone and (2) found food sooner when in groups. This apparent contradiction is most likely due to an increased proportion of movements being directed towards food items for focal microveliids in groups relative to those foraging alone. Foraging microveliids quickly responded to conspecifics that located food by moving in the direction of the feeding animal(s). In 20 out of 29 (69%) group foraging trials, the focal animal arrived at the food item after a conspecific. This interaction, termed "local enhancement," whereby individuals intentionally or unintentionally communicate the location of food to others (Krebs et al. 1972, Pitcher et al. 1982), may rely on surface waves created by actively feeding microveliids. Thus, despite the fact that microveliids in group contexts move less frequently per time unit relative to when alone, a larger proportion of the moves are towards food because of cues provided by successful microveliids; this results in lower food-finding times. Within each one of these foraging contexts, faster animals locate food sooner.

A likely mechanism for the location of successful foragers is detection of vibrations through the surface tension of water. Wilcox (1979) found that rapid movement of tarsi by water striders (*Gerris remigis* Say) on the water surface effectively communicates gender of one male to another male. Successful microveliids increased the movement rate of their tarsi upon finding food. Furthermore, other foraging microveliids seemed to move in the direction of the successful microveliid after its discovery. An intriguing possibility in this scenario is that the communication of food whereabouts is intentional, suggesting altruism on the part of successful foragers. Given a few assumptions (see Trivers 1971), intentional communication between all members of a population should evolve if the decrease in food-finding time associated with group foraging translates into fitness benefits. An individual can only gain the benefit of decreased food-finding times by cooperating with conspecifics that signal. However, once that individual cooperates

(signals), the cost of cooperation (sharing its find) will be outweighed by the benefit of shorter mean food-finding times in the long run, improving the individual's fitness.

Variance in food-finding time was lower in group foraging, as has been observed in other animals (Krebs et al. 1972, Brown 1988, Pitcher et al. 1982). Because my main goal in this experiment was simply to test for this relationship, I have no further data on whether microveliids switch to solitary foraging (risk-sensitive) when starved, as predicted by theory (Caraco 1980). Further experiments on this question may illuminate some of the selective forces responsible for the evolution of group living in this species.

The rate at which food items are encountered is only one of several components influencing a forager's rate of energy gain. Although an individual microveliid may find more food items per unit of time when in a group, the individual may gain less energy/time than a solitary forager because grouped microveliids are forced to share prey with conspecifics (see Clark & Mangel 1986). On the other hand, there may be a premium on finding food quickly because of behavioral tradeoffs between foraging, predation risk and mating behavior. Predatory sunfish (*Lepomus cyanellus* Rafinesque) and water striders (*Gerris remigis*) are known to disrupt the mating behavior (Travers & Sih 1991) and alter habitat use (Sih 1988) of *Microvelia austrina.* Thus, longer food-finding time for solitary individuals may lead to mating and predation costs that outweigh the benefits of feeding alone. Faster location of food resources may also be advantageous despite reduced per patch reward given the ephemeral nature of acceptable food floating downstream. Further experiments examining energy gains of individual microveliids foraging in groups and in field situations will be informative.

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FILES AND SCRAPERS: CIRCUMSTANTIAL EVIDENCE FOR STRIDULATION IN THREE SPECIES OF *AMBLYCERUS,* ONE NEW (COLEOPTERA: BRUCHIDAE)

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Abstract.—*Amblycerus stridulator* NEW SPECIES, *A. pollens* (Sharp) and *A. eustrophoides* (Schaeffer) have in common a fusiform node with transverse striations on the metepisternum and an apical tooth on the metafemur. The fusiform node (file) and the apical tooth (scraper) may be stridulatory organs. Similar structures in criocerine Chrysomelidae are discussed and compared to the bruchids. *Amblycerus eustrophoides* and *A. pollens* are redescribed. *Amblycerus stridulator* NEW SPECIES is described from Mexico. The species differ in the sclerites in the internal sac, patterns of pubescence, and the position of the fusiform node on the metepisternum.

Key Words.—*Amblycerus,* taxonomy, Mexico, *A. stridulator, A. pollens, A. eustrophoides,* Bruchidae, stridulation

This paper describes a new species and redescribes two named species of *Amblycerus* that have structures that may be stridulatory organs. To our knowledge, no bruchid is known to stridulate nor to have structures that resemble those reported here.

Our studies were stimulated by the observation by Kingsolver (1970) that *Amblycerus eustrophoides* (Schaeffer) has a unique structure for bruchids: a fusiform node with transverse striations on the metepisternum. He hypothesized that this structure "was apparently a stridulatory mechanism" when rubbed against a spine on the ventral margin of the metafemur. Thus, the structure on the metepisternum may be a stridulatory file and the spine on the metafemur a scraper (plectrum).

Amblycerus stridulator NEW SPECIES, described here, and *A. pollens* (Sharp) and *A. eustrophoides,* redescribed here, are the other two species of *Amblycerus* known to have these structures. No living specimens have been analyzed, so we do not know whether these structures are, in fact, stridulatory in function. We believe, however, that it is very important to present our accumulated morphological data here for its heuristic value.

Amblycerus is a large genus with 102 described species (Kingsolver 1990) and has a wide distribution, especially in the Neotropics.

AMBLYCERUS EUSTROPHOIDES (SCHAEFFER)

Spermophagus eustrophoides Schaeffer 1904: 228.
Amblycerus eustrophoides: Johnson 1968: 1268; Bottimer 1968: 1012; Kingsolver 1970: 4; Johnson & Kingsolver 1981: 410.

Type.—Lectotype. Locality: FLORIDA. *PALM BEACH Co.:* Lake Worth; Depository: U.S. National Museum of Natural History, Washington, D.C.; Schaeffer 1907: 293; Leng 1920: 306.

Redescription.—Length (pronotum–elytra) 4.9–6.5 mm. Width 3.1–4.0 mm. Maximum thoracic depth 2.3–3.1 mm.

Male.—*Integument Color.* Body uniformly red to dark red; frons and clypeus sometimes dark brown; eyes silvery or black.

Vestiture. Body covered with silvery gray setae; on elytron each foveola with 1 brown seta; pygidium with narrow median line of setae. *Structure.* Head. Elongated, densely punctulate; frons with median impunctate line extending from frontoclypeal suture to middle of frons. Eye ovoid, cleft to 0.2× its length by ocular sinus; medial margin of eye with row of long, golden setae. Segment 1 of antenna about 2× longer than second; third segment 1.8× longer than second; remaining segments more or less with proportions as first; antenna reaching middle area of hind coxa. Clypeus covered with punctures. Labrum with few punctures. *Prothorax.* Disk subcampanulate, median basal lobe weakly convex, basal margin with carina. Dorsal surface of pronotum punctulate with deep foveolae scattered on surface; lateral carina extending to anterior corner, not reaching cervical sulcus; cervical sulcus extending to midline, with 3 cervical setae. Prosternum flat, constricted between coxae, carinate laterally; proepisternum with foveolae on anterior half. *Mesothorax and Metathorax.* Scutellum slightly elongate, finely punctulate, 1.5× as long as wide, lateral margins straight, strongly tridentate at apex. Elytron 2.2× as long as broad; striae regular, weakly impressed and deeply punctulate; strial intervals finely punctured. Mesosternum tongue-like in basal area, finely punctulate, with a mesal sulcus for reception of posterior area of prosternum. Mesepisternum and mesepimeron finely punctulate, without foveolae. Metasternum punctulate with few foveolae on mesal region; longitudinal suture of metasternum 0.4× as long as sternum; antecoxal suture of metasternum interrupted before reaching median sulcus, bending caudad and reaching posterior margin near mesal area of metasternum. Metepisternum punctulate with shallow to deep foveolae over surface; metepisternal sulcus forming right angle with transverse axis slightly curved and reaching lateral margin of metepisternum, longitudinal axis wider, fusiform and striate transversely to form a "file" (Fig. 1). Surface of hind coxa punctulate, densely setose, and foveolate on lateral 0.66, remaining 0.33 polished, impunctate, with a small cluster of punctures near trochanteral insertion; both foveolae and cluster of punctures proximate; metafemur punctulate, without foveolae, with angulate tooth on ventral margin (Fig. 2); lateral tibial calcarium slightly curved, 0.55× as long as basitarsus; mesal calcarium 0.6× as long as lateral calcarium. *Abdomen.* Sterna finely punctulate with few foveolae on lateral surface, with few, long setae on mesal region of each; fifth sternum emarginate at apex; pygidium with terminal margin rounded or slightly truncate, surface finely punctulate, with scattered foveolae. *Genitalia* (Figs. 3, 4). Median lobe slightly constricted on lateral margins; ventral valve acuminate at apex, arcuate in lateral view; dorsal valve narrow and deeply concave at base; armature of internal sac with 2 basal, subtriangular sclerites with dorsal surfaces finely dentate; 2 median blades with 0.5 of dorsal surface dentate and wishbone-shaped sclerite; 2 irregular, apical, small sclerites; internal sac lined with many fine spinules. Lateral lobes cleft to 0.2× their length (Fig. 4).

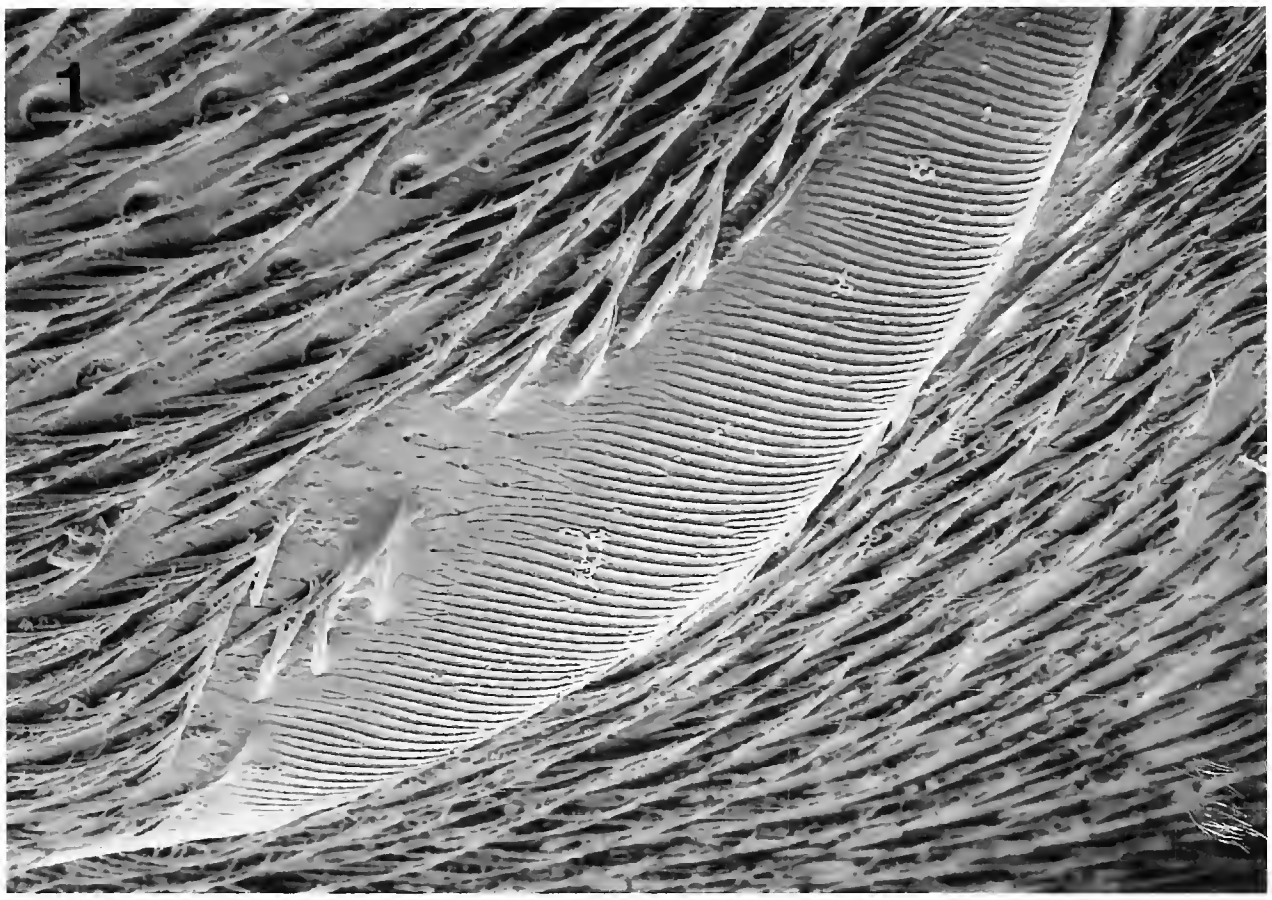
Female.—Similar to male, except fifth abdominal sternum not emarginate.

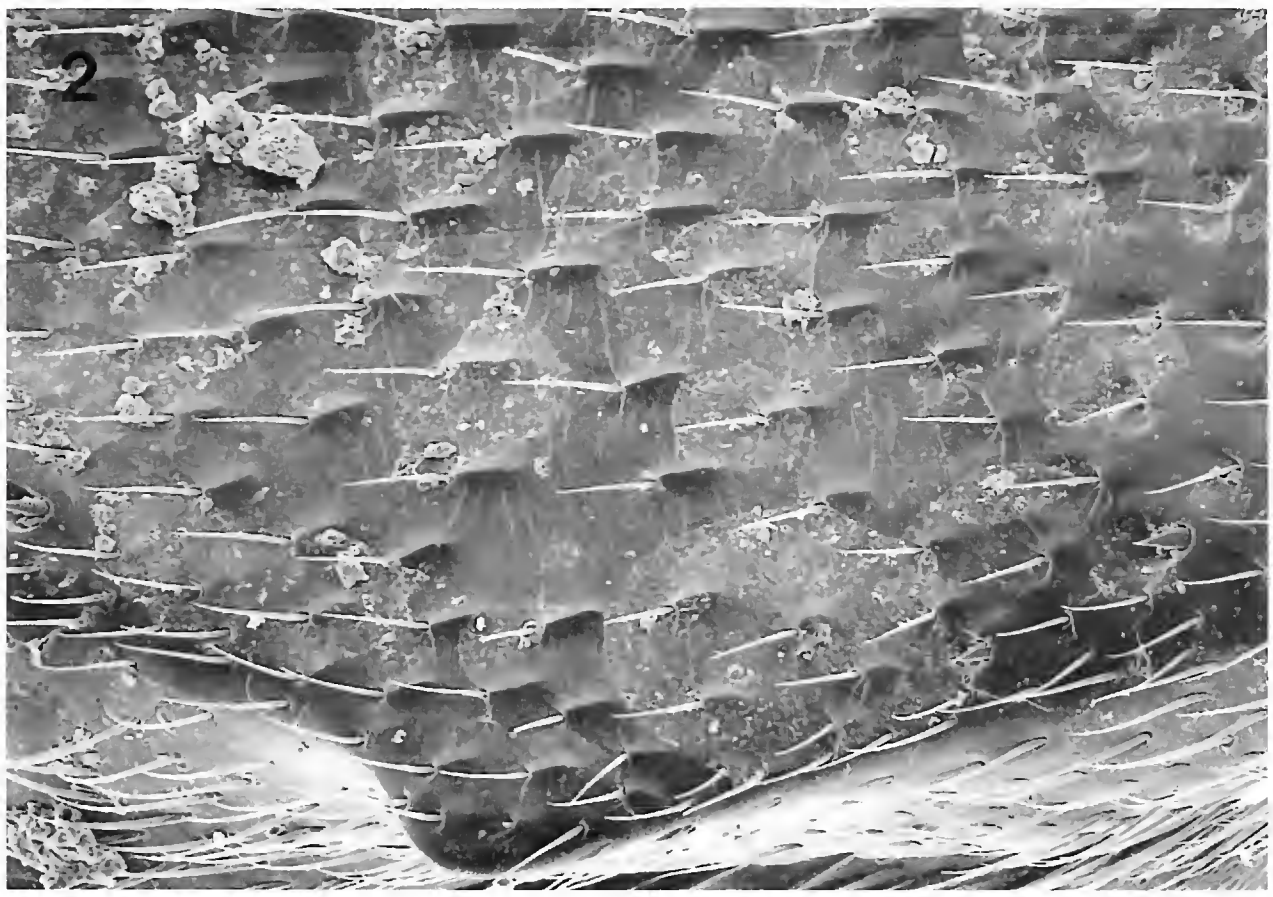
Host plants.—*Drypetes laterifolia* (Swartz): Kingsolver 1970: 475.
Distribution.—Costa Rica, Cuba, Mexico, United States.
Discussion.—*Amblycerus eustrophoides* is discussed under *A. stridulator.*

Material Examined.—See type. FLORIDA. *DADE Co.:* Matheson Hammock, Coral Gables, 20 Jun 1965, L. & C.W. O'Brien Collectors. MEXICO. *TAMAULIPAS:* Hda. Santa Engracia, May–Jun 1936, M. McPhail, Collector, reared from "huilotillo."

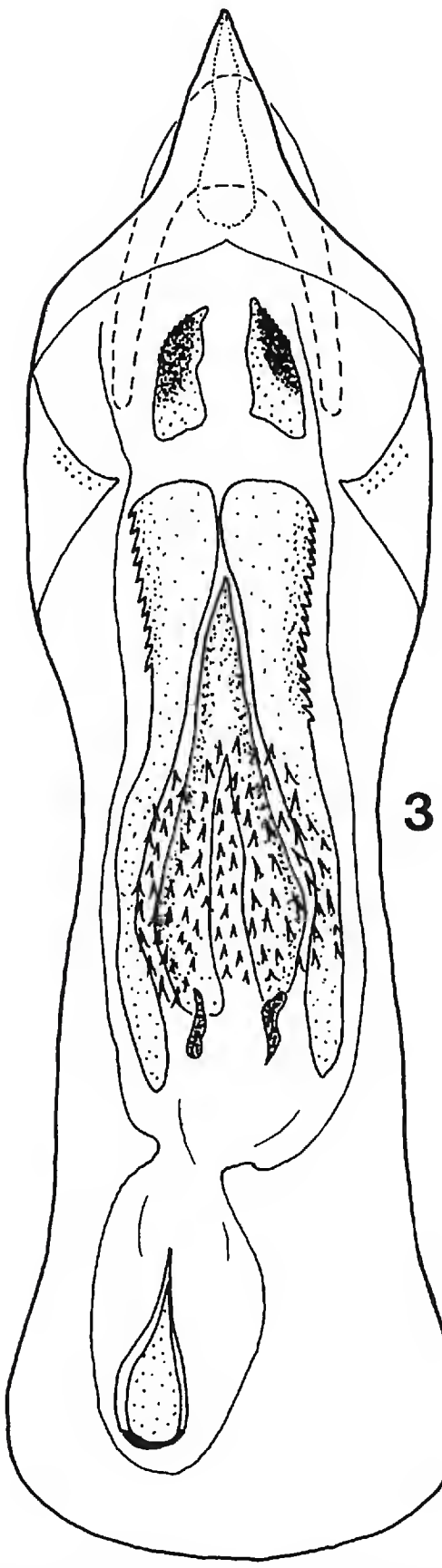
Amblycerus pollens (Sharp)

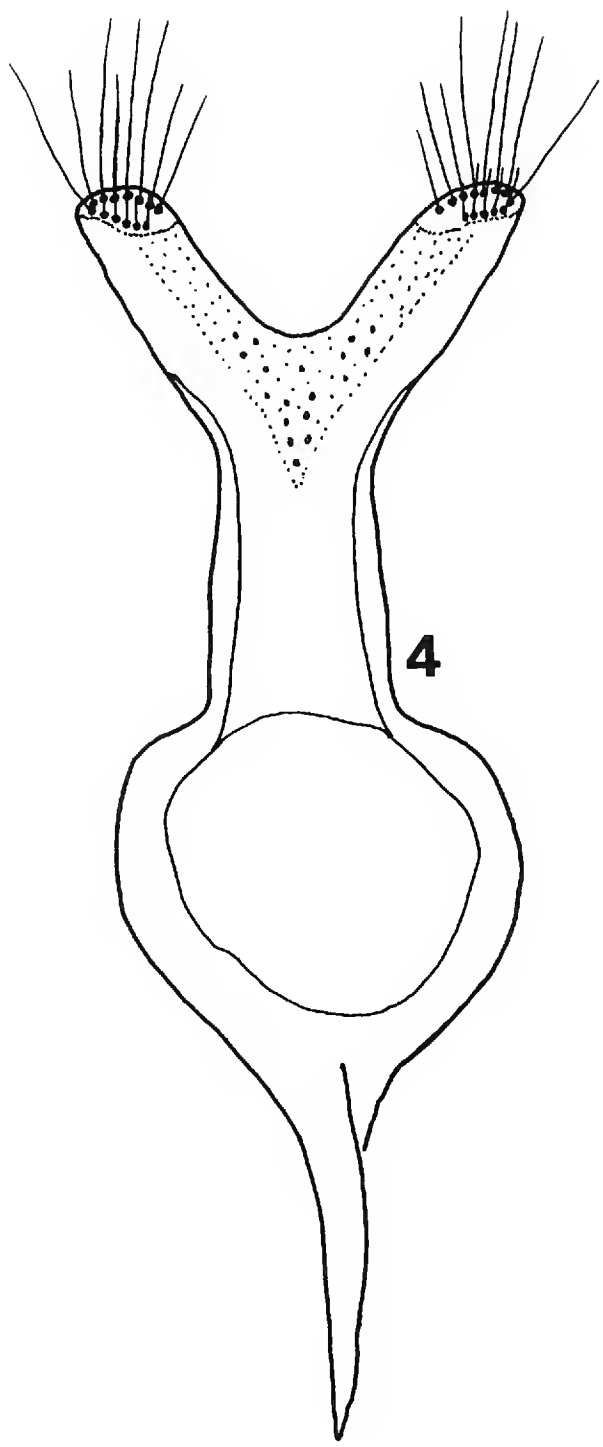
Spermophagus pollens Sharp 1885: 495.
Spermophagus subflavidus Pic 1902: 172 (Type. Locality: "Brésil"; Depository: Museum d'Histoire Naturelle, Paris); Kingsolver 1976: 151.





Figures 1–2. *Amblycerus eustrophoides.* Figure 1. Scanning electron micrograph (SEM) of metepisternum showing "file." Figure 2. SEM of ventromesal margin of hind leg showing "scraper" or tooth on ventral surface.





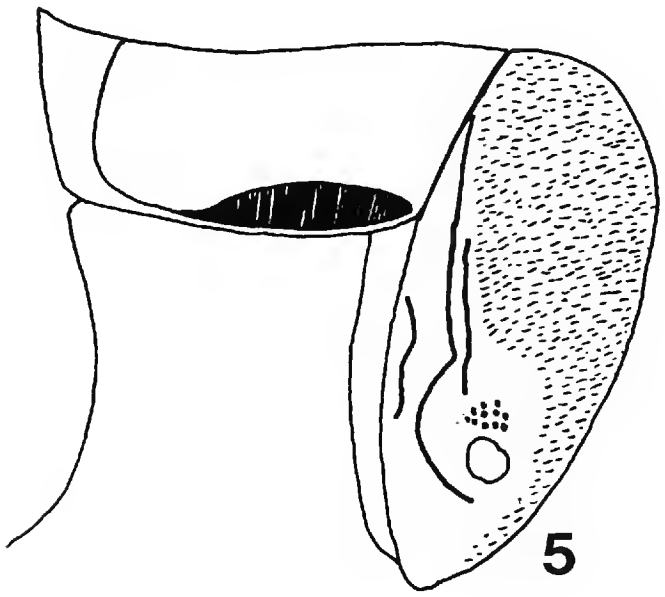
Figures 3–4. *Amblycerus eustrophoides*. Male genitalia: Figure 3. Median lobe, ventral view. Figure 4. Lateral lobes, ventral view.

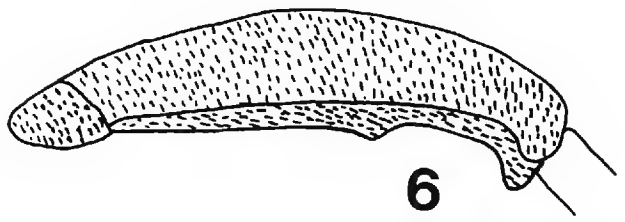
Amblycerus pollens: Blackwelder 1946: 763, Kingsolver 1976: 151, Kingsolver 1980: 238, Johnson & Kingsolver 1981: 410.
Amblycerus subflavidus: Blackwelder 1946: 763, Kingsolver 1976: 151.

Type.—*Spermophagus pollens.* Type Locality: "British Honduras, Belize"; Depository: British Natural History Museum, London).

Redescription.—Length (pronotum–elytra) 7.8–8.7 mm. Width 4.5–5.3 mm. Maximum thoracic depth 3.5–4.0 mm.

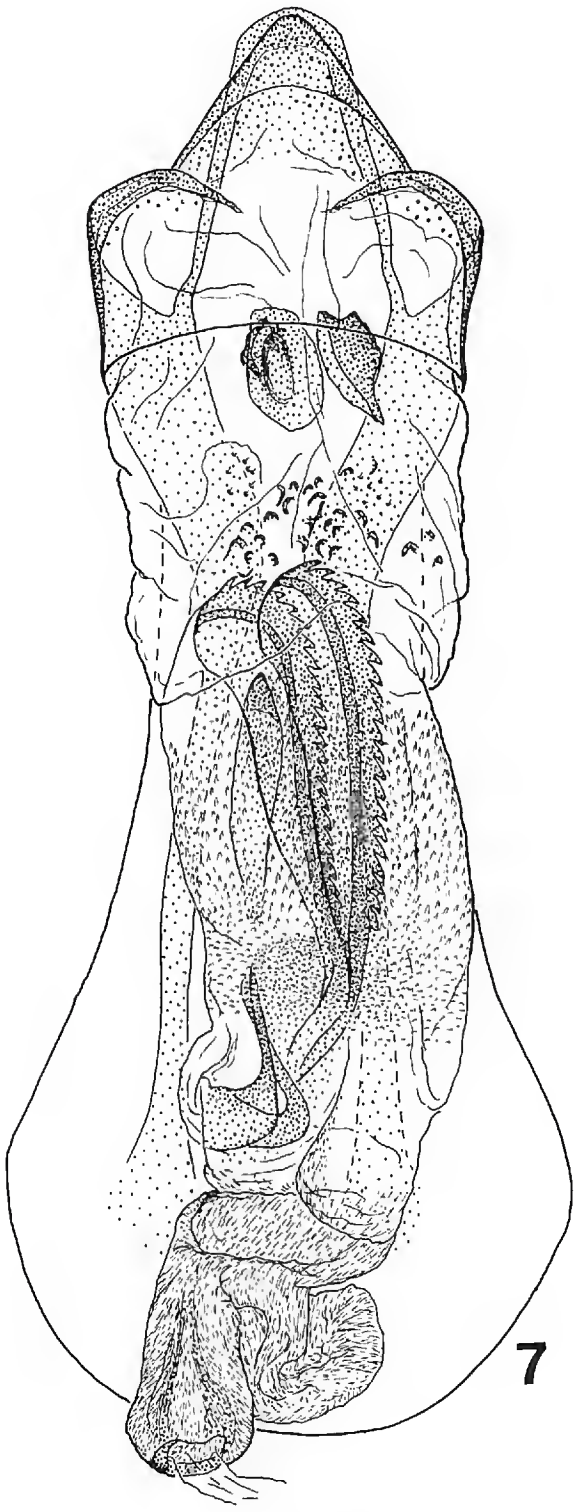
Male.—*Integument Color.* Pronotum and elytra red-brown, narrow, dark line on lateral margin of

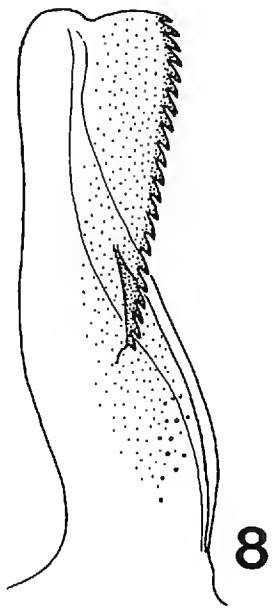


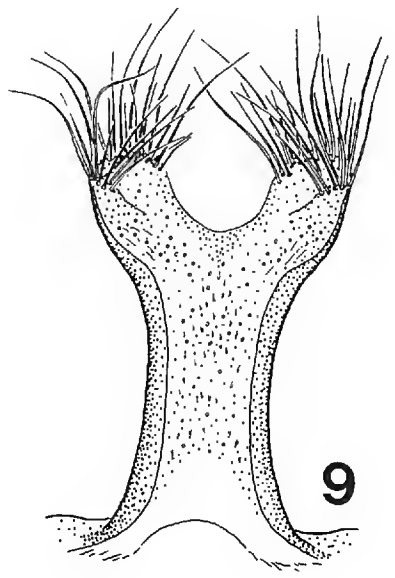


Figures 5–6. *Amblycerus pollens*. Figure 5. a. Metepisternum, b. file and c. metacoxa. Figure 6. Hind leg with short "scraper."

elytron; rest of the body dark brown or black; elytron, abdomen and pygidium may be yellow in some; eyes silvery or shiny black. *Vestiture.* Pronotum and pygidium covered with orange setae; elytron clothed with very fine orange setae, elytron with ten narrow, vague, longitudinal lines of white setae in striae, very vague in specimens with a slightly yellow integument; rest of the body covered with fine white pubescence, except the inner face of protibia clothed with golden setae. *Structure.* Head. Subtriangular, with many fine punctures interrupted by large punctations; frons with median impunctate line, without evident median carina. Eye width slightly more than base of frons, slightly more narrow at apex; eye cleft 0.20× its length by ocular sinus. Antennal segments with small foveolae; first segment of antennae 2.6× longer than second; third segment 2× longer than second; remaining segments about same length as first segment; antenna reaching anterior margin of hind coxa. Clypeus covered with punctures, except small fringe on apical margin. Labrum covered with fine punctures. *Prothorax.* Disk subcampanulate, median basal lobe weakly convex, basal margin with carina. Dorsal surface of pronotum finely punctulate, with 3 longitudinal lines of fine foveolae on each side; pronotum with lateral carina reaching 0.25 distance to cervical sulcus; cervical sulcus extending dorsad almost to dorsal midline; with 4 cervical setae; lateral margin of pronotum sinuate. Prosternum flat, finely punctate, constricted between coxae, apical portion curved; proepisternum finely punctate with foveolae on anterior half. *Mesothorax and Metathorax.* Scutellum slightly elongate, finely punctulate, with 2 weak sulci, tridentate apically. Elytron 2.7× as long as broad; striae regular, moderately impressed, deeply punctate, principally on anterior 0.33; strial intervals with many fine punctations. Mesosternum linguiform, with mesal sulcus for reception of prosternal process; mesepisternum and mesepimeron finely punctate, without foveolae; metasternum finely punctate, with few deep foveolae; longitudinal suture of metasternum 0.33× as long as sternum; antecoxal suture of metasternum interrupted before reaching median sulcus, bending caudad and reaching posterior margin near mesal area of metasternum. Metepisternum punctulate, without evident foveolae; metepisternal sulcus forming right angle, with the transverse axis curved and reaching lateral margin of metepisternum, lon-







Figures 7–9. *Amblycerus pollens*. Male genitalia: Figure 7. Median lobe, ventral view. Figure 8. Sclerite of internal sac. Figure 9. Lateral lobes, ventral view.

gitudinal axis fusiform, with fine, transverse striations to form fusiform node with transverse striations (Fig. 5). Hind coxa punctate, foveolate, lateral 0.66 and posterior margin densely setose, medial 0.33 polished, impunctate, except for cluster of punctures near trochanteral insertion (Fig. 5); metafemur finely punctate, pubescent with a small angulate tooth on ventral margin (Fig. 6); inner face of metafemur densely punctulate with cluster of foveolae on mesal portion; metatibia finely punctulate with scattered foveolae; lateral tibial calcarium curved, 0.8× as long as basitarsus, mesal calcarium 0.4× as long as lateral calcar. *Abdomen.* Sterna finely punctate with few foveolae on lateral areas; fifth sternum slightly emarginate at apex; pygidium with terminal margin rounded, surface finely punctate with deep foveolae. *Genitalia* (Figs. 7, 8, 9). Median lobe slightly constricted on lateral margins; ventral valve acuminate at apex; dorsal valve narrow, about 0.5× as wide as apex of median lobe, apex gently rounded; in ventral view base of internal sac with armature of two, spiny elliptic plates, 20–25 verrucae; median moderate-sized, acuminate sclerite, and two blade-shaped sclerites with 0.5 of dorsal surfaces serrate; middle and apex of internal sac lined with many fine spinules; triangular gonopore duct sclerite at apex. Lateral lobes cleft to about 0.3 their length (Fig. 9).

Female.—Similar to male except apical margin of fifth abdominal sternum truncate.

Host Plants.—Unknown.

Distribution.—Belize, Guatemala, Costa Rica, Venezuela, French Guiana, Brazil.

Discussion.—*Amblycerus pollens* is discussed under *A. stridulator.*

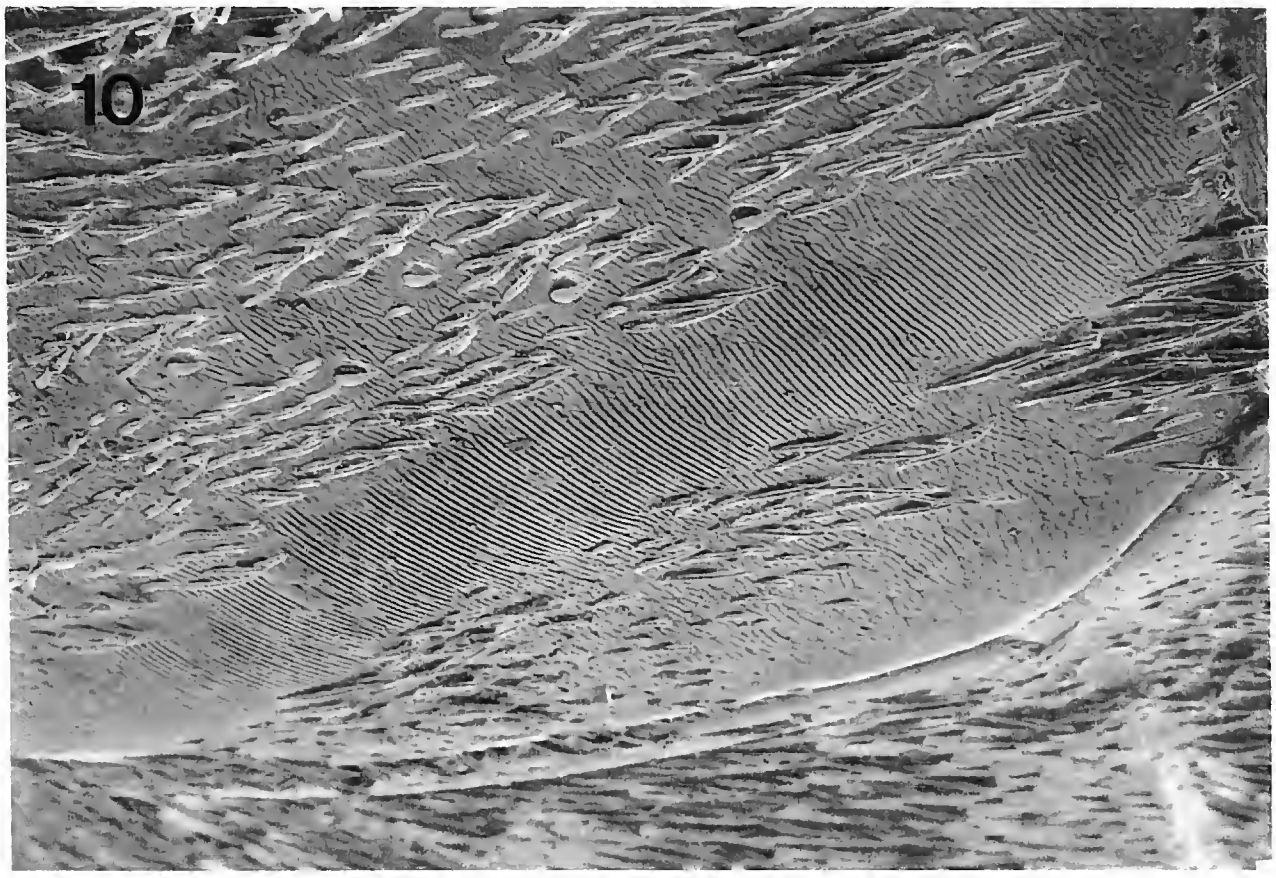
Material Examined.—See type. COSTA RICA. *PUNTARENAS:* Puntarenas, 28 May 1971, J. Fox, collector. Brésil.

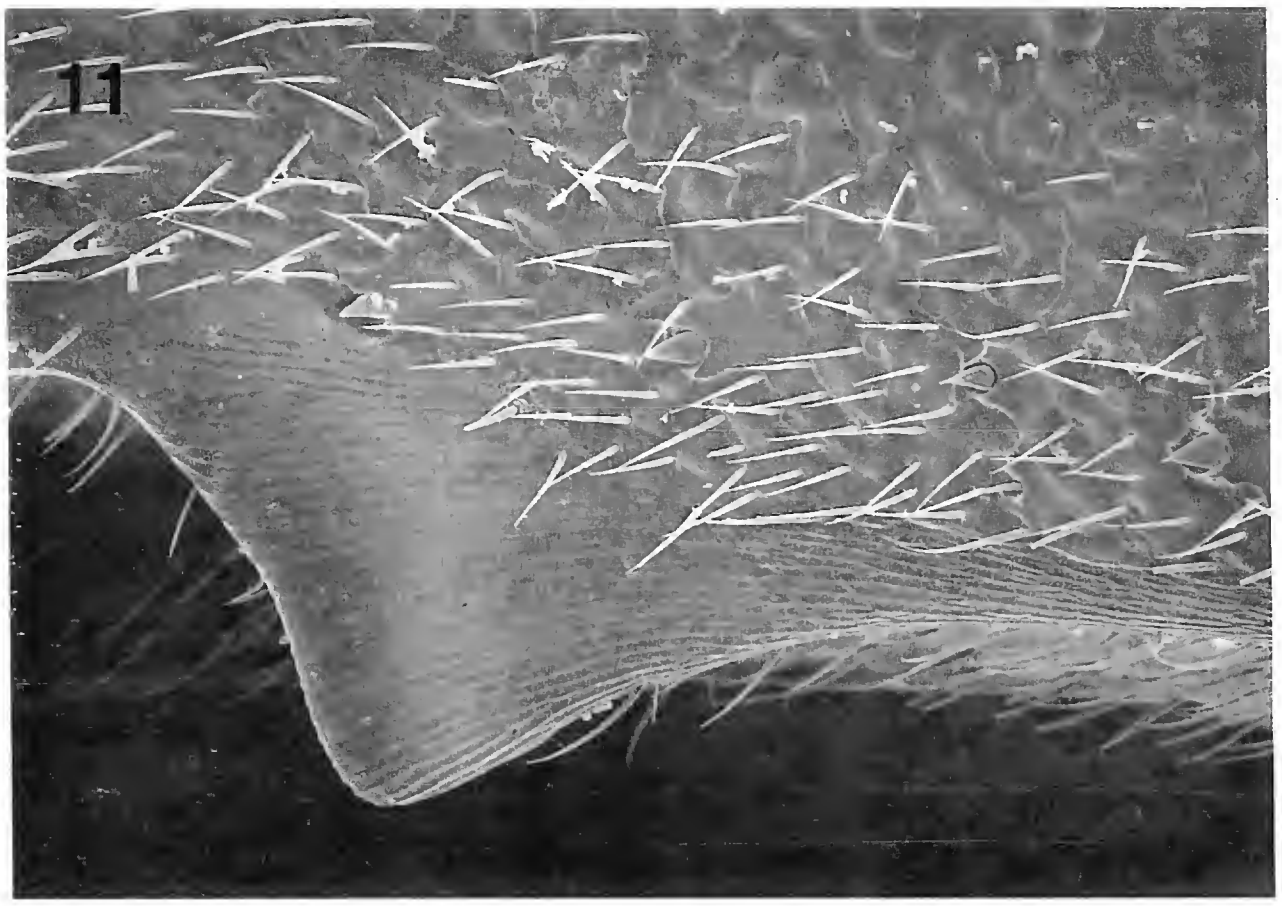
Amblycerus stridulator, NEW SPECIES

Type Series.—MEXICO. *JALISCO:* Estación de Biología, Chamela, 17 Feb 1985, ex seeds *Caesalpinia sclerocarpa* Standley, T.H. Atkinson (THA 167). Allotype and 4 paratypes, same data. Other paratypes: Same locality as holotype but April 1980, ex seeds *Caesalpinia sclerocarpa,* A. Pescador; same locality but 17 Jul 1987, R. Turnbow. *SINALOA:* 10.8 km (6 mi) N Mazatlan, nr. beach, 26 Feb 1973, reared seeds #215-73, *Caesalpinia sclerocarpa,* emerg. 15 Mar 1973, C.D. Johnson. *OAXACA:* Port Guatulca, 3 Dec 1937, Zaca Exped. Acc. 37483. COSTA RICA. *PUNT.:* Monteverde, 1400 m, 12–14 Aug 1987, 24 Aug 1987, H. & A. Howden. VENEZUELA. *LARA:* 4 km N La Pastora, 2–3 Mar 1978, riparian forest, J.B. Heppner. Holotype and paratypes deposited in the collection of the Universidad Nacional Autonoma de Mexico, Mexico, D.F. Allotype and paratypes deposited in the U.S. National Museum of Natural History, Washington, D.C. Paratypes also deposited in the American Museum of Natural History, New York; the H. & A. Howden collection, Ottawa, Ontario, Canada; the C. D. Johnson collection, Flagstaff, Arizona; and the Departamento de Biologia, Universidade Federal do Parana, Curitiba, Brazil.

Description.—Length (pronotum–elytra) 5.3–7.7 mm. Width 3.2–4.5 mm. Maximum thoracic depth 2.3–3.1 mm.

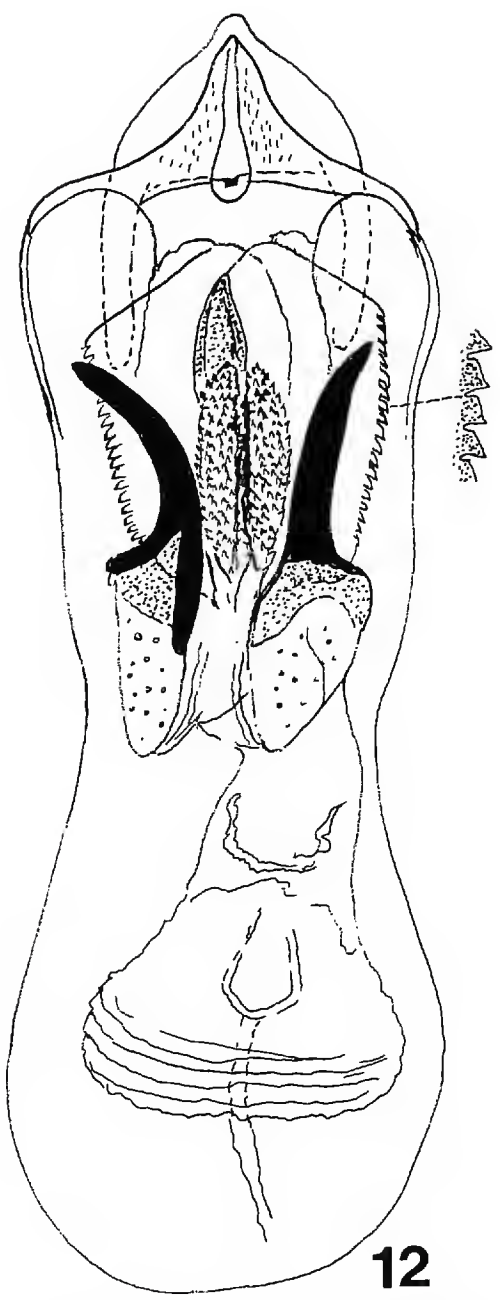
Male.—*Integument Color.* Body red-brown to piceous, eye black, antenna mostly piceous, metatibia and metatibial spurs dark red. *Vestiture.* Mostly with gray setae but with scattered spots of red-brown setae on pronotum and elytra; venter of body gray except slightly yellow along posterior border of each abdominal sternum, and slightly yellow spots along lateral margin of abdomen; tarsal pads yellow; pygidium with median line of gray setae. *Structure.* Head. Turbiniform, eyes strongly protuberant, coarsely faceted, ocular sinus less than 0.2× length of eye; frons narrowed toward frontoclypeal suture, frontal carina obtuse, frons finely, densely punctate, clypeus more strongly punctate, labrum finely punctate and setose along basal border, finely fringed on apical margin; basal antennal segment 3× length of second, segments 4–10 serrate, eleventh subelliptical; submentum coarsely punctate. *Prothorax.* Pronotum nearly semicircular, perceptibly angulate at anterolateral corners, basal lobe shallow, disk convex, somewhat depressed along base, surface finely foveolate, foveolae more dense on each lateral 0.33 of disk, intervals minutely punctate; lateral margin carinate and arcuate; hypopleuron concave; cervical sulcus extending from near anterior end of lateral carina to a point behind upper margin of eye; cervical boss bisetose; prosternum Y-shaped, with shallow sulcus before procoxae, intercoxal process flat, margins slightly constricted, apex bluntly attenuate. *Mesothorax and Metathorax.* Scutellum 2× as long as wide, constricted at middle, tridentate apically. Elytra 1.5× as long as wide, depressed around scutellum, striae regular in course except base of fourth closer to third than to fifth, sixth and seventh usually conjoined apically; striae moderately deep, regularly punctate, interstices nearly flat. Mesosternum nearly vertical, apex abruptly bent caudad and channeled to receive apex of prosternum; postmesocoxal sulci joined at midline and extending laterad to pleurosternal suture; metepisternal parasutural sulcus extending to metacoxal cavity, abruptly bent at anterior end and ending at elytral margin, metepisternal disk with arcuate stridulatory file extending anteriorly from coxal cavity 0.75× length of sclerite (Fig. 10). Metacoxal face sparsely, evenly punctate in middle 0.33, and with dense cluster of punctures near trochanteral fossa. Front and middle legs not modified; metafemur with angulate tooth on ventromesal margin (Fig. 11), mesal face of tooth finely striate;

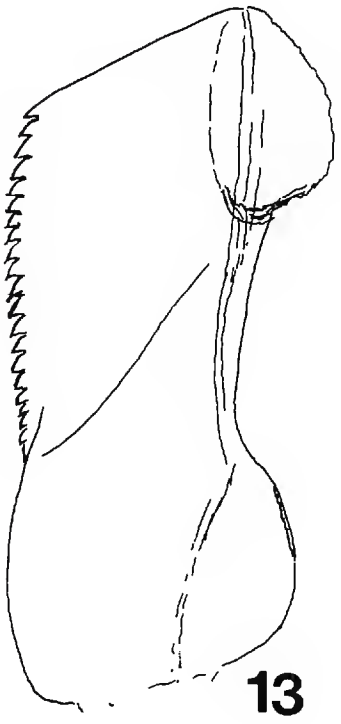


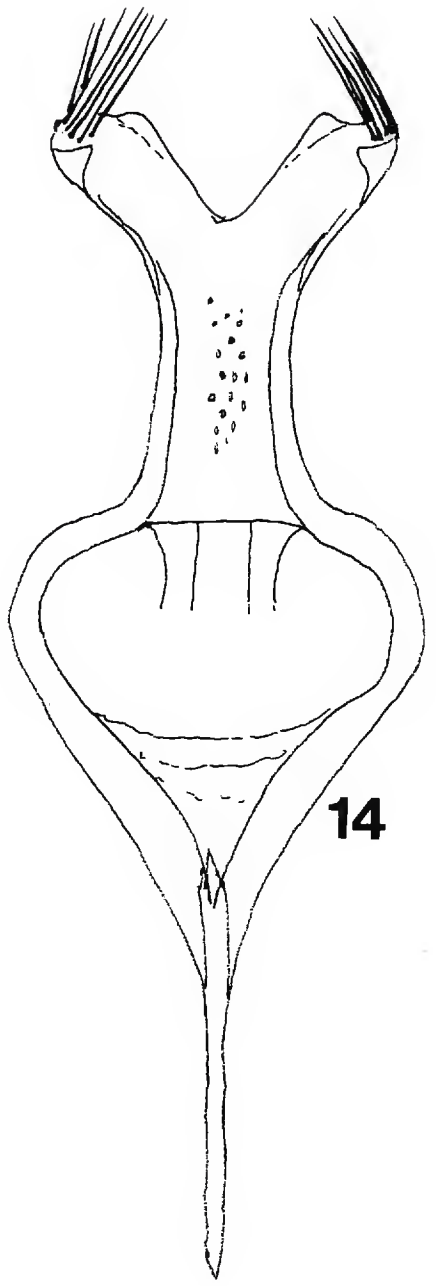


Figures 10–11. *Amblycerus stridulator.* Figure 10. SEM of metepisternum showing "file." Figure 11. SEM of ventromesal margin of hind leg showing "scraper" or tooth with many fine striations on ventral margin.

lateral metatibial spur 2× as long as mesal spur. *Abdomen.* Sternum 5 nearly as long as remaining 4 together; sternum 5 broadly emarginate apically; pygidium nearly semicircular, disk densely, irregularly microfoveolate. *Genitalia* (Figs. 12, 13, 14). Median lobe more than 3× as long as wide; ventral valve subtriangular, lateral margins concave; dorsal valve subelliptical, extending beyond apex of ventral valve; internal sac armed with 3 types of paired sclerites: a pair of flat blades with serrate lateral margins, a pair of large, falcate, thorn-like sclerites with swollen bases, and a pair of irregularly twisted,







Figures 12–14. *Amblycerus stridulator.* Male genitalia: Figure 12. Median lobe, ventral view. Figure 13. Sclerite of internal sac. Figure 14. Lateral lobes, ventral view.

densely spiny lobes; apex of sac membranous and plicate. Lateral lobes cleft to 0.26 their length, Y-shaped, truncate and setose apically, median strap with minute, cylindrical sensillae (Fig. 14).

Female.—Similar to male except fifth sternum evenly rounded.

Diagnosis.—*Amblycerus stridulator* can be separated from *A. pollens* and *A. eustrophoides* by its file, which is transverse to the metepisternal sulcus (see discussion).

Host Plants.—*Caesalpinia sclerocarpa* Standley.

Distribution.—Mexico.

Etymology.—The name *stridulator* is a noun in apposition to *Amblycerus.* It refers to the apparent stridulatory structures of this species.

Discussion

Systematics.—In addition to *A. stridulator, A. eustrophoides* and *A. pollens* have a fusiform node with transverse striations (Figs. 1, 5) on the metepisternum and an apical tooth on the metafemur (Figs. 2, 6). The species differ, however, in the sclerites in the internal sac (Figs. 3, 7), patterns of pubescence, and the position of the fusiform node on the metepisternum. *Amblycerus stridulator* is distinct from *A. pollens* and *A. eustrophoides* as the latter two species are more similar to

one another in external morphology (revisionary studies currently under way indicate, however, that the three species are in different species groups). *Amblycerus pollens* and *A. eustrophoides* have files that apparently are a modification of the longitudinal axis of the metepisternal sulcus, and the tooth (scraper) on the hind femur is not striate. The sclerites in the internal sac of both species are similar in shape and number, especially the spiny subelliptic plates and the blade-shaped, serrate sclerite. Also, the lateral lobes (Figs. 4, 9) do not have pads between their apices.

The file of *A. stridulator* is transverse to the metepisternal sulcus (Fig. 10), apparently originating as a modification of the metepisternum. The tooth on the hind femur has fine striations over its entire surface (Fig. 11). The internal sac of the male genitalia has only the blade-shaped serrate sclerites (Fig. 12) that are similar to those in *A. pollens* and *A. eustrophoides.* The lateral lobes have a pair of pubescent pads between them (Fig. 14). Unfortunately the host plants of *A. pollens* are unknown. That *A. stridulator* feeds on *Caesalpinia sclerocarpa* (Fabaceae) and *A. eustrophoides* in *Drypetes laterifolia* (Swartz) (Euphorbiaceae) is of significant value. Because *A. pollens* is more similar to *A. eustrophoides* increases the possibility that *A. pollens* may feed in a Euphorbiaceae. This suggests that two lines of development have occurred, with *A. stridulator* more distant from the other two species in both morphology and host plant preferences.

Stridulation.—Because we have no evidence that these three species actually produce sounds, we can do no more than hypothesize here. The "files" in our scanning electron micrographs (Figs. 1, 10) are remarkably similar to those in six species of criocerine Chrysomelidae studied by Schmitt & Traue (1990). Bruchids are very closely related to chrysomelids. Unlike the three bruchids, the sounds produced by the chrysomelids were discovered long before the mechanism for producing them. Schmitt and Traue hypothesized that the sounds produced by the chrysomelids were similar to "disturbance sounds" of other insects because they could not detect species-specific differences in sounds nor sexual dimorphism of the stridulatory organs. They used oscillograms, frequency spectra and sonagrams for their analyses. The files of the chrysomelids were located on "the last perceptible abdominal tergite, the so-called pygidium, and adjoined the rostral margin of the pygidium." The plectra (scrapers) "were situated on the underside of the elytra in the hind sutural angles." Sounds were produced during contraction of the abdomen.

Kingsolver (1970) observed that *A. eustrophoides* has a unique structure for bruchids: a fusiform node with transverse striations on the metepisternum. He hypothesized that this structure on *A. eustrophoides* "was apparently a stridulatory mechanism" when rubbed against a spine on the ventral margin of the metafemur. Thus, the structure on the metepisternum may be a file and the spine on the metafemur a scraper (plectrum). Because three species of bruchids are now known to possess what appear to be files and scrapers, we will begin a study shortly on *A. stridulator,* the species whose hosts, and thus living specimens, are most accessible.

Acknowledgment

We are grateful for partial support for this study from USDA Grants 12-14-100-9187 (33), 12-14-100-9970 (33) and NSF Grant BSR88-05861 to CDJ.

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SYNONYMY OF TWO GENERA OF CYNIPID GALL WASPS AND DESCRIPTION OF A NEW GENUS (HYMENOPTERA: CYNIPIDAE)

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Abstract.—The location and reexamination of the "lost" generatype of the cynipid genus *Xystoteras* Ashmead has made it possible to demonstrate that this genus is a junior synonym of *Phylloteras* Ashmead NEW SYNONYMY. Two species, *Phylloteras lyratum* NEW SPECIES and *P. primum* NEW SPECIES are described, and a key to the species of *Phylloteras* is included. *Euxystoteras campanulatum* NEW GENUS AND NEW SPECIES, is described and compared to other closely related genera.

Key Words.—Insecta, Cynipidae, unisexual female, monothlamous gall

Confusion has long existed as to the identities of two Ashmead genera: *Phylloteras* and *Xystoteras.* The type-species of *Phylloteras, Biorhiza rubinus* Gillette, 1888, was redescribed by Ashmead (1897a) as having toothed claws and 13-segmented antennae. The type-species of *Xystoteras, Xystoteras volutellae* Ashmead (1897b), was described as having simple claws and 14-segmented antennae. On the basis of these characters the genera could not be confirmed. In cynipid taxonomy, the presence or absence of a tooth on the tarsal claw is considered to be of fundamental importance in separating major genera of the group. Lewis Weld (personal communication) and others believed that Ashmead, in his description, had erred in stating that *X. volutellae* had simple claws because no other species in these closely related genera had simple claws. As a result, all of the described species in these genera were considered to have toothed claws and were separated only by the number of antennal segments.

When the William Beutenmuller collection of Cynipidae came to the National Museum of Natural History in 1935, the "missing" *X. volutellae* type was found. Ashmead's label, host and host locality were on the pin, but it did not have a type label on it; I have examined this specimen and found that it agrees with the published description. However, a slide preparation, examined under high magnification, clearly shows the tarsal claws to be toothed. The antennae have 14 segments. I have concluded that this is the holotype and it has been so labeled. Study of a series of *Phylloteras rubinum* (Gillette) shows the number of antennal segments to be variable. Most specimens have 13 segments with the terminal segment at least 1.5× the length of the preceding segment. Some specimens, however, have 14 segments and the terminal segment slightly shorter than the preceding one. Therefore there no longer seems to be a valid reason to separate the two genera. *Xystoteras* (November 1897) is proposed as a junior synonym of *Phylloteras* (May 1897) NEW SYNONYMY. The concept of the genus must now be modified: wings absent or rudimentary; antennae with 13 or 14 segments; tarsal claws toothed; notauli absent or present only as traces; head massive, at least 0.5× as long as broad, broader than the mesosoma; gena broadened behind the eyes; metasoma compressed, knife-like, with all tergites visible along the dorsal margin, longer than the head and mesosoma combined. The following *Xystoteras*

species are transferred to *Phylloteras*: *X. nigrum* (Fitch), *X. poculum* (Weld), and *X. volutellae* (Ashmead).

Weld (1926), believing that the type of *Xystoteras volutellae* had been lost, erroneously designated a series of specimens, collected at Texarkana, Arkansas, on *Quercus lyrata* Walt as lectotypes (sic!). These were widely distributed to various museums. After he located the "lost" type, he (Weld 1952) acknowledged the error and stated that the specimens from Texarkana represented a new species that should be described. This was never done, however, so a description of this new species is provided here.

Phylloteras

Phylloteras lyratum Lyon NEW SPECIES
(Fig. 1)

Types.—Holotype female. Paratypes: 20 females, ARKANSAS. *MILLER Co.:* Texarkana, from galls on *Quercus lyrata* Walt, Oct 1917 emerged from rearing 19 Feb, 20 Mar, 23 May, 6 Apr, 14 & 21 Jun 1918. Holotype and 4 paratypes in National Museum of Natural History, Washington, D.C.; 4 paratypes in Natural History Museum of Los Angeles County.

Description.—Unisexual female. Black, fading in older specimens; antennae, legs and ventral spine brown. Head (Fig. 1D) massive; from above, more than 0.5× as long as broad, broader than mesosoma; gena broadened behind eyes, nearly as high as broad in frontal view (Fig. 1C), appearing nearly circular in outline; interocular space broader than high; malar space without a groove, 0.33× length of the eye; frons coarsely rugose with large, shallow punctures. Antennae with 14 segments. Scutum slightly longer than broad, smooth, shining, punctate anteriorly but without notauli; wing rudimentary but reaching nearly to end of scutellum (Fig. 1D). Scutellum rounded behind, pubescent, with deep roughened area across base; disk punctate, raised, appearing "humped" in side view, 0.5× length of mesoscutum. Metasoma (Fig. 1A) smooth, polished, all terga visible along dorsal curvature; compressed laterally, appearing knife-like beyond second tergum. Ventral spine long, slender, sparsely pubescent. Tarsal claw (Fig. 1B) with short tooth. Length 1.5–2.2 mm ($\bar{x}$ = 1.8 mm; n = 12).

Gall.—(Fig. 1E) Tiny, 3.5 mm high, monothalamous gall, attached to undersides of leaf blades. Developing galls covered with white bloom during growth, but lost at maturity. Larval cell occupies gall base.

Diagnosis.—See Key

Host.—*Quercus lyrata* Walt.

Etymology.—This species is named after its host oak, *Quercus lyrata.*

Material Examined.—Type series.

Phylloteras prinum Lyon NEW SPECIES
(Fig. 2)

Types.—Holotype female. Paratypes: 4 females, VIRGINIA. *FAIRFAX Co.:* East Falls Church, 17 Oct 1946, emerged from rearing cages 22 Jan 1948. Holotype and 1 paratype female in the U.S. National Museum of Natural History, Washington, D.C. Three paratypes in the Weld collection, which is in R. J. Lyon's possession.

Description.—Unisexual female. Ant-like, deep chocolate brown; head (Fig. 2D), massive, more than 0.5× as long as broad, wider than mesosoma; gena (Fig. 2C) slightly broadened behind eyes; interocular space broader than high and coriaceous; frons punctate; malar space slightly less than 0.5× length of eye, without groove; antennae with 13 or 14 segments; scutum as broad as long, smooth,

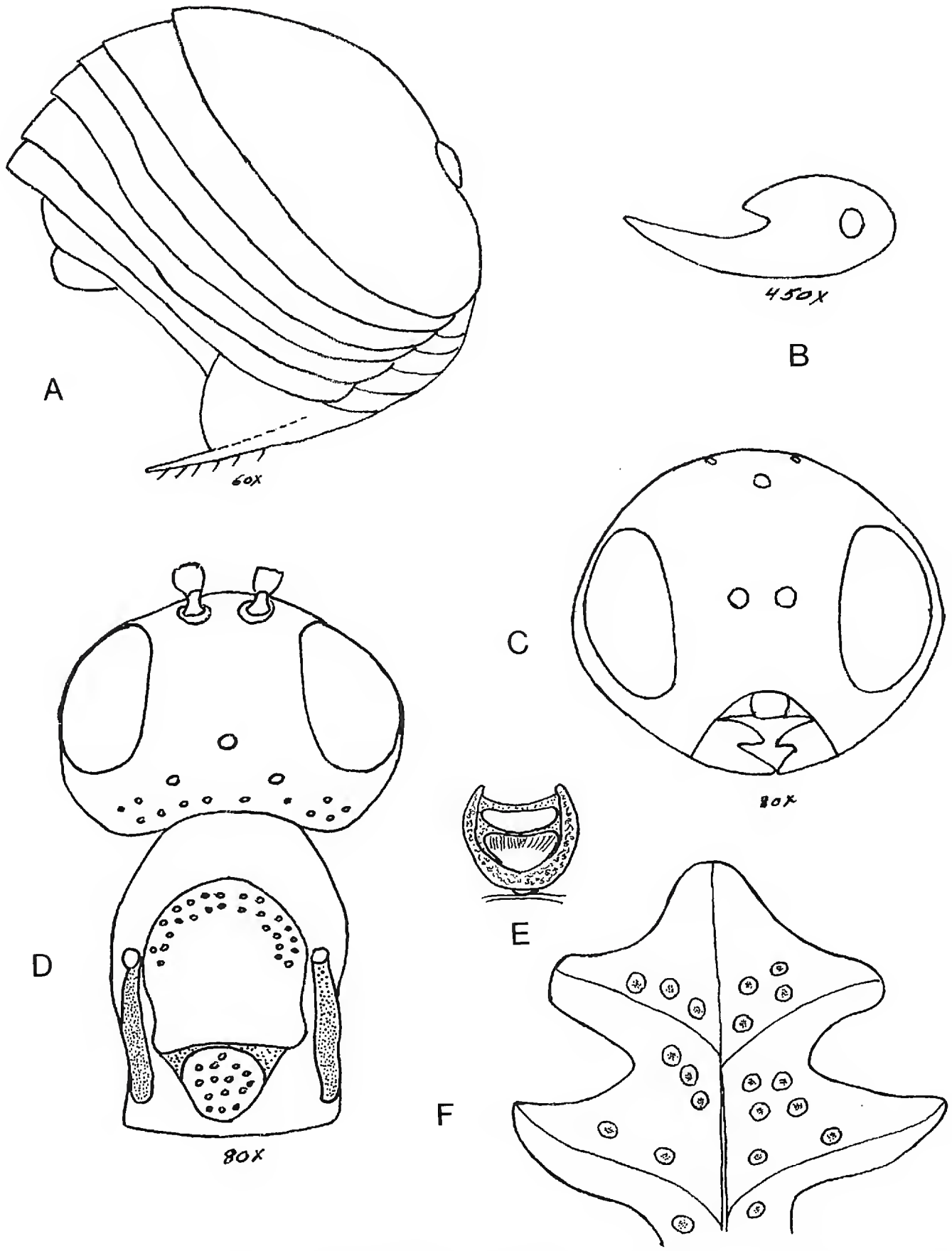

Figure 1. *Phylloteras lyratum* NEW SPECIES. A. Metasoma, lateral view, showing shape of terga. B. Tarsal claw with short tooth. C. Outline of head, frontal view. D. Head and mesosoma showing wing and scutum without notauli. E. Monothalamous gall showing position of larval cell. F. Leaf of *Q. lyrata* showing distribution of galls on leaf.

shining, without punctures or notauli but with indentations in position of lateral lines, posterior margin slightly emarginate; wings rudimentary, extending almost to end of scutellum (Fig. 2D); scutellum grooved at base, punctate, humped in side view, 0.5× length of mesoscutum. Metasoma (Fig. 2A), laterally compressed, knife-like, longer than head and mesosoma combined, all terga visible along dorsal curvature; tip of ovipositor hooked; ventral spine slender, bare; tarsal claws (Fig. 2B) strongly toothed. Length 1.45–2.2 mm ($\bar{x}$ = 2.1 mm; n = 5).

Gall.—(Figs. 2E, 2F) Monothalamous, circular, flattened disk, 4 mm diameter, with depressed center.

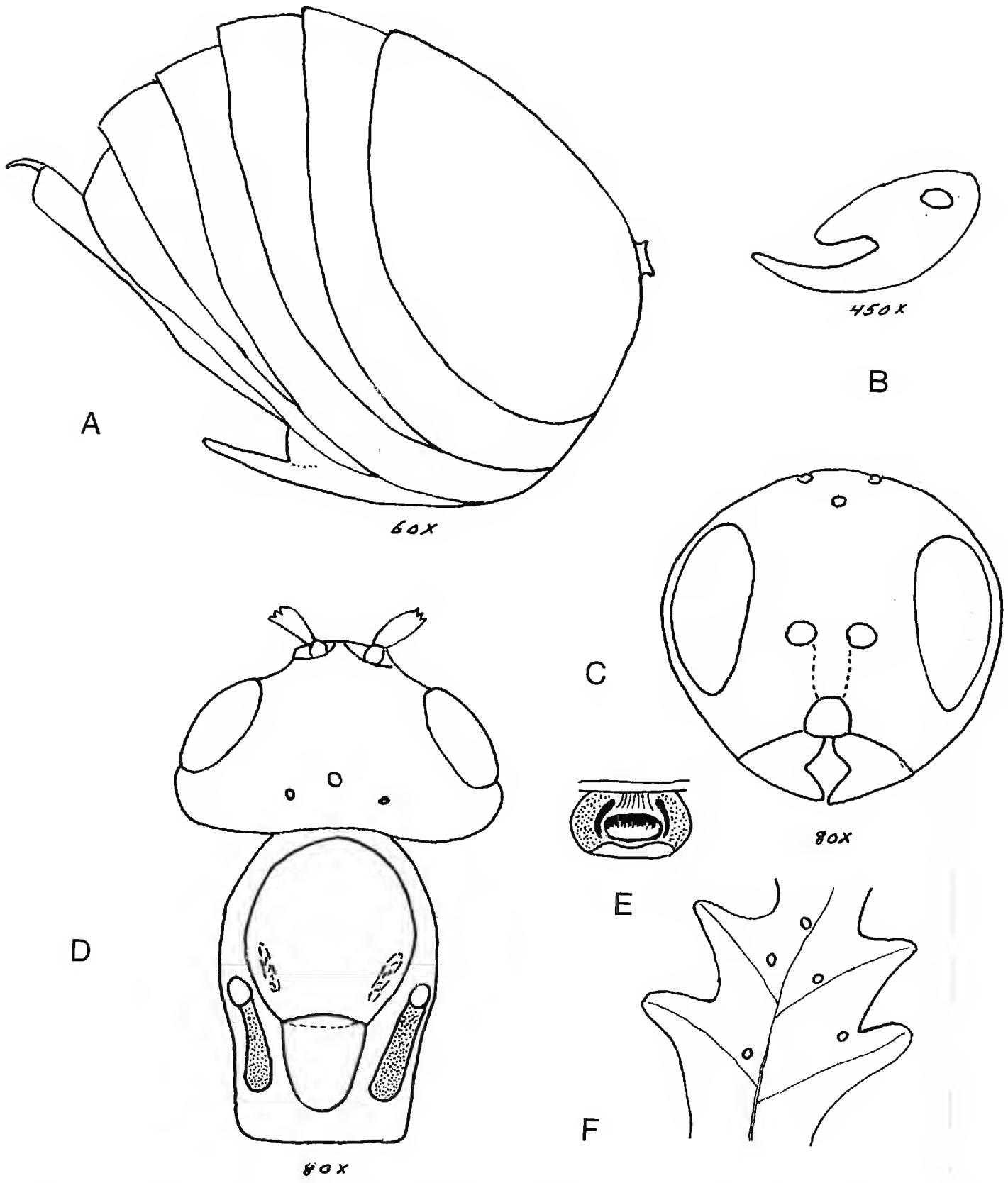

Figure 2. *Phylloteras prinum* NEW SPECIES. A. Metasoma, lateral view, showing shape of terga. B. Tarsal claw with long tooth. C. Outline of head, frontal view. D. Head and mesosoma showing rudimentary wing and lateral depressions on the scutum. E. Monothalamous gall showing position of larval cell. F. Leaf of *Q. prinus* showing distribution of galls.

Larval Development.—The insects were in the larval stage September 1946, but adults did not emerge until 22 Jan 1948.

Diagnosis.—See Key.
Host.—*Quercus prinus* L.
Etymology.—This species is named after its host oak.

Material Examined.—Type series.

KEY TO SPECIES OF *PHYLLOTERAS*

1. Wings[1] extending at least to middle of scutellum 2
– Wings represented only by small pads 5
2(1). Wings reaching to metasoma; scutum 3× length of scutellum; scutum anteriorly deeply and conspicuously punctate. Small (3.5 mm) cylindrical galls on underside of leaf of *Quercus macrocarpa* Michaux (Kansas) ..... *P. volutellae* (Ashmead)
– Wings not reaching beyond scutellum; scutum less than 3× length of scutum; scutum punctate or smooth 3
3(2). Tarsal claws[2] with short tooth (Fig. 1B); scutum smooth, without traces of notauli or lateral grooves. Small (3.5 mm) cylindrical galls on undersides of leaves of *Quercus lyrata* (Arkansas) ..... *P. lyratum* Lyon
– Tarsal claws with long tooth (Fig. 2B); scutum with traces of notauli and/or with lateral grooves 4
4(3). Scutum punctate anteriorly, faint notauli visible near center; scutellum punctate. Small (3.5 mm) depressed, spherical galls on underside of leaves of *Quercus alba* L. (Virginia) ..... *P. nigrum* (Fitch)
– Scutum and scutellum smooth, impunctate; no trace of notauli, but grooved laterally (Fig. 2D). Small (4.5 mm) circular spangles on the underside of leaves of *Quercus prinus* L. (Virginia) ....*P. prinum* Lyon
5(1). Tarsal claw with long tooth; scutellum narrow in front, angled on sides and wider behind, with 2 small foveae at base. Depressed, spherical galls (2–3 mm) on underside of leaves of *Quercus alba* (Illinois, Missouri, New York and Virginia). ..... *P. rubinum* Gillette
– Tarsal claw with short tooth; scutellum not as above 6
6(5). Mesonotum as long as broad, from above, circular in outline; scutellum equal in length to scutum; scutum smooth, without traces of notauli. Small (2.6 mm) cup spangles on underside of leaves of *Quercus arizonica, Q. grisea* and *Q. undulata* (Arizona and New Mexico) ..... *P. cupella* Weld
– Mesonotum longer than broad, not circular in outline; scutellum less than 0.5× length of scutum 7
7(6). Scutum 3× length of scutellum; scutum and scutellum smooth, impunctate; head outline triangular in frontal view. Sigmoid-shaped galls on underside of leaves of *Quercus alba* L. (Maryland, New York, Virginia and District of Columbia ..... *P. sigma* Weld
– Scutum 2.5× length of scutellum; scutum and scutellum punctate; head oval in frontal view. Button-shaped spangles on underside of leaves of *Q. alba, Q. prinus* and *Q. prinoides* (Connecticut, Indiana, Kansas, Maryland, Missouri, New York, Virginia and District of Columbia) ..... *P. poculum* (Osten Sacken)

[1] Presence of rudimentary wings may be difficult to see because the wings are usually stuck to the body or encased in membrane.

[2] Tarsal claw traits should be determined with a compound microscope at 350–450×.

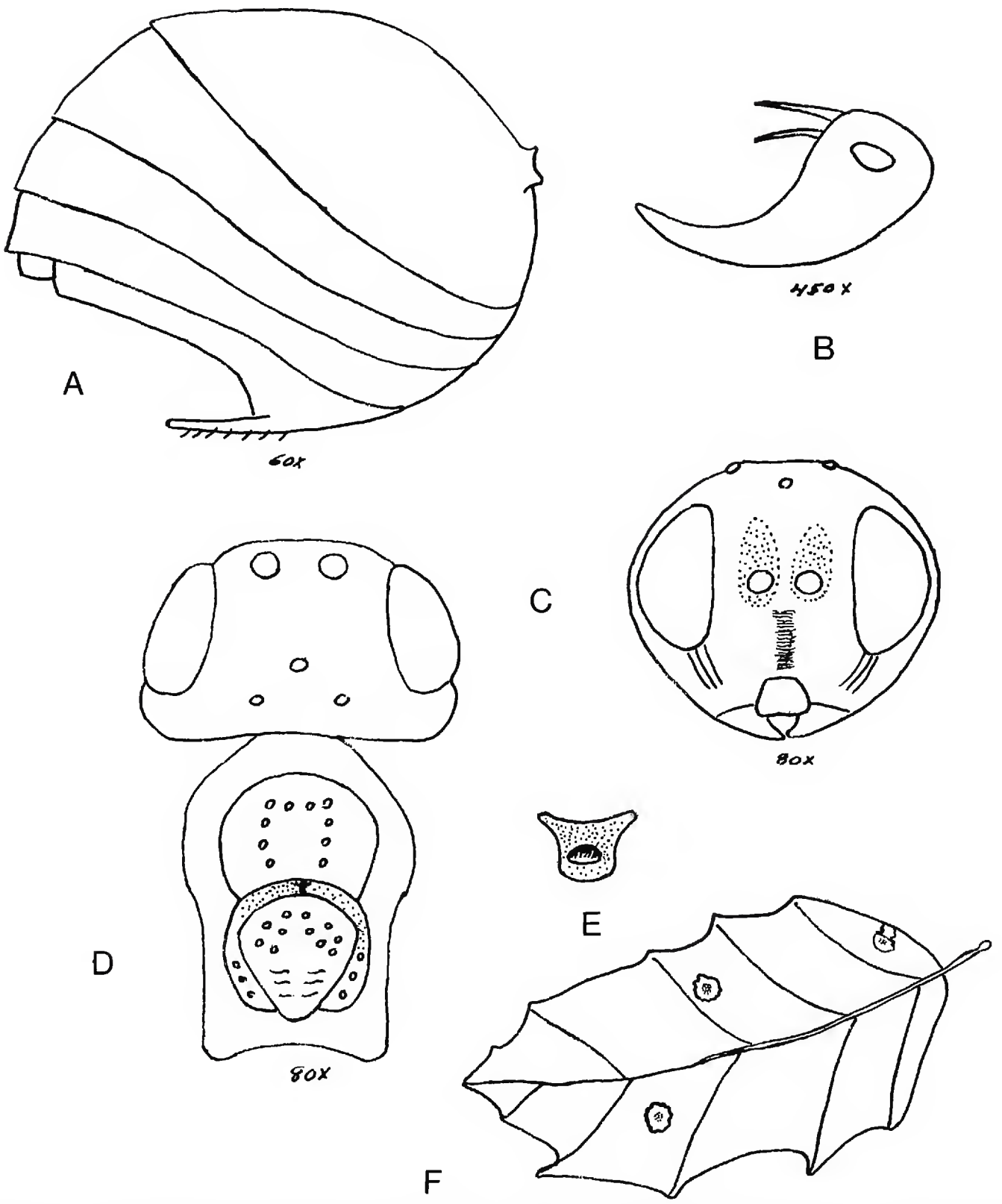

Figure 3. *Euxystoteras campanulatum* NEW SPECIES. A. Metasoma, lateral view, showing shape of terga. B. Simple (edentate) tarsal claw. C. Head, frontal view. D. Head and mesosoma showing punctate scutum and distinctive scutellar shape. E. Monothalamous gall, showing position of larval cell. F. Leaf of *Q. pungens* showing distribution of galls.

Euxystoteras NEW GENUS

Type-Species.—*Euxystoteras campanulatum* Lyon NEW SPECIES

Description.—Generally similar to *Phylloteras* and *Zopheroterus* Ashmead 1897(b), except: tarsal claws simple; lacking knob-like scutellar process; distinct malar groove absent.

Diagnosis.—*Euxystoteras* is separable from *Phylloteras* by its simple tarsal claws. It is separable from *Zopheroterus* by its lack of a knobbed scutellum and a distinct malar groove.

Material Examined.—See *Euxystoteras campanulatum* NEW SPECIES.

Euxystotera campanulatum Lyon NEW SPECIES

Types.—Holotype female. Paratypes: 19 females, TEXAS. *EL PASO Co.:* Franklin Mountains, El Paso, emerged from galls 21 Oct 1972. Holotype and 4 paratypes in the collection of the U.S. National Museum of Natural History, Washington, D.C. Four paratypes each in collections of the California Academy of Sciences and the Natural History Museum of Los Angeles County.

Description.—Unisexual female (Fig. 3). Wingless, ant-like, black, except dark brown legs; head massive (Fig. 3D), more than 0.5× as long as broad, broader than mesosoma; gena broadened behind eyes (Fig. 3C); interocular area 2× as wide as high and coriaceous; face sculptured, with numerous white bristles; two short convergent ridges extending from antennal sockets toward clypeus; malar space 0.5× length of eye, striate and with traces of furrow; antennae with 13 or 14 segments; scutum flattened (Fig. 3D), wider than long, with scattered bristles; notauli represented by several punctures; scutellum arrow-head shaped, separated from scutum by 2 comma-like curving pits extending toward median; bluntly pointed apex with sculptured ridges. Metasoma (Fig. 3A) higher than long, longer than head and mesosoma combined, all terga visible along dorsal curvature. Ventral spine slender, bare. Tarsal claws simple (Fig. 3B). Length 1.1–1.8 mm ($\bar{x}$ = 1.55 mm; n = 20).

Gall.—(Figs. 3E, 3F) Small, campanulate cup, 5 mm diameter, 3 mm high; on lateral veins of upper and lower leaf surfaces. Monothalamous, larval cell occupying base. Appear in late summer as tiny, purple spangles that grow rapidly to reach maturity in October; mature galls red-brown; adults emerged 21 October.

Diagnosis.—This is the only species in the genus.

Host.—*Quercus pungens* Liebmann, an unusual little shrub oak that grows at elevations of 3500–6000 ft on limestone cliffs of mountains at scattered locations in Arizona, New Mexico and Texas. No cynipids or galls have previously been described from this oak. Lewis Weld, in his field notes, made frequent reference to it as a host oak; however, in later years, he (Weld 1960) indicated that he misidentified the oak and that his "*Quercus pungens*" was actually *Q. turbinella* Greene. A number of years ago, John Tucker, of the University of California at Davis, located specimens of this oak in the Franklin Mountains at El Paso, Texas, and indicated that an excellent opportunity to study the cynipid fauna existed. I have made periodic visits to these montains since 1964 and have found that the oaks were abundantly "galled" with both described and undescribed species.

Material Examined.—Type series.

Acknowledgments

I thank John M. Tucker (University of California, Davis, California) for his help in locating and identifying specimens of the oak *Quercus pungens*; Arnold Menke of the U.S. National Museum of Natural History, Washington, D.C. for providing the type of *Xystoteras volutellae* and for helpful assistance with the taxonomy; Roy Snelling, Los Angeles County Museum of Natural History) for constructive comments during the writing of this paper.

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EFFECTS OF INCORPORATING CHEMICAL LIGHT SOURCES IN CDC TRAPS: DIFFERENCES IN THE CAPTURE RATES OF NEOTROPICAL *CULEX, ANOPHELES* AND *URANOTAENIA* (DIPTERA: CULICIDAE)[1]

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Abstract.—Differential attraction of mosquitoes to chemical and incandescent light sources was compared using battery operated suction traps placed in a tropical lowland forest. Females of *Culex adamesi* Sirivanakarn, *Cx. amazonensis* (Lutz), *Cx. corniger* Theobald, *Cx. declarator* Dyar & Knab, *Anopheles mattogrossensis* Lutz & Neiva, *Aediomyia squamipennis* (Lynch), *Mansonia amazonensis* (Theobald), *Uranotaenia apicalis* Theobald, and *Ur. geometrica* Theobald were significantly attracted to chemically produced light. Light sources influenced the number of species attracted, the time (trap-nights) necessary to detect them, and the numbers of specimens collected per species.

Key Words.—Insecta, *Aediomyia,* light traps, mosquitoes, *Mansonia,* phototaxis

Data from light traps are subject to several systematic errors, or biases, which can complicate the interpretation of mosquito surveys. An important source of bias is the unequal phototactic responses of mosquitoes to different wavelengths and intensities of light. Because species do not respond alike, light trap collections may not approximate true species' abundances proportional to one another in nature, let alone their relative attraction to man (Huffaker & Back 1943). This can undermine the purpose of mosquito collections and affect survey time and labor costs.

Although phototactic responses present pitfalls in data interpretation, they do offer valuable opportunities to improve sampling regimes. Whether the intent is to capture many species of a fauna or many individuals of one species, judicious selection of an attractant can increase capture rates and shorten survey time.

The present study reintroduces a neglected method for quantifying losses and gains in efficiency produced by light trap attractants (Gaufin et al. 1956). In the process, some useful but seldom employed analysis techniques are examined for their value in pilot studies. Chemical light sticks are used as attractants, because a variety of them have recently become available commercially, and their portability may soon bring them into popular entomological use.

[1] The opinions and assertions contained herein are the private ones of the authors and are not to be construed as official or as reflecting the views of the U.S. Department of the Navy or of the naval service at large.

Methods and Materials

Testing Response to Light.—Data for testing responses were collected in a Latin square design of CDC light traps. Trap sites were located 20–50 m apart along the forest perimeter of the grounds of the Naval Hospital in Iquitos, Loreto Department, Peru. Treatments were five chemical light sticks (yellow, green, blue, white, and red; Cyalume®, American Cyanamid Company, One Cyanamid Plaza, Wayne, New Jersey 07470), an incandescent bulb (type CM49), and a control (a trap operating without light).

Treatments were assigned randomly to traps. Sticks (one per trap) were secured over the intake vents of CDC-style battery operated downdraft light traps (Model CDC-4; Hausherr's Machine Works, Old Freehold Road, Toms River, New Jersey 08753) from which the light bulbs were removed. Traps remained in place at sites, and sticks were switched each night, until the fauna of each site had been sampled once with each treatment.

The manufacturer's estimates of light duration were 12 hours (yellow, green, and red sticks) and 8 hours (white and blue). Traps were set at 1730 h and emptied at 0900; they ceased emitting blue and white light at 0130, but continued to emit red, green, and yellow until 0530, and incandescent light until 0900. Traps were operated on seven consecutive rainless nights in March 1989.

Female mosquitoes from light collections were identified to species and counted. Counts of common ($n > 40$) species were examined in separate Friedman tests, one test per species. Test hypotheses were, H_0: Treatments attracted equal numbers of females; H_1: At least one treatment attracted more females than at least one other. The Friedman test statistic, T2, was computed according to formulae cited by Conover (1980) to approximate the F distribution. This statistic was then used to calculate the minimum rank sum difference for multiple *a posteriori* comparisons among treatments, as detailed in Conover (1980).

Sampling Efficiency.—The March experiment on light response was replicated in several different sites in the same forest during June, October, and January, using only red, blue, green and yellow as treatments. Efficiency estimates were then derived by analyzing these replicates jointly with data from the March collection (25 sampling nights total). Analysis was based only on species that were present in all four months and had shown significant phototaxis in March testing.

Sampling efficiency was defined as the average rapidity with which species were discovered in the traps. This was inspected graphically by plotting changes in a statistic termed P_k by Gaufin et al. (1956). P_k measured the average probability of collecting a species not collected previously, by each treatment on each successive night. To compute P_k, each treatment was tabulated to reflect a distribution of the number of nights that resulted in capture of each mosquito species (nights/species/treatment). Coefficients $a_{i,k}$ were determined, representing the probability of a species occurring on the k-th night but none previously, given that it occurred in k nights out of $i = 1$ to $n = 25$ nights. These coefficients were multiplied by the probability of the species being found in only k nights out of n; the result was summed across all remaining k. Formally,

$$a_{i,k} = \frac{\mathrm{i} \cdot C_{n-k+1,i}}{(n - k + 1) \cdot C_{n,i}},$$

and

$$P_k = \sum_{i=1}^{n-k+1} a_{i,k} \cdot (S_i/S),$$

where S_i = the number of different species appearing in i out of n samples, and S = the number of species in n. Program source code for these computations is available from the senior author. Computation and rationale has been discussed in detail by Gaufin et al. (1956), who provide a worked example based on a survey of aquatic benthos.

Results

A total of 5749 females was captured by traps during the seven nights of collection in March. More than 36 species were represented, of which 11 were common enough to include in Friedman tests: *Anopheles mattogrossensis* Lutz & Neiva (n = 198), *Aediomyia squamipennis* (Lynch) (n = 195), *Culex adamesi* Sirivanakarn (n = 1497), *Cx. amazonensis* (Lutz) (n = 271), *Cx. corniger* Theobald (n = 93), *Cx. declarator* Dyar & Knab (n = 1137), *Mansonia amazonensis* (Theobald) (n = 47), *Ma. indubitans* Dyar & Shannon (n = 68), *Coquillettidia venezuelensis* (Theobald) (n = 43), *Uranotaenia apicalis* Theobald (n = 54), and *Ur. geometrica* Theobald (n = 72).

Tests on *Ma. indubitans* and *Cq. venezuelensis* revealed no significant differences between control traps and traps incorporating any of the light sources. Captures of the remaining nine species were significantly ($P < 0.05$) higher in lighted traps, with important differences depending on the light employed (Fig. 1).

Red, green, and yellow sticks were not equally attractive to most species. *Anopheles mattogrossensis* and *Ur. apicalis* were more attracted to yellow than to green ($P < 0.05$). Red was unattractive (i.e., indistinguishable from controls) to several species that were attracted ($P < 0.05$) by both yellow and green, including: *Cx. adamesi, Cx. amazonensis, Cx. corniger, Cx. declarator, An. mattogrossensis, Ad. squamipennis,* and *Ma. amazonensis. Uranotaenia apicalis* and *Ur. geometrica* were attracted to yellow, but not to green or red. These capture differences cannot be ascribed to duration of light emission, inasmuch as red, green, and yellow sticks each emitted light for 12 hours per night.

Similarly, blue and white sticks each emitted light for eight h, but *Cx. adamesi* was more attracted by white than by blue.

Incandescent light was the most attractive source for *Ur. apicalis* and *Ur. geometrica* ($P < 0.05$). *Cx. amazonensis* could perceive incandescent light ($P < 0.05$), but was more attracted by chemical light sticks ($P < 0.05$).

Six of the species tested in March (*Cx. adamesi, Cx. amazonensis, Cx. corniger, Cx. declarator, Ad. squamipennis* and *Ma. amazonensis*) were also present in June, October, and January, although in much reduced numbers. The sampling efficiency of light sticks was compared with respect to these six species. In 25 nights of sampling divided among the four months, all six species were detected by yellow sticks in an average of 11 days, by green in 13 days, by blue in 15 days, and by red in 25 days.

Sampling reward (the number of newly detected species) was greatest during the first two nights of trapping with light, indicated by increased slope near the

Aediomyia squamipennis

13	Red
15.5	Control
28	White
30	Blue
35	Incan.
36	Green
38.5	Yellow

Anopheles mattogrossensis

12	Control
22	Red
23.5	White
25.5	Green
33	Blue
37	Incan.
43	Yellow

Culex adamesi

8.5	Control
19	Red
25.5	Blue
30.5	White
37.5	Yellow
37.5	Green
37.5	Incan.

Culex amazonensis

12.5	Control
18.5	Red
27	Incan.
32.5	Blue
32.5	Green
33.5	Yellow
39.5	White

Culex corniger

11.5	Control
20	Blue
21	Red
25	Yellow
29	White
29.5	Green
32	Incan.

Culex declarator

9	Control
14	Red
23	White
28	Blue
36.5	Yellow
38.5	Green
47	Incan.

Mansonia amazonensis

17.5	Control
19.5	Red
25.5	White
26.5	Green
33.5	Incan.
35.5	Blue
38	Yellow

Uranotaenia apicalis

18.5	Control
20.5	White
22.5	Green
25.5	Red
28.5	Blue
33.5	Yellow
47	Incan.

Uranotaenia geometrica

18	Control
22.5	White
24	Green
26.5	Red
29.5	Blue
31	Yellow
44.5	Incan.

Figure 1. Relative attraction of female mosquitoes to chemical and incandescent light sources, ordered by rank sums of the Friedman test. Order is from least (top) to greatest (bottom) attraction. Sums not subtended by the same vertical line differ at $P < 0.05$.

origin of P_k curves (Fig. 2). For example, yellow detected four species in the first two nights of sampling, but took nine additional nights to detect all six species. Blue detected three species in the first two nights, and the remaining three species 13 nights later.

Discussion

A Latin square arrangement is useful in removing two extraneous sources of variation from a desired comparison of treatments (Damon & Harvey 1987). This ability can be particularly effective in controlling the effects of time and place in a pilot study. Both effects are very real in mosquito surveys, due to the habitat preferences of mosquito species, and their fluctuating population sizes over time (Jones et al. 1991, Williams 1951). Actually, three unwanted sources of variation (location, time, and trap effects) commonly occur in mosquito surveys, but location and trap effects are pooled if traps are not moved while sampling. By leaving traps in the same collection stations during our experiments, trap variation

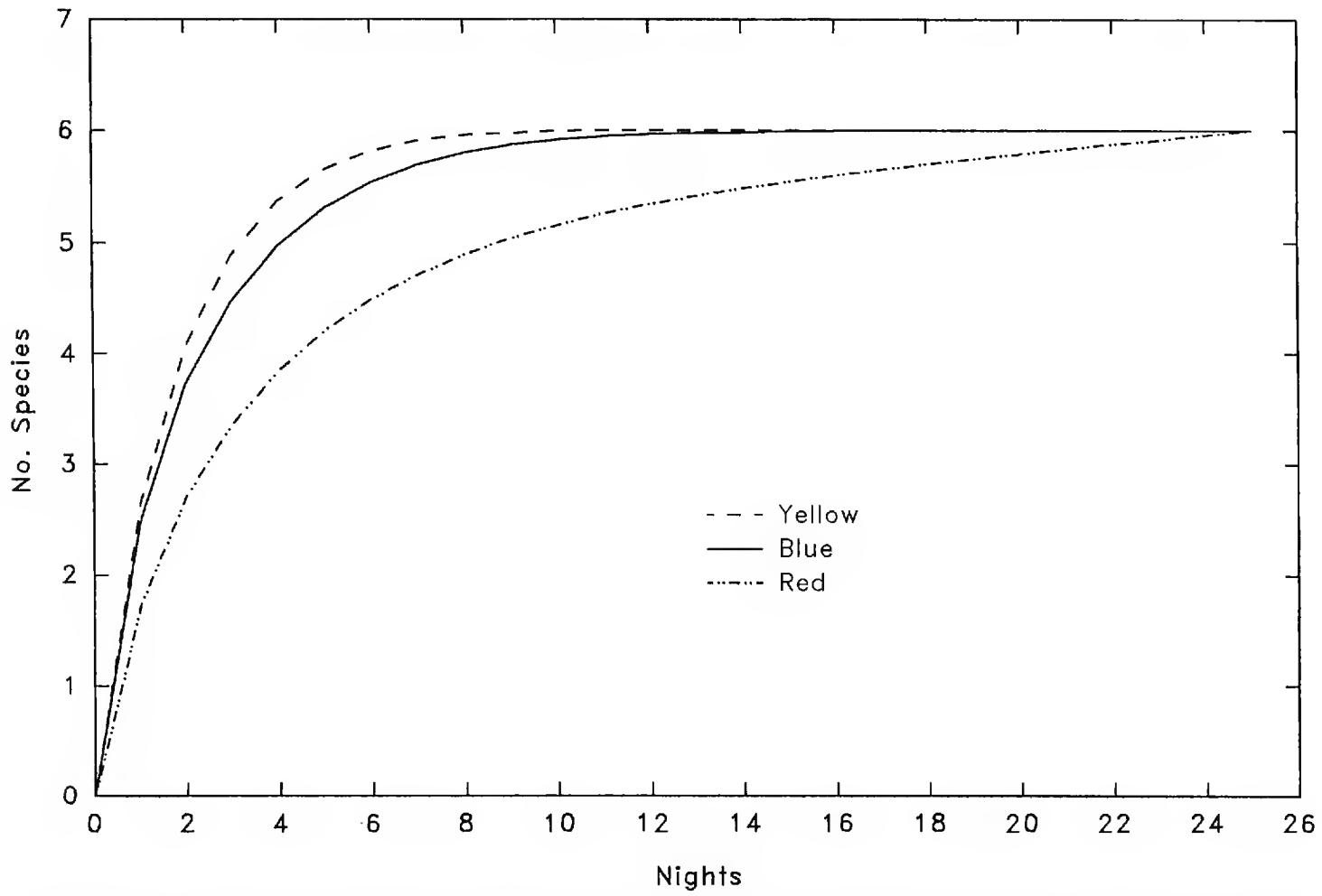

Figure 2. Average time required to detect six mosquito species at light sticks in CDC traps placed near Iquitos, Peru. The curve for green light sticks (not shown) lies very close to yellow.

(motor speed, bag resistance to air flow, etc.) was collapsed onto the location effects (shrubbery, wind, and so forth), and blocked.

An additional use of the Latin square is to subject data to a powerful non-parametric test of significance used for complete block designs, the Friedman test (Friedman 1940). This relatively old test is particularly suited to non-normal sampling distributions such as counts of insects in traps. The recent development of *a posteriori* error rates for it enhances its usefulness. Although the test is commonly used by ecologists, it is rarely employed in insect surveys. Entomologists have instead favored incompletely blocked designs (Belton & Pucat 1967, Holbrook & Bobian 1989, Rowley & Jorgensen 1967, Service & Highton 1980, Service et al. 1983, Slaff et al. 1983, Vavra et al. 1974), or transformed data and analyses based on assumed normality and homoscedasticity (Kline et al. 1991, Williams 1951, Williams et al. 1955). An exception is Anderson & Linhares (1989) in which the Friedman test was used to demonstrate the attractiveness of combined CO_2 and ultraviolet lures for *Culicoides variipennis* (Coquillett).

Friedman *a posteriori* contrasts (Fig. 1) indicate how to survey particular species in the Iquitos study site. For example, *Cx. declarator* and the *Uranotaenia* species should be sampled with an incandescent bulb instead of light sticks. *Cx. adamesi* is attracted to white, yellow, and green sticks, and to incandescent light, but should not be sampled with blue sticks. *Cx. amazonensis* should not be sampled with incandescent bulbs. *An. mattogrossensis* should not be sampled with green or white sticks. Red should not be used for any of the 11 species tested.

The strong performance of incandescent light in most tests may owe to the fact

that incandescent bulbs emit light longer than light sticks. Long duration of light emission is an advantageous quality that extends specimen collection from evening well into the following morning, thereby increasing trap exposure to crepuscular species. Nevertheless, the decision to use incandescent light depends on which species are of interest. For example, incandescent light lasting 15.5 h was definitely less productive in collecting *Cx. amazonensis* than were white sticks that last eight h (Fig. 1).

Because the Friedman test checks the equality of treatments, it is sensitive to the effects of mosquito repellency as well as attraction (positive and negative phototaxis). However, a control can be used to distinguish the two effects. Thus, there was no evidence of mosquito repellency by red or other treatments in the March survey, because the experimental control was never significantly ($P < 0.05$) more productive than any treatment in *a posteriori* comparisons. For the same reason, we cannot conclude that *Ma. indubitans* and *Cq. venezuelensis* were either repelled or attracted by light of any kind.

The generally poor performance of red sticks is noteworthy, as is the failure to capture *Ma. indubitans* and *Cq. venezuelensis* at light. Both observations are important from the practical standpoint of sampling this local fauna. However, we stress that these results should not be generalized to faunas composed of other species, nor to surveys of the same species in other localities. Pilot studies should always be conducted in the locale of interest, before conclusions are drawn.

Sampling efficiency is broadly defined as the cost necessary to obtain an estimate of a desired precision (Freese 1962). The cost can be stated in various currencies to serve specific purposes (Castleberry et al. 1989, Wilkinson & Gregson 1985, Zimmerman & Garris 1985). For mosquito surveys, which incur costs related to the nightly labor of servicing traps, it is intuitively meaningful to express efficiency as the number of trap nights needed to detect a given number of species. Viewed in these terms, the most efficient attractant is that which captures more species in less time than other attractants. It represents the best compromise for sampling a local fauna.

We, therefore, compared the average rapidity with which certain important species were recovered in traps, by a method that translated mosquito capture rates into time cost. It estimated the proportion of the species captured in a large number of nights that would have been detected, on the average, in a smaller number of nights. Under conditions prevailing in the study site during March, June, October, and January, yellow sticks were more efficient than red, blue or green in surveying a fauna composed of *Cx. corniger, Cx. adamesi, Cx. declarator, Cx. amazonensis, Ad. squamipennis,* and *Ma. amazonensis.* The amount of survey time saved by use of yellow to detect all six species ranged from two days (compared to green) to 14 days (compared to red).

Some practical generalizations deserve emphasis in conclusion. First, the advantage in choosing an efficient mosquito attractant is realized in a few initial evenings of use. Most of the species that can be detected are caught rather quickly, in about two nights. Second, chemical light sticks can be more productive than incandescent bulbs in collecting certain species. Finally, the amount of time needed to detect a given number of mosquito species depends upon which light stick is employed.

Acknowledgment

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RECORDS OF CERAMBYCIDS FROM THE MARIANA ISLANDS, MICRONESIA, WITH DESCRIPTION OF A NEW SPECIES OF THE GENUS *SYBRA* (COLEOPTERA: CERAMBYCIDAE: LAMIINAE)

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Abstract.—Eight cerambycid species (Lamiinae) collected at four islands (Saipan, Tinian, Rota and Guam) of the Mariana Islands in December, 1989–1991, are recorded. *Sybra guamensis* NEW SPECIES is described from Guam, and *Sciades* (*Micronesiella*) *boharti* (Gressitt) is newly recorded from Saipan and Rota.

Key Words.—Insecta, Coleoptera, Cerambycidae, Lamiinae, Micronesia, Mariana Islands

Although many reports have been published on the cerambycid fauna of the Bonin Islands, Japan, including biogeographical revisions by Fujita (1976) and Makihara (1987), very few records have been published from the Mariana Islands, which are situated directly south of the Bonin Islands, since Gressitt's (1956) revision of the cerambycid fauna of Micronesia. The fauna of the Mariana Islands is of great interest to Japanese biogeographers because the two island groups form a chain.

I had opportunities to visit and collect cerambycid beetles on four of the Mariana Islands: Guam and Rota, in 1989 December, Saipan and Tinian, in 1990 December, and again Guam in 1991 December.

This paper records the data obtained, as well as the description of a new species belonging to the genus *Sybra* and a note on *Sciades* (*Micronesiella*) spp. All specimens were collected by me, and are included in my collection in Nihon University, except for the holotype and one paratype of the new species, which are deposited in the National Science Museum (Natural History), Tokyo, Japan. The generic and subgeneric status of *Sciades* spp. follows the most recent treatment by Breuning (1977).

PROSOPLUS BANKII (FABR.)

Japanese Name.—Murayama-munekobu-sabi-kamikiri.

Records.—GUAM. Tumon Beach, 23 Dec 1989, 1 female; same locality, 22 Dec 1991, 2 males, 3 females. NORTHERN MARIANA ISLANDS. *TINIAN:* Tinian Shrine, 22 Dec 1990, 1 male. *ROTA:* Tatuga Beach, 21 Dec 1989, 4 males, 2 females.

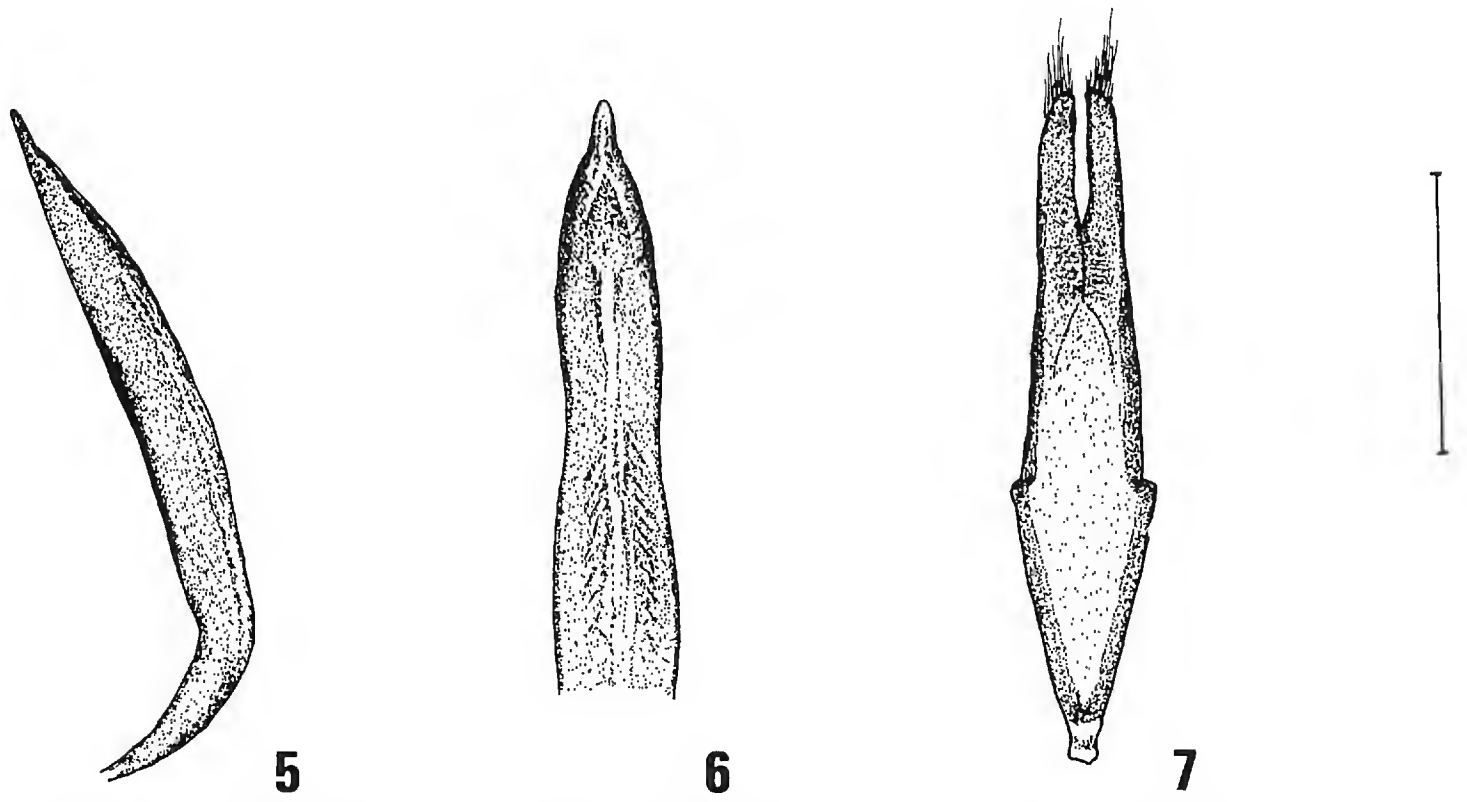
SYBRA (S. STR.) *ALTERNANS* (WIEDEMANN)

Figs. 1, 2, 5, 6, 7

Japanese Name.—Kuro-chibi-kamikiri.

Records.—GUAM. Talofofo Falls, 22 Dec 1989, 1 female; Tumon Beach, 23 Dec 1989, 5 males, 2 females; Fujita Guam Tumon Beach Hotel, Tumon Beach, 23 Dec 1989, 1 female; Tumon Beach, 21 Dec 1991, 2 males, 2 females; same locality, 22 Dec 1991, 15 males, 13 females (Figs. 1, 2).

Figures 1–2. *Sybra* (s. str.) *alternans* (Wiedemann) (scale: 10 mm). Figure 1. Male. Figure 2. Female. Figures 3–4. *Sybra* (s. str.) *guamensis* Iwata (scale: 10 mm). Figure 3. Male (holotype). Figure 4. Female (paratype).



Figures 5–7. Male genital organs of *Sybra alternans* (scale: approximately 1 mm). Figure 5. Median lobe in lateral view. Figure 6. Median lobe in dorsal view. Figure 7. Lateral lobes.

NORTHERN MARIANA ISLANDS. *SAIPAN:* Navy Hill near Garapan, 20 Dec 1990, 1 male; Lourdes Shrine, 21 Dec 1990, 1 male, 3 females.

Sybra (s. str.) *guamensis* Iwata, new species

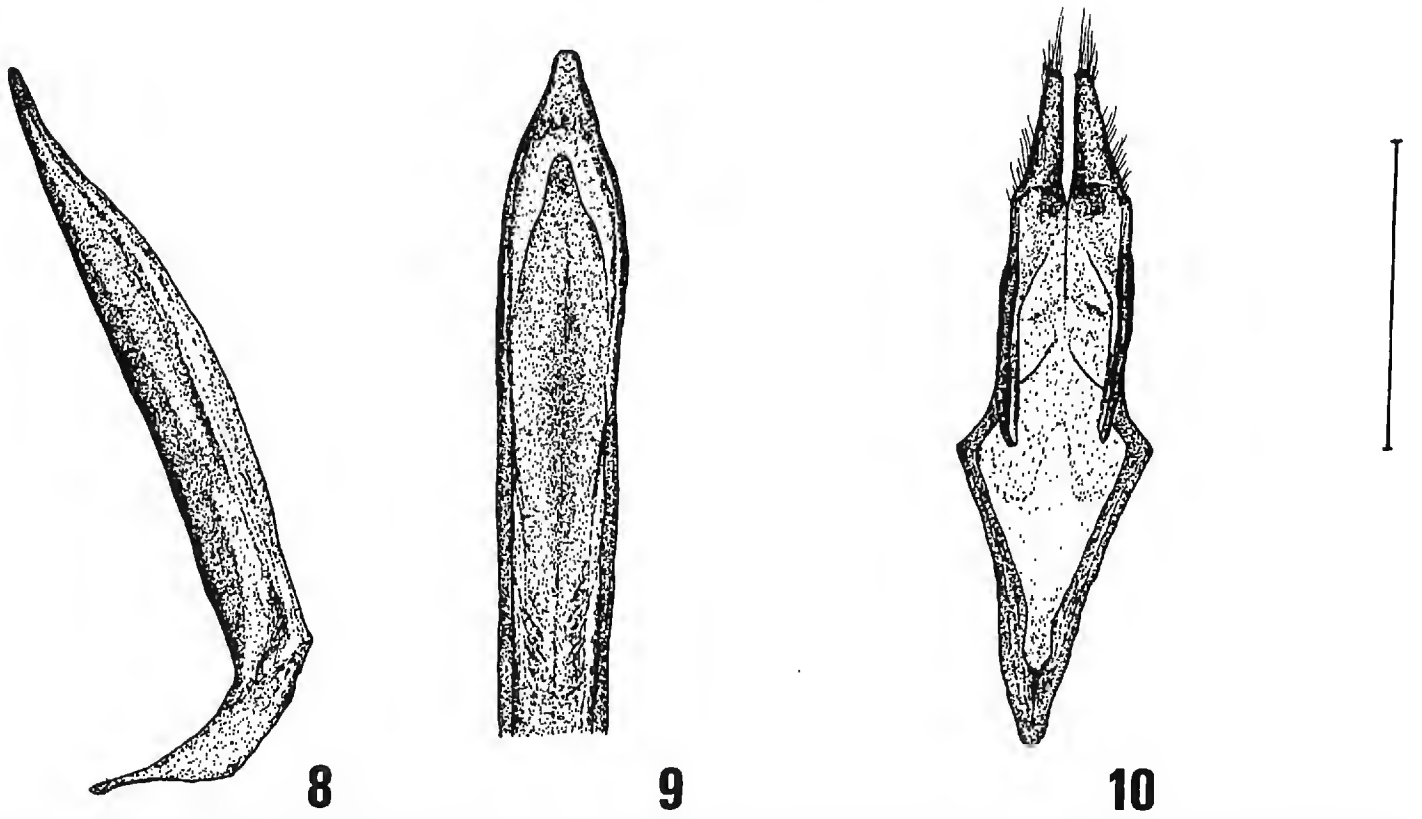
Figs. 3, 4, 8, 9, 10

Types.—Holotype: male (Fig. 3), deposited in National Science Museum (Natural History), Tokyo, Japan, data: GUAM. Tumon Beach, 22 Dec 1991, R. Iwata. Paratypes: 1 female, same locality as holotype, 23 Dec 1989; 2 males, 2 females (Fig. 4), same data as holotype.

Description.—Male. Length: 10.6–10.8 mm. *Color:* head dark brown, densely clothed with fine long red-brown hairs; pronotum dark brown, median area very sparsely clothed with red-brown hairs, sublateral areas with white pubescence, other parts with dense fine red-brown pubescence; scutellum posteriorly clothed with bright red-brown hairs; elytra dark brown, with fine red-brown and white pubescence arranged in alternate longitudinal rows of variable width; sterna pitchy brown, very finely and densely clothed with tawny pubescence; antennae brown to dark brown, with very fine tawny pubescence, apices of segments 4–11 much darker and lacking pubescence; legs brown, with dense long red-brown and white hairs. *Head:* almost as broad as anterior edge of pronotum; frons not punctate, broader than long; vertex punctate; genae approximately 0.7–0.8× as deep as inferior eye-lobes. *Antennae:* approximately 1.3–1.4× as long as body, segments 2–8 inferiorly with suberect setae; scape subfusiform; third segment slightly but distinctly shorter than fourth. *Prothorax:* as broad as or slightly broader than long, distinctly punctate, convex at center. *Elytra:* approximately 2.5× as long as wide, approximately 2.2× as long as head plus prothorax, bearing rather regularly arranged punctures in 9 rows; lateral margins subparallel along anterior two-thirds; apices rotundate-truncate. *Scutellum* linguiform, broader than long. *Legs:* robust; femora markedly swollen; mid- and hind-tibiae apically with row of strong setae. *Genitalia:* with a simple median lobe (Figs. 8, 9), lateral lobes stout, parallel-sided medially (Fig. 10).

Female. Length: 8.8–12.0 mm. *Antennae* approximately 1.1× as long as body. *Pronotum* slightly broader than long. *Elytra* with denser pubescence and alternate rows more distinct.

Diagnosis.—This new species is closely related to, and resembles, *S.* (s. str.) *alternans,* but is distinguishable from it in having: (1) thicker antennae, (2) a non-



Figures 8–10. Male genital organs of *Sybra guamensis* (scale: approximately 1 mm). Figure 8. Median lobe in lateral view. Figure 9. Median lobe in dorsal view. Figure 10. Lateral lobes.

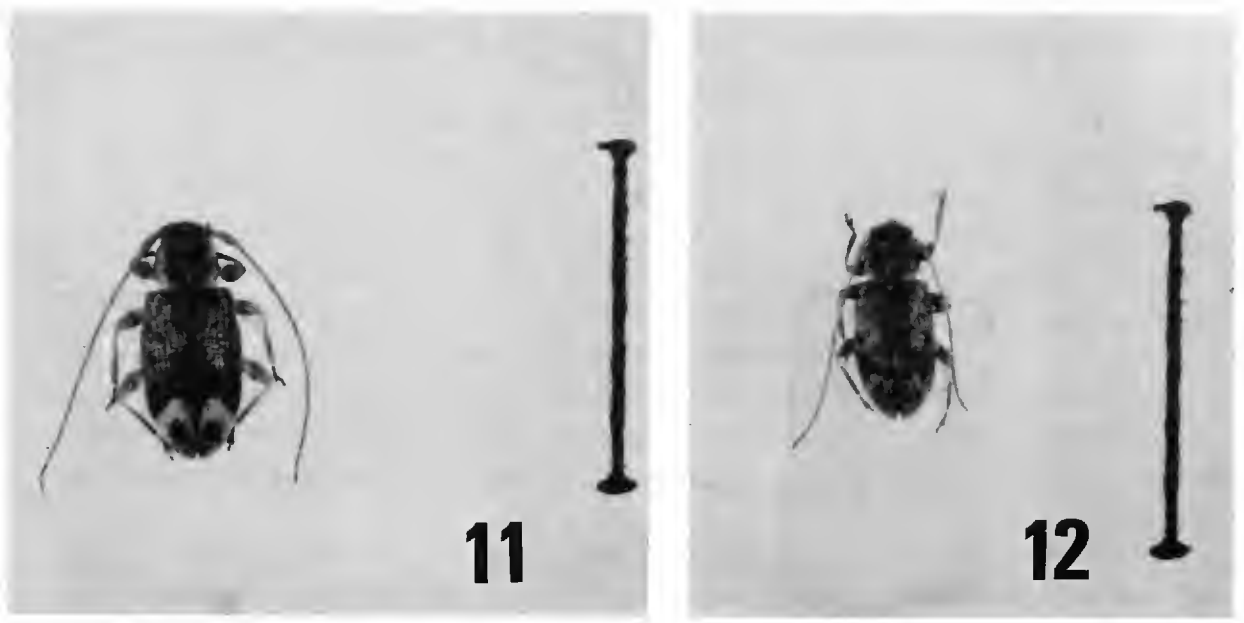
punctate frons, (3) elytra lacking white elongate patches and having blunter apices, and (4) the male genital organ with a blunter apex of median lobe (Figs. 5, 6, 8, 9), as well as with stouter lateral lobes rather parallel-sided medially (Figs. 7, 10).

This species seems also to resemble another species endemic to Guam, *Sybra* (s. str.) *schurmanni* Breuning, but is distinguishable from it, according to its description by Breuning (1983), in having: (1) longer antennae, (2) antenna segment 3 shorter than 4, (3) elytra lacking light-yellow patches, and (4) the apical halves of tibiae lacking dark-brown hairs.

New Japanese Name.—Guamu-chibi-kamikiri.

Distribution.—Guam (USA).

Biological Remarks.—All of the types were captured in a tree grove and bush



Figures 11–12. *Sciades* (*Micronesiella*) spp. (scale: 5 mm). Figure 11. *Sciades* (*M.*) *marianus* (Gressitt), female. Figure 12. *Sciades* (*M.*) *boharti* (Gressitt), female.

that are very near a swimming beach and resort hotels, and it is possible that it is an introduced species. They were captured, together with *S. alternans,* by beating dead branches of broad-leaved trees with dead leaves still attached. It appears that the capture location will be destroyed in the near future, due to the construction of new hotels.

Etymology.—An adjective (female, nominative) from the name of the type locality, Guam.

Material Examined.—See types.

Ropica squamulosa Breuning

New Japanese Name.—Uroko-chibi-sabi-kamikiri.

Records.—GUAM. Tumon Beach, 21 Dec 1991, 1 male; same locality, 22 Dec 1991, 1 male. NORTHERN MARIANA ISLANDS. *SAIPAN:* Navy Hill near Garapan, 20 Dec 1990, 1 male, 6 females; Lourdes Shrine, 21 Dec 1990, 2 males, 5 females. *TINIAN:* Carolinas Heights, 22 Dec 1990, 1 male, 1 female. *ROTA:* Tatuga Beach, 21 Dec 1989, 1 male, 1 female; Teteto Beach, 21 Dec 1989, 1 female.

Pterolophia (s. str.) *bigibbera* (Newman)

Japanese Name.—Sujidaka-sabi-kamikiri.

Records.—GUAM. Tumon Beach, 23 Dec 1989, 4 males, 3 females; same locality, 22 Dec 1991, 2 males, 1 female. NORTHERN MARIANA ISLANDS. *SAIPAN:* Navy Hill near Garapan, 20 Dec 1990, 3 males; Lourdes Shrine, 21 Dec 1990, 1 male. *TINIAN:* Mt. Lasso, 22 Dec 1990, 1 female; Carolinas Heights, 22 Dec 1990, 3 males, 1 female; Tinian Shrine, 22 Dec 1990, 1 female. *ROTA:* Tatuga Beach, 21 Dec 1989, 2 males, 1 female; Teteto Beach, 21 Dec 1989, 1 male.

Sciades (*Micronesiella*) *marianus* (Gressitt)
Fig. 11

New Japanese Name.—Mariana-keshi-kamikiri.

Records.—GUAM. Talofofo, 22 Dec 1989, 1 male, 1 female. NORTHERN MARIANA ISLANDS. *SAIPAN:* Navy Hill near Garapan, 20 Dec 1990, 3 males, 2 females; Lourdes Shrine, 21 Dec 1990, 1 female. *ROTA:* Tatuga Beach, 21 Dec 1989, 6 males, 1 female.

Sciades (*Micronesiella*) *boharti* (Gressitt)
Fig. 12

New Japanese Name.—Bohâto-keshi-kamikiri.

Remarks.—These are new records from both of the islands. This species, as originally described from Agrihan Island in the Marianas, can be distinguished from *S. (M.) marianus* by its shorter antennae and a wider pronotum (Gressitt 1956). However, its status in relation to *S. marianus* is still tentative and it may prove to be a synonym of that species, which is quite variable.

Records.—NORTHERN MARIANA ISLANDS. *SAIPAN:* Navy Hill near Garapan, 20 Dec 1990, 2 females. *ROTA:* Teteto Beach, 21 Dec 1989, 1 female.

Sciades (*Miaenia*) *meridianus* (K. Ohbayashi)

New Japanese Name.—Minami-futatsume-keshi-kamikiri.

Records.—NORTHERN MARIANA ISLANDS. *SAIPAN:* Lourdes Shrine, 21 Dec 1990, 1 male (without distinct elytral markings).

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BIOLOGICAL STUDIES OF *HEMICOELUS GIBBICOLLIS* (LECONTE) (COLEOPTERA: ANOBIIDAE), A SERIOUS STRUCTURAL PEST ALONG THE PACIFIC COAST: ADULT AND EGG STAGES

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Abstract.—The anobiid beetle, *Hemicoelus gibbicollis* (LeConte), is among the most serious structure-infesting insect pests along coastal areas of western North America. Adult beetles are difficult to find due to their small size, cryptic coloration, and sedentary behavior. They readily oviposit in crevices of building timbers that eventually may be damaged sufficiently to require replacement. Females can lay in excess of 100 eggs and egg hatch ranges between 85 and 89%. Pheromones play a key role in mate location. These beetles are primarily found in damp crawl spaces and unheated outbuildings.

Key Words.—Insecta, *Hemicoelus gibbicollis,* structure-infesting, adult, egg, pheromone

Structural damage caused by anobiid beetles in the northwestern United States has only recently come to the attention of concerned individuals. Prior to 1970, structural pest inspections were seldom conducted before home sales (T. Whitworth, personal communication), so many infestations went undetected. During the 1980s home prices dramatically increased and inspections became common. Additionally, energy audits conducted by public utilities prior to home insulation programs revealed many serious infestations. As a result of these inspections the extent of beetle damage became much more apparent.

Hemicoelus gibbicollis (LeConte) is the most widespread and damaging anobiid in coastal areas of Washington, Oregon, California, and British Columbia (Suomi 1992). Despite the damage caused by this insect, its biology has remained unrecorded (Furniss & Carolin 1977). A project was begun in 1987 to document the biology and management options of the most damaging anobiids in Washington and adjacent areas. This, and a subsequent paper (Suomi & Akre in press), will describe the life stages, biology, and behavior of *H. gibbicollis.*

Anobiids are difficult to study, and the biologies of only a few species have been documented. The furniture beetle, *Anobium punctatum* (De Geer), is probably the best known wood-infesting anobiid. This insect is the most serious wood-destroying pest throughout England and much of northern Europe, far surpassing termites or any other group of insects (Hickin 1975). Studies conducted by various researchers (Becker 1940; Spiller 1948; Bletchly 1952; Hickin 1953, 1960, 1981; Fisher 1958; Berry 1976) reported most of our knowledge regarding this species. The deathwatch beetle, *Xestobium rufovillosum* (De Geer), caused damage to several wooden landmarks in England and the United States that led Fisher (1937, 1938, 1940, 1941) to document its habits. Moore (1968, 1970), Williams (1977, 1983), and Williams & Mauldin (1974, 1981) studied another structure-infesting anobiid, *Euvrilletta peltata* (Harris), and reported on life cycle, wood species

infested, and management options. Little information on other wood-infesting anobiids exists because of; 1) long life cycles, often in excess of 5 years, 2) difficulty in rearing, and 3) small size and sedentary behavior of the adults.

Materials and Methods

Wood Collection and Storage.—Subflooring and support timbers, primarily Douglas-fir, *Pseudotsuga menziesii* (Mirbel), infested with *H. gibbicollis* larvae were collected from western Washington and Oregon homes and outbuildings during June, July, and August, 1987 to 1991. This wood was transported to the laboratory at Washington State University in sealed containers to maintain moisture content at the higher levels found in coastal areas. A concrete blockhouse (4 m by 1 m by 1 m and covered with 6 mil black polyethylene) was constructed in a shaded location to retain infested timbers until they could be cut into smaller pieces, approximately 30 cm long. These pieces were kept in covered, darkened boxes measuring 38 cm by 28 cm by 15 cm with 1 cm plaster of Paris/charcoal as a substrate to maintain wood moisture between 14 and 17%. Ventilation was provided through two screen-covered holes (35 mm diameter) in the top cover. Wood moisture readings were taken with a Delmhorst Model RC-1C Moisture Meter (Delmhorst Instrument Company, Boonton, New Jersey). An environmental growth chamber was used to maintain conditions at 65 ± 3% RH and 18 ± 1° C. These conditions are commonly found in crawl spaces under buildings in western Washington. Daily observations were made, and upon emergence adult beetles were collected, measured, sexed, and individually stored in gauze-covered glass vials until tested.

Oviposition Chambers.—Bottoms of clear, polystyrene insect diet cups (4 cm tall by 4 cm diameter) were removed and replaced with plastic mesh glued in place. One layer of muslin cloth was attached to a 9 cm by 9 cm by 2 cm wood block top surface to permit oviposition. A male and female beetle were released in each cup which was then inverted and positioned in the center of the block. Test blocks were kept in separate enclosures, and egg counts were made after 30 days. Relative humidity was recorded with a thermohygrometer (Model 8564, Hanna Instrument Company, Chicago, Illinois) and maintained at two levels with saturated salt solutions (Winston & Bates 1960); 75 ± 1% with sodium chloride and 85 ± 1% with potassium chloride (Sigma Chemical Company, St. Louis, Missouri). Relative humidities below 50% and at 65 ± 3% were maintained in laboratory incubators.

Pheromone Tests.—A modified 9 cm plastic petri dish served as the test arena (Suomi et al. 1986). Ovipositors were dissected from ten newly-emerged *H. gibbicollis,* ground in 3 ml methylene chloride, and the extract filtered. Filter paper, 0.5 cm^2, was immersed in this solution and allowed to air dry. Control filter paper squares were immersed in methylene chloride alone. In the arena a filter paper square was placed at each 90 degree interval with test and control squares alternating, for a total of 4 squares. Stegobiol (Fuji Flavor Co., Ltd., Tokyo, Japan), a commercially available attractant for the drugstore beetle, *Stegobium paniceum* (L.), was tested in a similar manner. Pheromone packets were placed at opposing locations within the arena; empty packets served as controls. Three male *H. gibbicollis* were released in the arena center and their movements monitored under red-filtered light. Five replicates were conducted for each material.

Figure 1. Lateral view, male *H. gibbicollis* (×30).

Scanning Electron Microscopy.—The external morphology of male and female *H. gibbicollis* was examined with a scanning electron microscope (SEM; Hitachi S570) at 20 kV. Dried specimens were placed on cardboard points, then mounted on stubs and coated with 30 nm of gold using a Technics Hummer Sputter Coater V. Antennae were removed from 11 beetles (6 males and 5 females), mounted, and individually gold-coated for increased clarity.

Results and Discussion

Adults.—*Hemicoelus gibbicollis* adults are small beetles. Males range in size from 2.5–5.1 mm, (n = 165, $\bar{x}$ = 3.4 mm), and females range from 3.5–6.0 mm (n = 95, $\bar{x}$ = 4.9 mm). They are light to chocolate brown, occasionally red or dark brown. The eyes of the male tend to be larger than those of the female (Figs. 1, 2). A more reliable character for differentiating between sexes is a semicircular depression in the last abdominal sternum, clearly present in males (Figs. 3, 4). *Hemicoelus gibbicollis* can be separated from most anobiid species in the Pacific Northwest by a pointed, thoracic dorsum (Figs. 1, 2). LeConte's (1859) original description is from a specimen collected at Point Reyes, near San Francisco, California.

Emergence.—Adults emerge any time during the day or night. Both sexes chew a circular exit hole approximately 1.5 mm in diameter. Small amounts of frass are evident during this procedure. Eight adult emergences were witnessed, the shortest was 25 min, the longest 18 h. Upon emergence both males and females moved rapidly on the wood surface. If overturned, the beetles used their wings to right themselves, but despite being probed with objects, were not driven to flight. Several authors (Linsley 1943, Mampe 1982) reported that anobiid adults

Figure 2. Lateral view, female *H. gibbicollis* (×45).

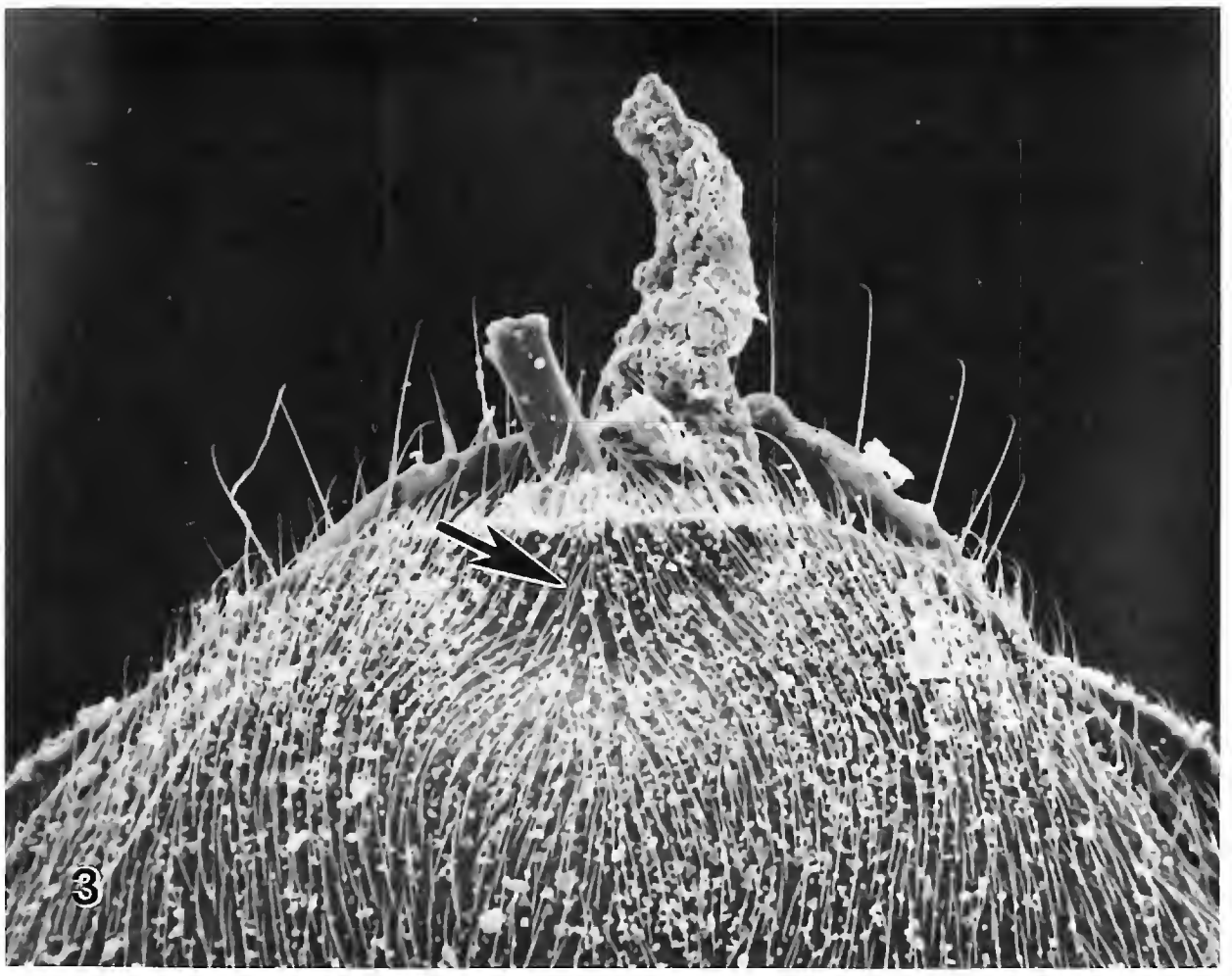

Figure 3. Terminal abdominal sternum, male *H. gibbicollis* (×150).

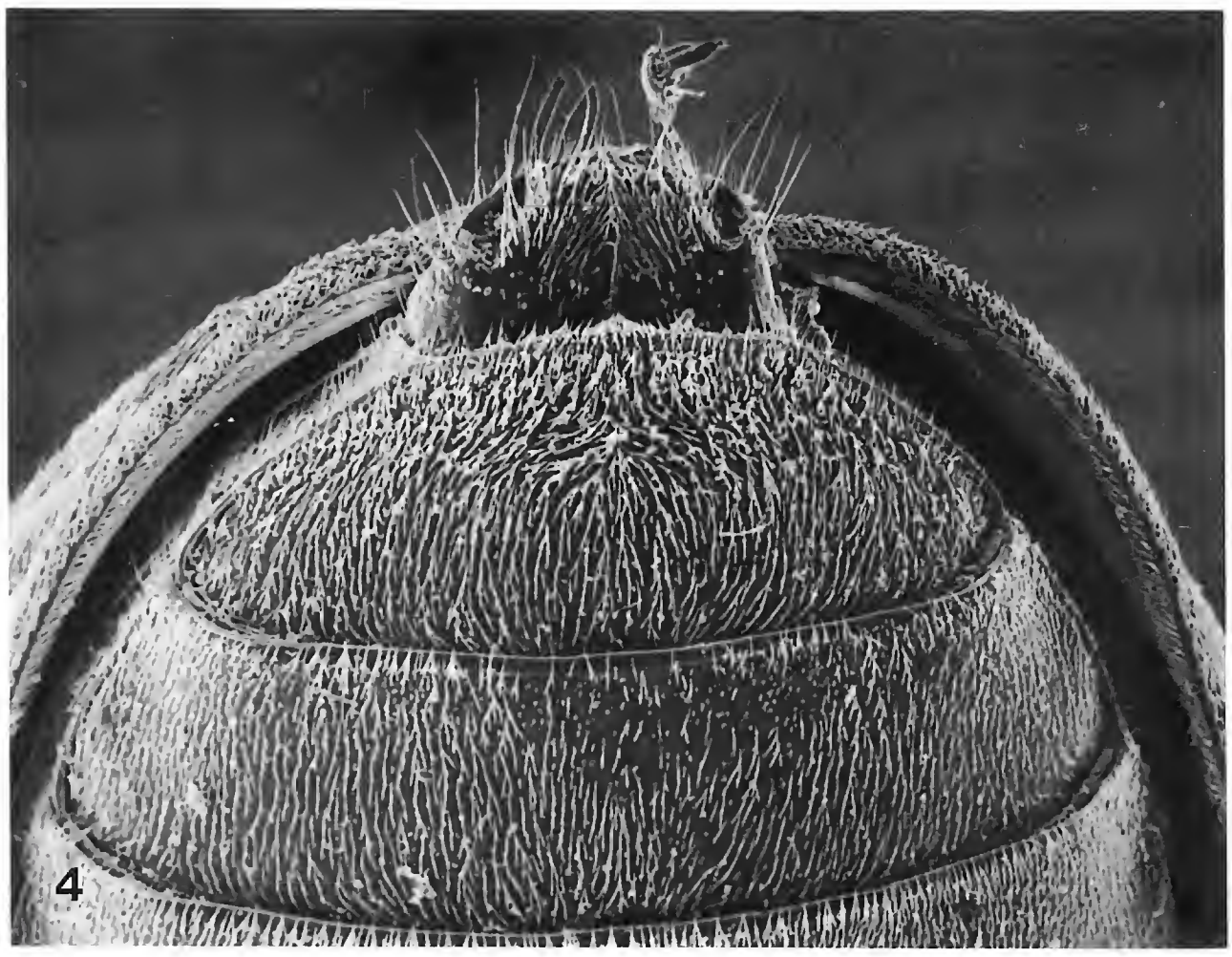

Figure 4. Terminal abdominal sternum, female *H. gibbicollis* (×60).

were attracted to lighted windows and when found in spider webs, one could assess the amount of beetle activity in the structure. During this research only a single male was observed flying toward a florescent light in the laboratory. Keen (1895) stated that *H. gibbicollis* could be captured in flight, but that it was a rare occurrence.

Kelsey et al. (1945) noted a "swarming" phenomenon where 167 male and 3 female *A. punctatum* were found at the same site on a timber. We observed similar behavior on three separate occasions but with smaller numbers of insects (< 20, both sexes). Following this event the wood from which these insects emerged produced very few adult beetles the following year. Pheromones may mediate this coordinated emergence.

In general, anobiid beetles are rarely collected in good numbers (White 1969). Although a building can be seriously infested, *H. gibbicollis* adults are difficult to locate. Both males and females remained motionless on the surface unless engaged in reproductive behavior. Females had a greater tendency to withdraw into emergence holes. When disturbed, males and females feigned death by drawing the appendages close to the body and remained motionless for several minutes. In the laboratory, beetle activity increased between 18:00 and 03:00 h, but adults were seen copulating or ovipositing at various times during the day. After these activities ceased, both males and females returned to a sheltered location, usually an old emergence hole, where they eventually died. Seven male and eight female beetles were closely observed to document longevity (Table 1).

Each year more males than females were collected during laboratory emergences (Table 2). Searching behavior by males may result in increased exposure and greater numbers recorded. Males attempted to copulate immediately upon emer-

Table 1. Longevity of male and female *H. gibbicollis* adults.

Female No.	No. days surviving	Male No.	No. days surviving
1	35	1	17
2	26	2	31
3	30	3	28
4	12	4	27
5	29	5	5
6	19	6	24
7	20	7	13
8	22		
	$\bar{x} = 24.13 \pm 2.59$[a]		$\bar{x} = 20.71 \pm 3.55$[a]

[a] Means ± SEM followed by the same letter do not differ significantly ($P = 0.05$) based on t-tests (SAS Institute 1985).

gence, but female beetles required 24–36 h before successful copulation occurred. Upon emergence, females located a crack or depression where they remained prior to mating. Generally, males did not attempt to mate with females found in these locations.

Chemical Communication.—Female *H. gibbicollis* exhibited a calling behavior similar to that observed in other anobiids (Cymorek 1960). The abdomen was raised 45 degrees to the substrate, and the ovipositor tip then everted. A female remained in this position for approximately 15 sec, then returned to a horizontal position for about 30 sec. This behavior was repeated six to eight times, or until a male appeared. A male within 20 cm of the female immediately responded and approached, antennated her head area for 3–4 sec, circled, and mounted from behind. The male then rotated 180 degrees and both beetles remained motionless. Nine observed matings took place under either fluorescent or red-filtered light. Duration of the copulatory period averaged 65.4 min (range = 44–133 min).

In petri dish arenas ($n = 5$ replicates), male *H. gibbicollis* were immediately attracted to filter paper treated with female ovipositor extract. Males antennated the paper 3–4 sec, then remained motionless adjacent to the paper. After 10–15 min, the males moved to the periphery of the arena and ceased movement. On one occasion a male that contacted treated filter paper was pursued by another in an attempt at copulation. This continued for several minutes until the pursuing male lost interest. Beetles did not respond to filter paper controls.

Table 2. Number of male and female *H. gibbicollis* adults emerged from samples during 1987–1991, eastern Washington.

Year	No. males	No. females
1987	70	65
1988	91	86
1989	132	85
1990	186	108
1991	53	52
	$\bar{x} = 106.40 \pm 23.88$[a]	$\bar{x} = 79.20 \pm 9.62$[a]

[a] Means ± SEM followed by the same letter do not differ significantly ($P = 0.05$) based on t-tests (SAS Institute 1985).

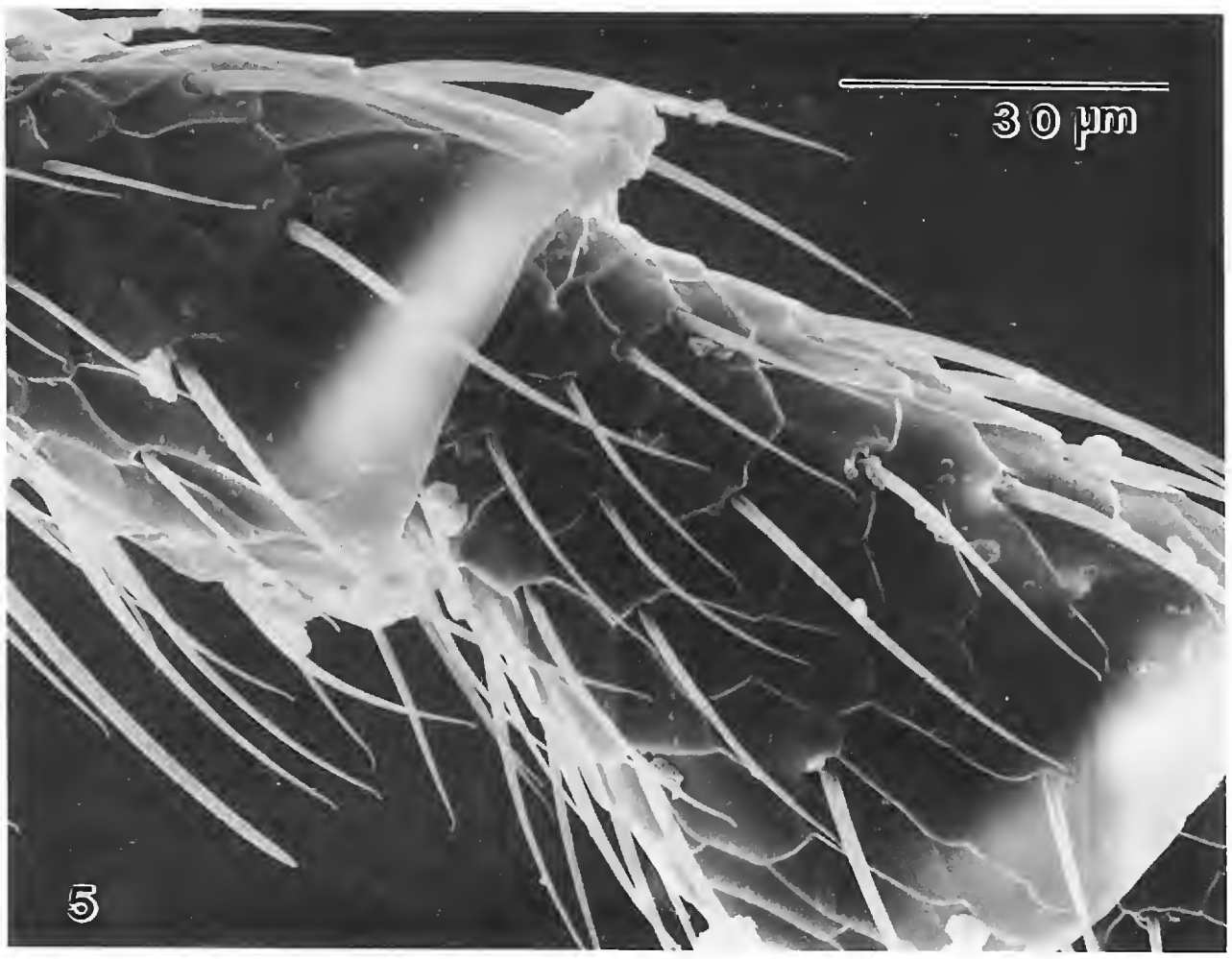

Figure 5. *Hemicoelus gibbicollis* antennal segments 5 and 6 (×1000).

Observations were made of six male and five female *H. gibbicollis* adult antennae to determine if sensory structures were present for sex pheromone reception. Unlike most species that use attractant pheromones (Payne 1974), there is no marked sexual dimorphism of antennal size or shape in this species. All antennal segments of males and females (Fig. 5) are covered with hairs which may be sensory in nature, but these are not thought to be pheromone receptors (Chapman 1982). In species using chemicals as sex attractants, one type of sensory device, the sensilla trichodea, is responsible for sex pheromone perception. These sense receptors were found in greater numbers on male antennae. A presumed olfactory sensillum (Figs. 6, 7) is present which is similar to those seen in the bedbug, *Cimex lectularius* L. (Levinson et al. 1974). Male beetles had, on average, twice as many of these structures on antennal segments 9–11 than did females. Numbers of sensillae were relatively low (approximately 12 in males) which may indicate that large amounts of pheromone are released by the female.

In studies conducted on insects relying on chemoreceptors to detect sex pheromones, openings or pores in the integument were often found in large numbers (Steinbrecht 1987). These pores are thought to allow passage of odor molecules while preventing water loss (Fig. 8). Male *H. gibbicollis* beetles had approximately 50% more of these pores on antennal segments 9–11 than were present on female antennae.

A sex pheromone, stegobiol, has been isolated from *S. paniceum* and is available for use in pheromone traps (Fuji Traps, Tama Trading Co., Ltd., Tokyo, Japan). This compound was discovered (White & Birch 1987) to be structurally identical to the mating pheromone produced by female *A. punctatum.* In laboratory arenas

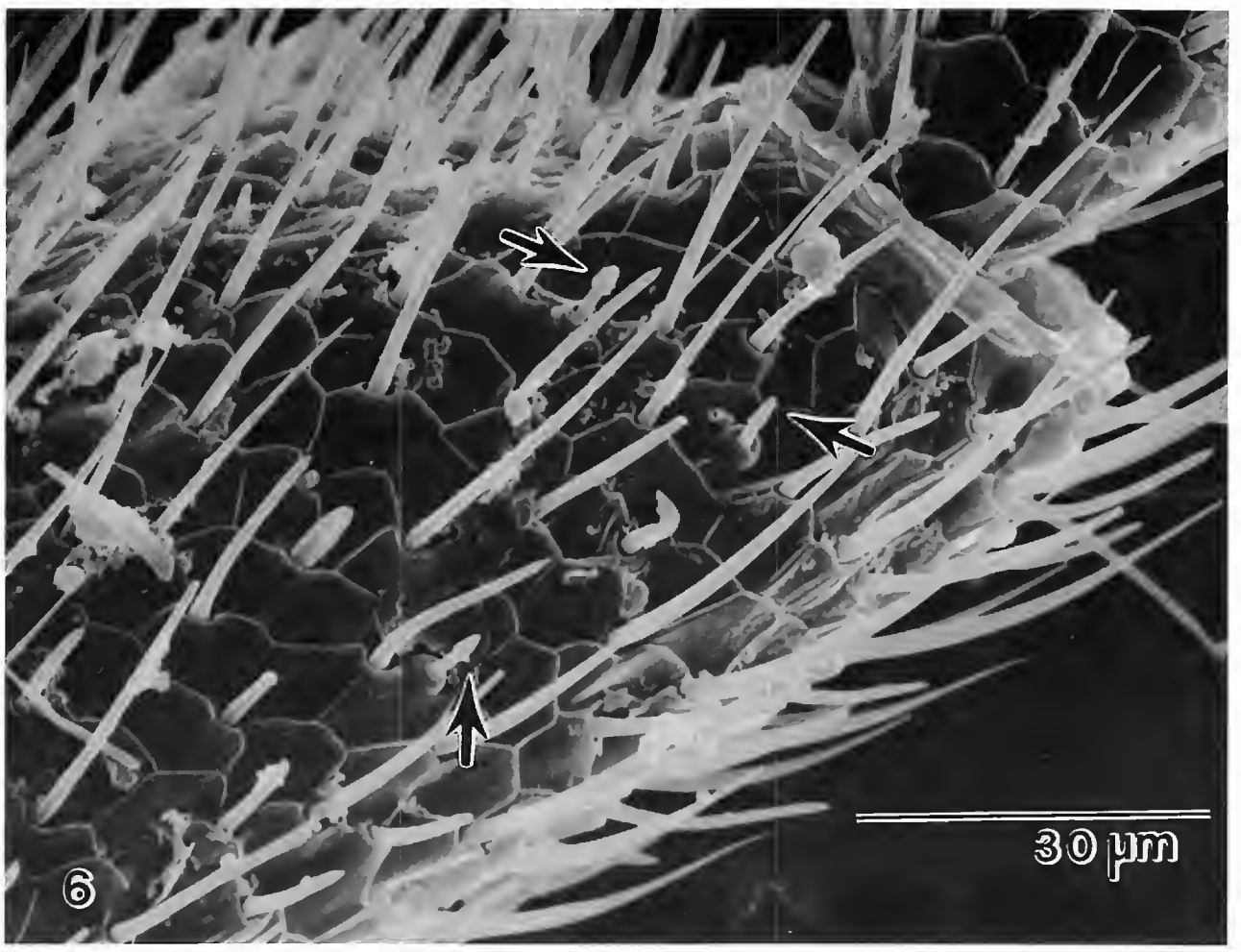

Figure 6. Male *H. gibbicollis* antennal segment 10; note presumed sensilla (×1000).

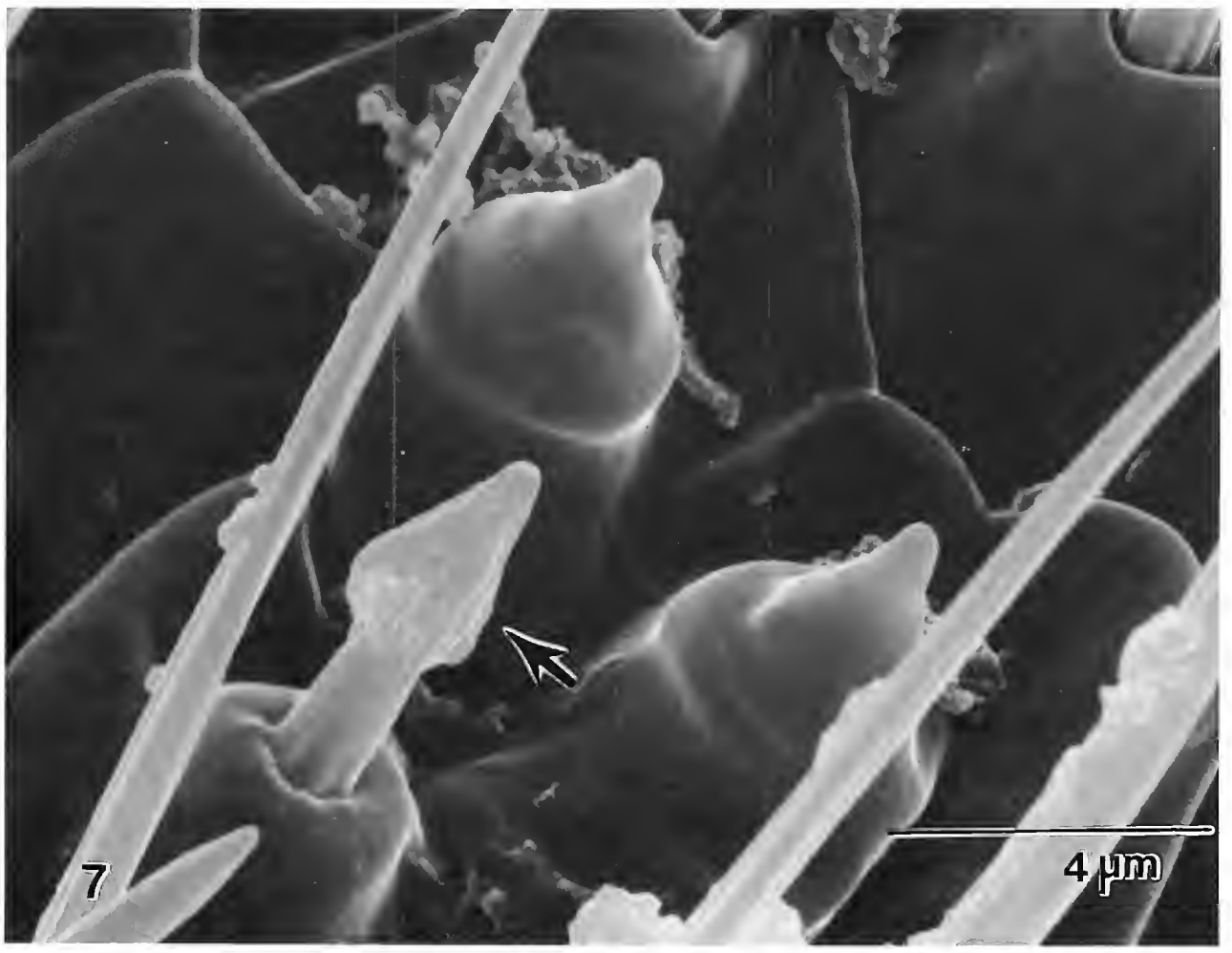

Figure 7. Presumed olfactory sensillum of *H. gibbicollis* (×7000).

Figure 8. Presumed integumentary pheromone receptor pore; *H. gibbicollis* male antennal segment 11 (×4000).

and field trials stegobiol was ineffective as an attractant for *H. gibbicollis* males. The authors stated that stegobiol isomerizes over time and becomes inhibitory to *S. paniceum*. Within laboratory arenas, male *H. gibbicollis* rapidly moved away from the material when placed near it, possibly due to isomerization of the compound.

Oviposition.—After mating, females located sheltered sites, such as cracks in wood or old exit holes, and remained motionless for 18–36 h. On four separate occasions males mated with three different females. Females were, on three occasions, observed to mate after they had initially oviposited. Few eggs were produced after these second matings (range = 3–8, $\bar{x} = 6$). Females laid eggs singly or in clusters of >100 in cracks or the end grain of the wood. Rarely were eggs laid in old exit holes. Kelsey (1946) and Bletchly (1952) used muslin to encourage oviposition of *A. punctatum* with good results. Thus, on smooth wood surfaces in laboratory tests, muslin cloth was used to stimulate oviposition. In 1990 and again in 1991, 14 females were permitted to oviposit on this surface. Eggs produced per female ranged from 0 to 202, $\bar{x} = 33.9$ per female. These numbers are similar to those reported by Spiller (1964) for *A. punctatum* (range = 0–123, $\bar{x} = 54.8$ per female). In several instances no eggs were produced which may have resulted from female beetles ovipositing prior to capture (Bletchly 1952). Other oviposition studies conducted in 1989 and 1990 resulted in a smaller number of eggs produced per female (Table 3).

A female extruded her ovipositor for 3–4 sec before an egg became visible. Five to 10 sec elapsed for each egg to be laid. While moving through the oviduct anobiid eggs are coated with symbiotic yeasts which supply the larvae with nu-

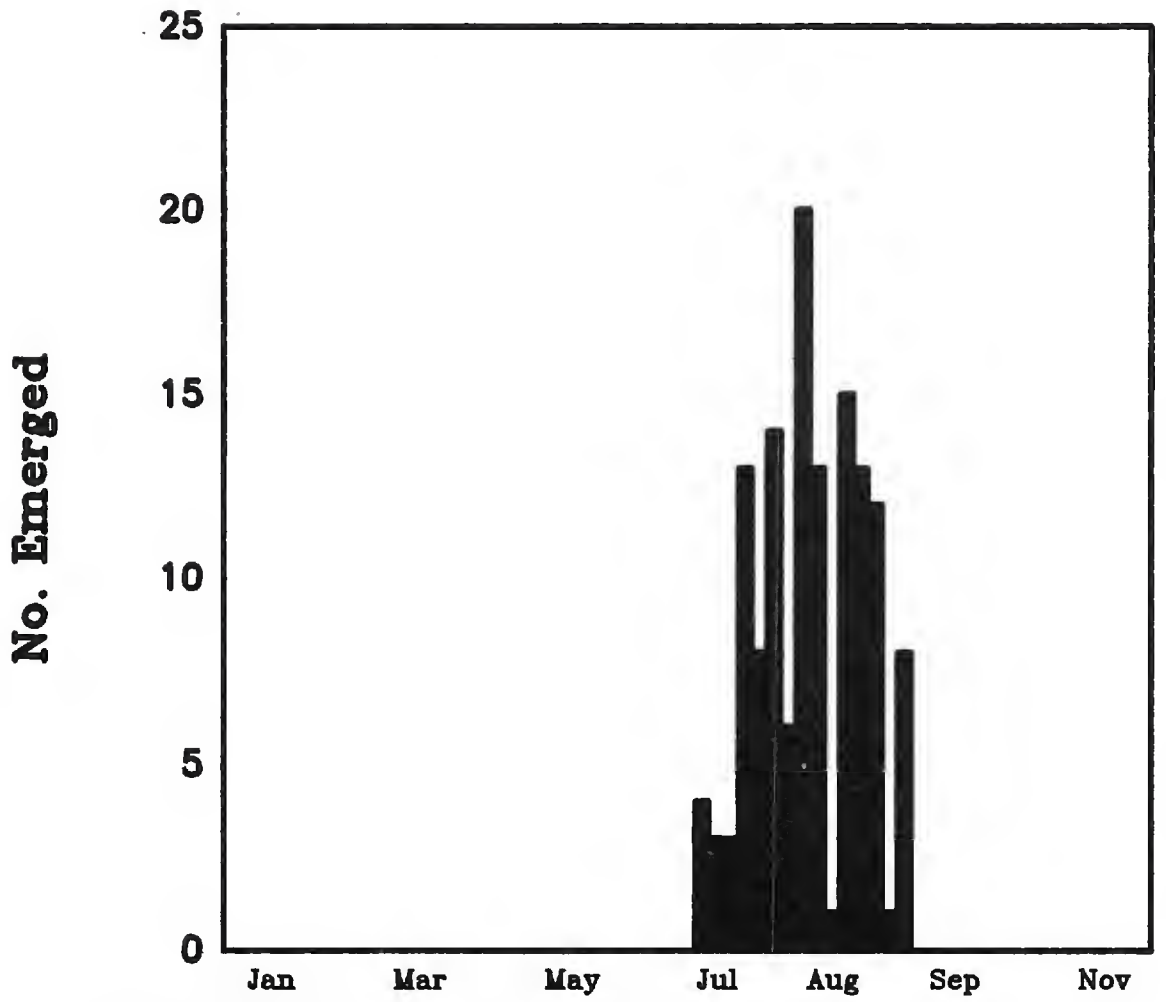

Figure 9. Adult *H. gibbicollis* emergence; e. Washington, 1987.

trients and amino acids (Jurzitza 1979). An adhesive material is produced by the colleterial glands of the female which adheres eggs to the substrate.

Eggs.—*Hemicoelus gibbicollis* eggs are approximately 0.5 mm long, creamy white, and tapered. A micropyle is evident at one end of the egg. Eggs are typically laid in cracks and crevices and are often distorted when forced into these restricted sites. Larval morphology did not become apparent until a few days before eclosion. Between 85 and 89% of eggs hatch under laboratory conditions which simulated the crawl space environment found in western Washington homes (Table 3). These conditions support a wood moisture regime between 13 and 19% that creates an environment conducive to anobiid larval development. Eggs required between 2–4 weeks to produce first instars (Suomi 1992). No eggs hatched when the RH was <50% (uncommon in western Washington), and fungal development prevented larval emergence if the RH exceeded 85%. Eggs developed normally between these

Table 3. Eggs produced,[a] percent hatch, and number of days to emergence; field collected *H. gibbicollis*.

Year	Total no. females	Mean no. eggs/ female (range)[b]	Mean no. days to hatch (range)	% hatch
1989	7	18.7 ± 3.9[a] (3–32)	22.1 ± 0.5[a] (11–33)	88.6
1990	8	17.4 ± 6.5[a] (1–50)	16.9 ± 0.3[b] (10–31)	84.9

[a] Adults and eggs were maintained in observation boxes at 65 ± 3% RH and 18 ± 1° C.

[b] Means ± SEM followed by the same letter do not differ significantly ($P = 0.05$) based on t-tests (SAS Institute 1985).

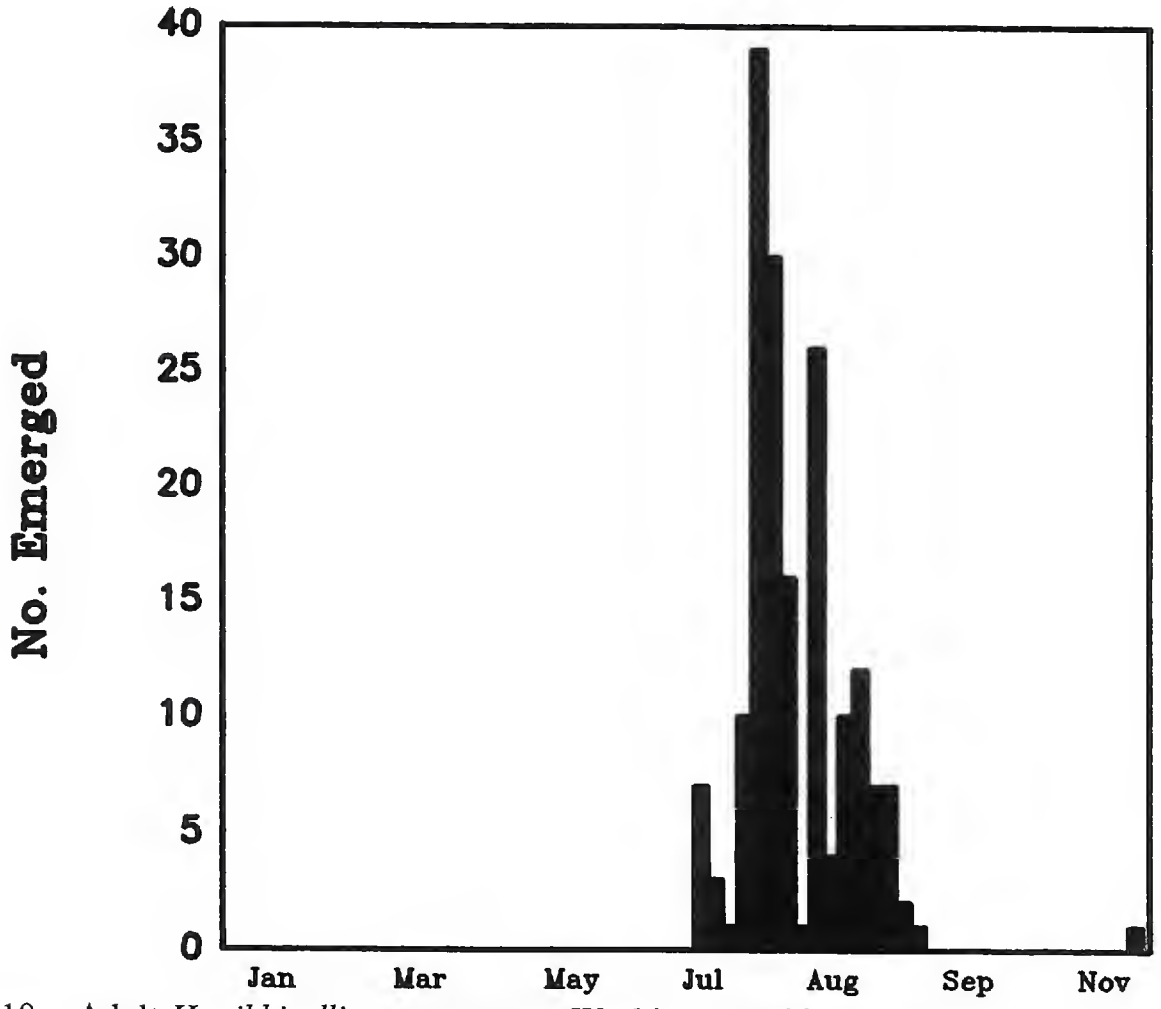

Figure 10. Adult *H. gibbicollis* emergence; e. Washington, 1988.

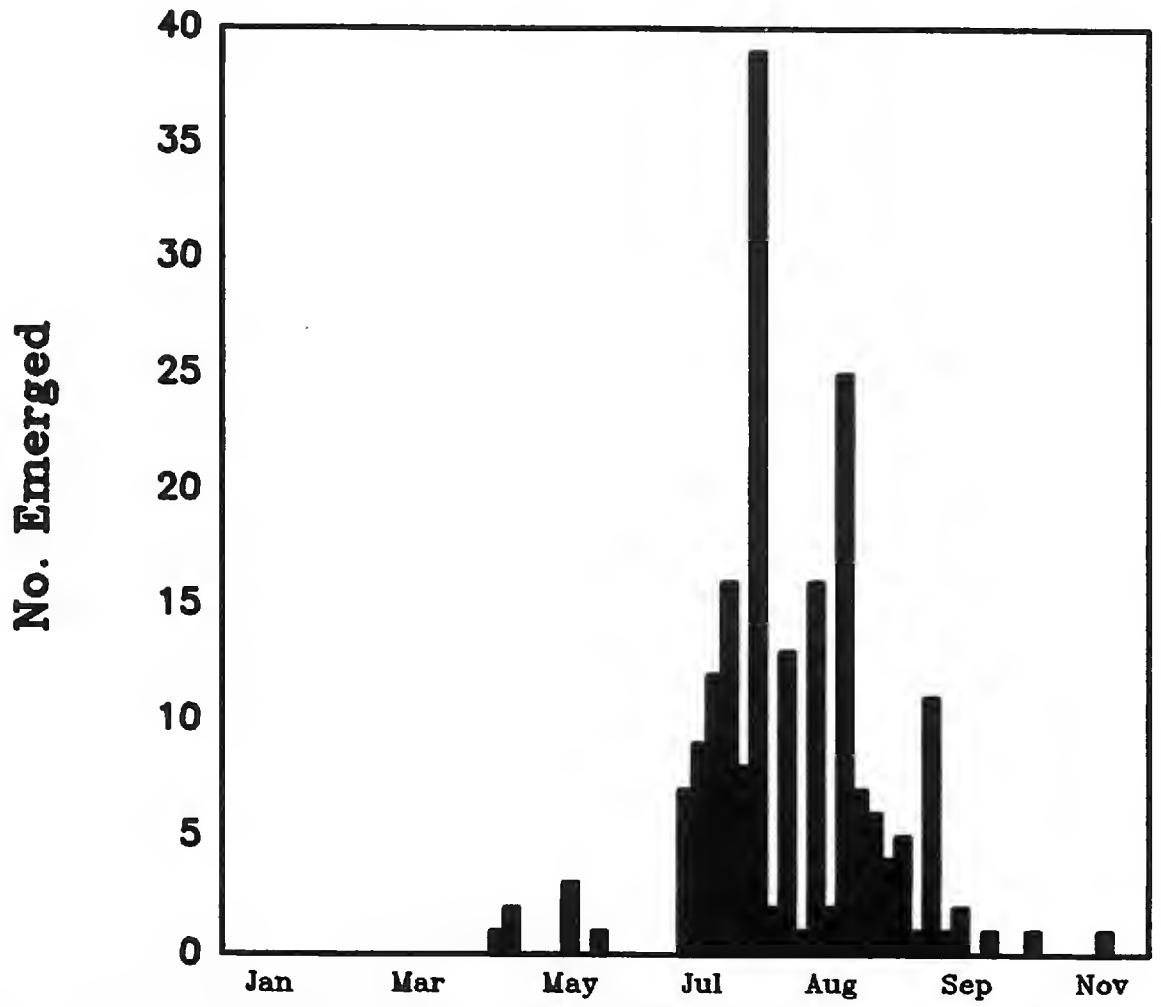

Figure 11. Adult *H. gibbicollis* emergence; e. Washington, 1989.

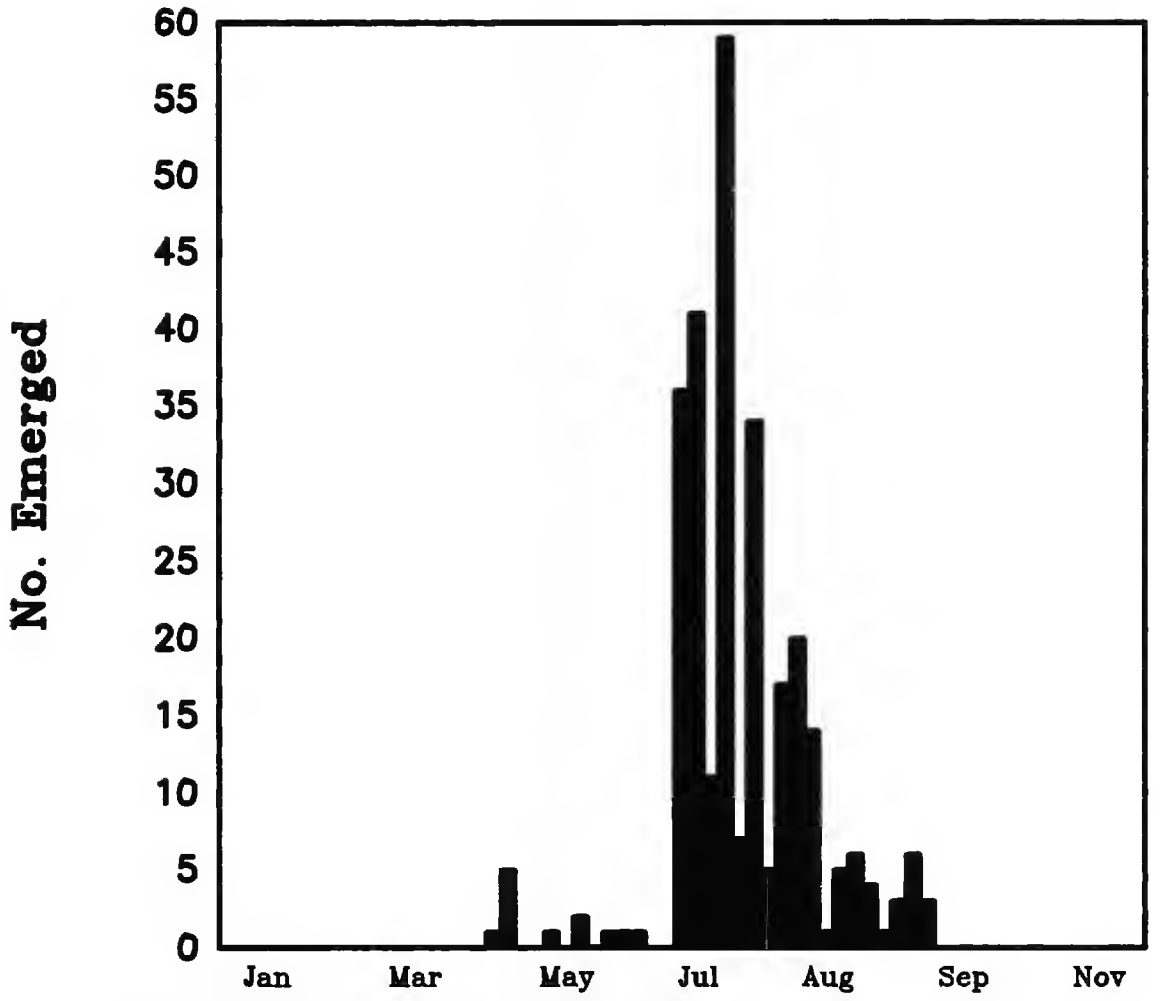

Figure 12. Adult *H. gibbicollis* emergence; e. Washington, 1990.

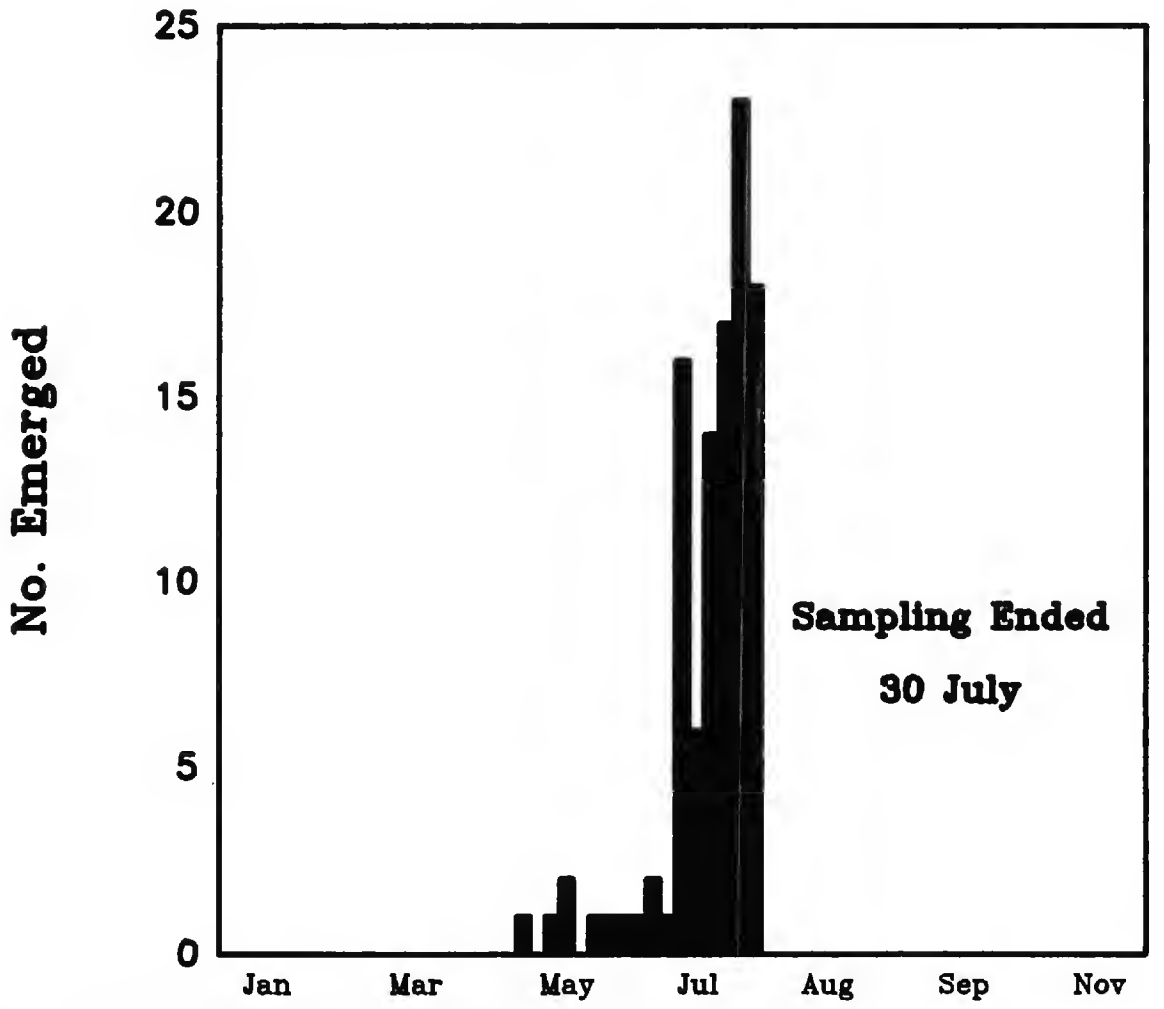

Figure 13. Adult *H. gibbicollis* emergence; e. Washington, 1991.

Figure 14. Distribution of the structure-infesting anobiid, *H. gibbicollis,* western United States.

extremes. The moisture content of recently milled, air-dried lumber found in lumberyards is probably too high for most *H. gibbicollis* eggs to survive.

Adult Activity Period.—Adult beetles are active primarily during summer months in the Pacific Northwest. Laboratory emergence records during 1987–1991 showed that *H. gibbicollis* began emerging in early June and continued until late August. In warmer parts of the range (southern California), emergence may start earlier and continue later in the year. Records acquired from museums and collections along the Pacific Coast (Suomi 1992) showed that most adults were captured during these months. The earliest laboratory collections were on 9 Apr and the

Table 4. Temperature extremes (°C) in emergence containers, eastern Washington.

Year	Maximum	Minimum
1987	35.0	−19.0
1988	34.5	−20.5
1989	39.5	−27.0
1990	36.0	−18.0

latest on 18 Dec (Suomi 1992: appendix 4). These emergences were unusual and probably represent a response to laboratory conditions. The earliest field collections of *H. gibbicollis* were made in Marin County, California on 1 Apr and the latest from 22 Oct in Lincoln County, Oregon. Label data did not always state whether the beetles were alive or dead when collected. Still, only 17 of 183 field collections were made before June or after August (Suomi 1992: appendix 2). Adult beetle emergence in the laboratory during 1987–1991 closely followed this trend, as 869 of 928 collections were made during June, July, and August (Figs. 9–13).

Hemicoelus gibbicollis occurs, for the most part, along the Pacific Coast of western North America where milder climatic conditions prevail (Fig. 14). Higher relative humidity, resulting in greater wood moisture, creates conditions conducive to their survival (Suomi 1992). Temperature extremes do not favor, but will not prevent, emergence of *H. gibbicollis* adults. Infested wood collected in western Washington and stored out-of-doors in eastern Washington produced adult beetles every summer. Temperatures ranged from −27.0° C to 39.5° C within the concrete enclosure (Table 4). Fewer beetles emerged from out-of-door storage than those retained within the laboratory, so these extremes may have had a deleterious effect. Wood moisture is the limiting factor related to larval anobiid survival and although this remained within the optimal range (13–19%), other conditions were quite different from those found along coastal areas. Low relative humidity and low wood moisture found within most inland area buildings may be the major reason for limiting the distribution of *H. gibbicollis*.

Acknowledgment

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DICHAETOCORIS CALOCEDRUS, A NEW SPECIES OF PLANT BUG ASSOCIATED WITH INCENSE CEDAR (CUPRESSACEAE), FROM WESTERN NORTH AMERICA (HETEROPTERA: MIRIDAE: ORTHOTYLINI)

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Abstract.—*Dichaetocoris calocedrus* NEW SPECIES, is described. This species is associated with *Calocedrus decurrens* (Torrey) Florin (Cupressaceae) in west-central Oregon. Characters defining the genus *Dichaetocoris* Knight are discussed and two new combinations are proposed: *Orthotylus ovatus* Van Duzee = *Dichaetocoris ovatus* (Van Duzee) NEW COMBINATION; *Orthotylus vanduzeei* Carvalho = *Dichaetocoris vanduzeei* (Carvalho) NEW COMBINATION.

Key Words.—Insecta, Miridae, *Dichaetocoris, Calocedrus*

The genus *Dichaetocoris* was erected by Knight (1968) for species of western North American orthotylines that differed from *Orthotylus* by the presence of both simple and sericeous, decumbent setae on the dorsum. Polhemus (1985) suggested that *Dichaetocoris* has two types of simple, unmodified setae. He further diagnosed *Dichaetocoris* as lacking sexual dimorphism in hemelytral length, and being restricted to coniferous host plants. Stonedahl & Schwartz (1986) showed that *Dichaetocoris* has, in addition to simple setae, modified, narrowly lanceolate, sericeous setae, with converging ridges. They also noted that this setal type was also found in *Oaxacacoris* Schwartz & Stonedahl and *Presidiomiris* Stonedahl & Schwartz, but that these genera are also sister groups to *Pseudopsallus* Van Duzee, and not closely related to *Dichaetocoris.*

Clearly, an extensive analysis of character distributions among western North American orthotylines is required to better delimit genera and determine generic relations. Nevertheless, we suggest that the following characters presently define the genus *Dichaetocoris,* although all characters may not be unique synapomorphies: (1) dorsal vestiture with erect to inclined simple setae, and recumbent, lanceolate, apically acuminate sericeous setae, with short, converging ridges; (2) lack of alar sexual dimorphism; (3) weakly convex pronotum, with rounded, lateral pronotal margins; (4) weakly sclerotized, flattened, or at least basally splayed out vesical spiculae; and (5) coniferous host plants. Using these criteria, we here describe a newly discovered species of *Dichaetocoris,* and transfer to *Dichaetocoris,* two other species currently placed in different genera.

The 15 species presently assigned to the genus *Dichaetocoris* are now known to occur on at least five genera of conifers: *Sequoia* Endlicher (Taxodiaceae); *Calocedrus* Kurz, *Cupressus* L., and *Juniperus* L. (Cupressaceae); and *Pinus* L. (Pinaceae). The pines from which *Dichaetocoris* is known are both pinyon pines, *Pinus edulis* Engelmann and *P. monophylla* Torrey & Fremont.

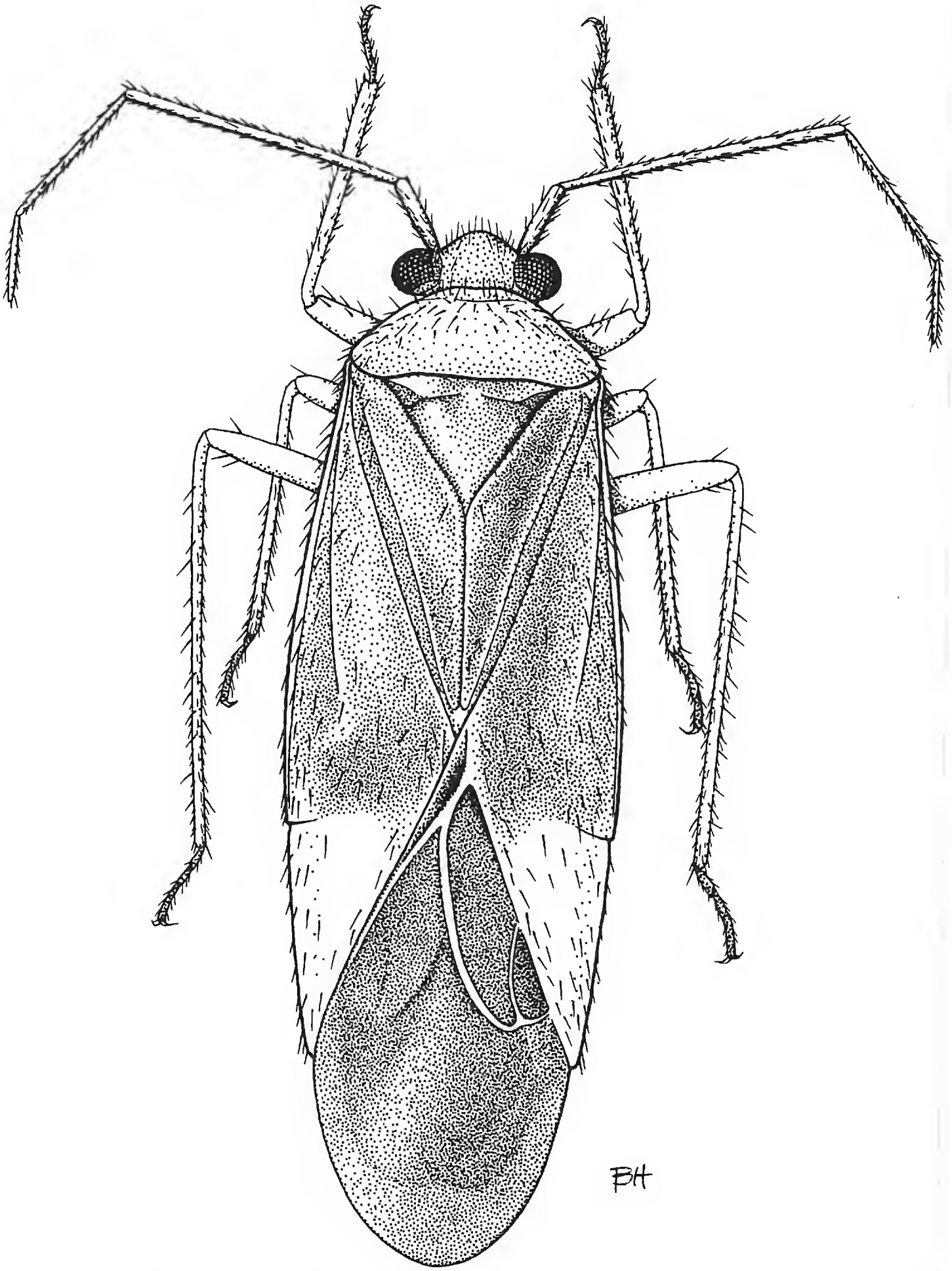


Figure 1. *Dichaetocoris calocedrus,* dorsal habitus male.

Dichaetocoris calocedrus Asquith & Lattin, new species

Types.—Holotype male. Data: OREGON. *DESCHUTES Co.:* SE base of Black Butte, 14 Jun 1990, A. Asquith & J.D. Lattin, ex. *Calocedrus decurrens* (Torrey) Florin. Holotype deposited in the collection of the California Academy of Sciences (CAS), San Francisco. Paratypes. Data: OREGON. *DESCHUTES Co.:* 9 males,

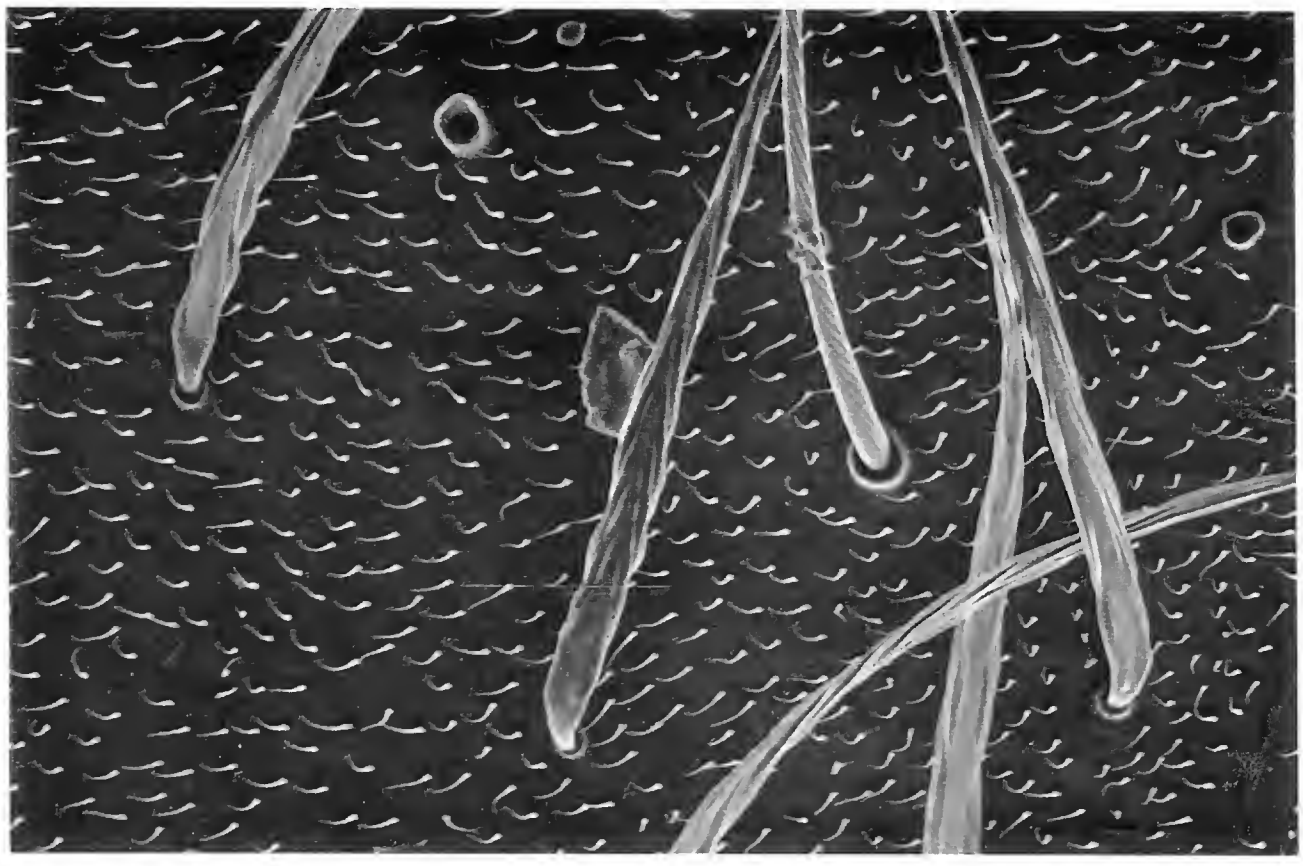


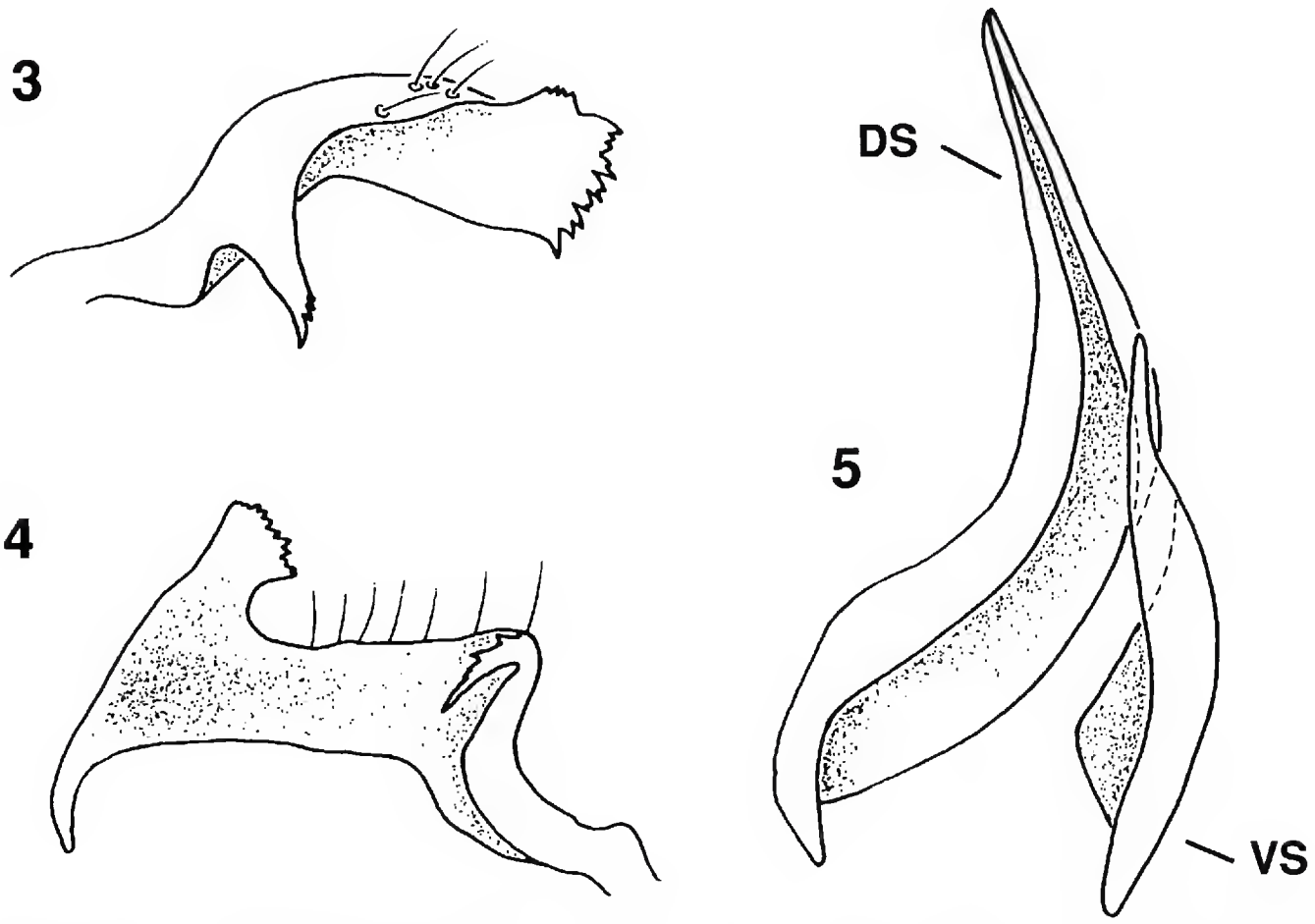
Figure 2. *Dichaetocoris calocedrus,* sericeous setae on hemelytra.

10 females, same data as holotype; deposited in Systematic Entomology Laboratory, Oregon State University (OSU-SEL) and the California Academy of Sciences (CAS), San Francisco.

Description.—Male (Fig. 1). Length 5.16–5.59 mm; general coloration green fuscous, with hemelytral margins and cuneus pale; dorsal vestiture with erect or inclined, short setae, dark on fuscous areas and pale on light colored areas, and recumbent, narrowly lanceolate, sericeous setae, with short, converging ridges, giving fluted appearance (Fig. 2). *Head:* Width across eyes 0.82–0.83 mm; width of vertex 0.39–0.41 mm; yellow-brown; antennae yellow, tinged with brown, segment I 0.41–0.43 mm; segment II 1.52–1.59 mm; segment III 0.93–0.96 mm; segment IV 0.43–0.48 mm; labium reaching to or beyond apices of metacoxae. *Pronotum:* Posterior width 1.30–1.35 mm; yellow anterior of calli; calli and disk yellow green; mesoscutum yellow-green to fuscous medially, yellow laterally; scutellum yellow fuscous, apex usually pale. *Hemelytra:* Green fuscous; embolium, corium bordering embolium, and cuneus pale; membrane grey fuscous, veins dark. *Legs:* Yellow; tibiae weakly tinged with green; tarsi, particularly distal segments, variably fuscous. *Genitalia:* Posteroventral surface of genital capsule with short, peg-like setae; apex of right paramere squared and strongly serrate (Fig. 3), basal arm with apex dentate. Left paramere hammer-shaped (Fig. 4); apicodorsal process broad and serrate; apicoventral process narrowly elongate, curved mesally; narrow basal arm present, with two or three small teeth. Apex of theca acuminate, heavily sclerotized, but entire and slightly convoluted; vesica with 2 large, weakly sclerotized, apically acuminate, trough-shaped spiculae (Fig. 5); ventral spicula one-half the length of dorsal spicula.

Female.—Length 4.73–5.12 mm; width across eyes 0.81–0.83 mm; width of vertex 0.43–0.44 mm; antennal segment I 0.41–0.43 mm; segment II 1.46–1.59 mm; segment III 0.83–0.87 mm; segment IV 0.43–0.44 mm; posterior width of pronotum 1.29–1.36 mm.

Diagnosis.—Dichaetocoris calocedrus NEW SPECIES is most similar to *D. vanduzeei* (Carvalho) (see below) in its large size, dark colored scutellum and infuscated hemelytral membrane. *Dichaetocoris calocedrus* is differentiated by its larger size (total length $>$ 4.5 mm), elongate hemelytra, the narrowly hammer-shaped structure of the left paramere (Fig. 4), and by its fuscous dorsal coloration with contrasting pale lateral margins and cuneus (Fig. 1).



Figures 3–5. *Dichaetocoris calocedrus,* male genitalia. Figure 3. Right paramere, medial view. Figure 4. Left paramere, medial view. Figure 5. Vesical spiculae. DS = Dorsal spicula, VS = Ventral spicula.

Etymology.—Named for the plant genus from which this species was collected. The genus *Calocedrus* Kurz is sometimes included as a segregate of the genus *Libocedrus* Endlicher; however, most recent references consider *Calocedrus* to be a distinct genus, containing only those species in the Northern Hemisphere.

Distribution.—Known only from the eastern slopes of the Cascade Mountains in west-central Oregon.

Discussion.—*Dichaetocoris calocedrus* is unusual in its broad, trough-shaped spiculae. Other genera of western Orthotylini with modified setae have a variable number of narrowed, sclerotized, usually serrate spiculae (Asquith 1991, Stonedahl & Schwartz 1986). Some species of *Pseudopsallus* approach the condition in *D. calocedrus* in having broadly trough-shaped spiculae, particularly near their bases. We examined the spiculae of two other species of *Dichaetocoris,* both undescribed, associated with *Juniperus* L. in western Oregon. Both of these species have moderately broad spiculae, with weakly recurved lateral margins, but unlike that of *D. calocedrus.* In addition, the spiculae of both *Juniperus* species are serrate distally.

Material Examined.—Type series.

Dichaetocoris vanduzeei (Carvalho), NEW COMBINATION

Orthotylus cupressi Van Duzee 1925:399.
Orthotylus vanduzeei: Carvalho 1955:225. Replacement name.

Originally described as *Orthotylus cupressi* by Van Duzee (1925), this name was preoccupied and the species was given its replacement name by Carvalho (1955). We examined paratypes of this species in the California Academy of

Sciences and consider it to be a *Dichaetocoris,* based on the characters described above. Of all species that we have examined, *D. vanduzeei* most closely resembles the new species, *D. calocedrus,* in its large size, color pattern and general shape of the left paramere. This species is known only from *Cupressus sargenti* Jepson in Marin Co., California.

Dichaetocoris ovatus (Van Duzee), NEW COMBINATION

Orthotylus ovatus Van Duzee 1916:105.
Orthotylus (*Melanotrichus*) *ovatus*: Carvalho 1958:117.
Melanotrichus ovatus: Henry & Wheeler 1988:429.

When first described, Van Duzee (1916) allied *ovatus* with an eastern North American species, *Orthotylus catulus* Van Duzee, which is now recognized as a species of *Melanotrichus.* Based on our examination of paratypes in the California Academy of Sciences, we found that *ovatus* clearly belongs to the genus *Dichaetocoris.* This species is associated with *Juniperus,* and is thus far known only from the original collection near Lake Tahoe, in El Dorado Co., California.

Acknowledgment

We thank Paul H. Arnaud, Jr. (California Acadamy of Sciences) for specimens; Michael D. Schwartz (Canada Agriculture) for manuscript review; Bonnie B. Hall for her habitus drawing; and Alfred Soeldner for the SEM photographs. This paper is no. 3764 of the Hawaii Institute of Tropical Agriculture and Human Resources Journal Series.

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FIRST RECORDS OF *DICHOCERA* (DIPTERA: TACHINIDAE) REARED FROM *CEUTHOPHILUS* (ORTHOPTERA: RHAPHIDOPHORIDAE) HOSTS IN NEVADA AND NEW YORK

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Abstract.—*Dichocera* sp. was reared from the camel cricket *Ceuthophilus utahensis* Thomas collected in 1990 in Nevada; its puparium is described. La Rivers' speculation on the likelihood of *C. utahensis* occurring in Nevada is substantiated. In 1968, a *Dichocera* sp. probably *lyrata* Williston was reared from *Ceuthophilus guttulosus guttulosus* Walker in New York.

Key Words.—Insecta, Tachinidae, *Dichocera,* Rhaphidophoridae, *Ceuthophilus,* parasitoid, puparium

We present two rearings of the tachinid genus *Dichocera* from the rhaphidophorid genus *Ceuthophilus* made over 20 years apart and from opposite sides of the North American continent. Nevada is newly included in the range of *Ceuthophilus utahensis* Thomas.

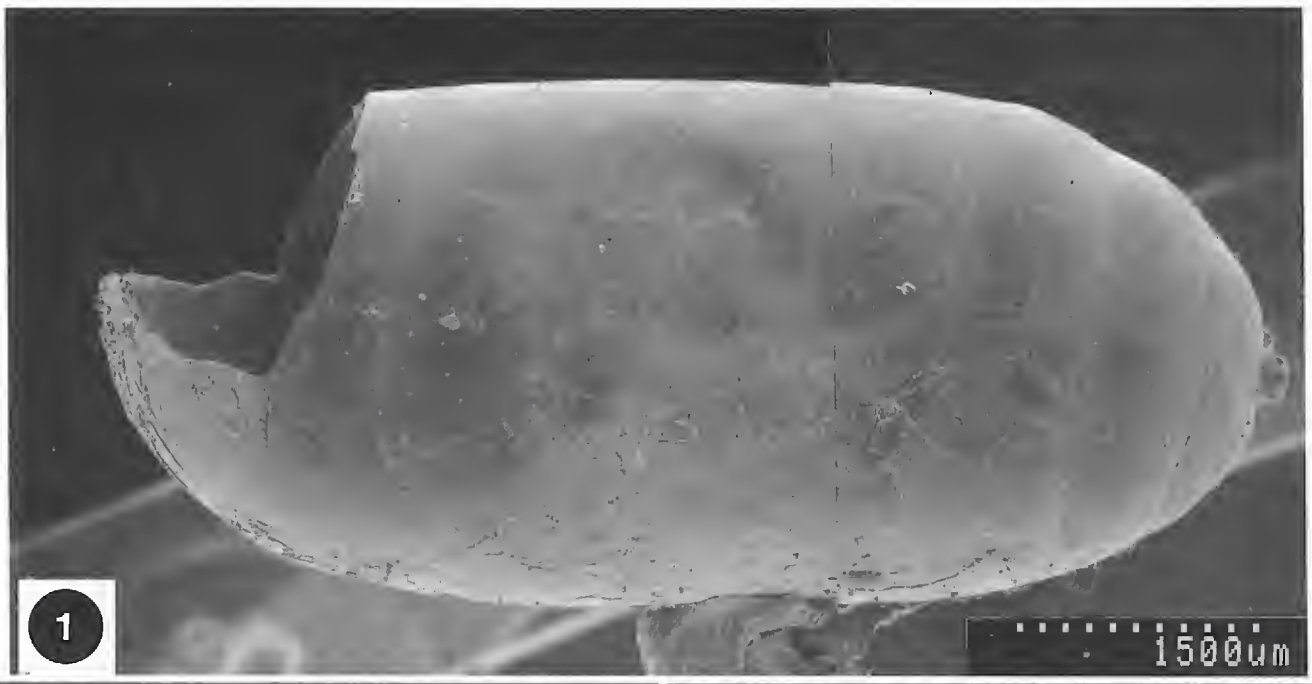
Current records of tachinids reared from the Rhaphidophoridae in North America include: *Meigenielloides cinereus* Townsend from *Gammarotettix bilobatus* (Thomas) in California (Arnaud 1973: 82), *Dichocera orientalis* (Coquillett) from cave crickets (Wood 1987: 1198), and *Anisia flaveola* (Coquillett) from *Ceuthophilus latibuli* Scudder in Florida. The *A. flaveola* was cited as *Oedematocera flaveola* (Coquillett) (Hubbell 1936: 507, Arnaud 1978: 607); Wood (1985: 20) synonymized *Oedematocera* with *Anisia.* We confirm that *Dichocera* and *Ceuthophilus* are sympatric.

REARING IN NEVADA

This rearing involves an adult male gracilifemoral "*utahensis*" phase (not robustifemoral "*uniformis*" phase) of *C. utahensis* (Hubbell 1936: 68–80) collected by Graeme Lowe (see material examined), and given to JSC for identification and observation. Several days later, JSC transferred the camel cricket to a covered plastic container provided with water, rolled oats, and rabbit feed pellets. At 1430 h (PDT) on 27 Aug 1990, the camel cricket was observed to be grossly debilitated with a large opening on the left side of its thorax, its left middle and hind legs severed at the coxae, and its abdomen hollowed. On the floor of the container was a white dipterous larva. The larva completed pupariation within three hours, gradually changing from white to red-brown.

→

Figures 1–5. Puparium of *Dichocera* sp. Figure 1. Lateral view. Figures 2, 3. Posterior views. Figure 4. Left posterior spiracular plate. Figure 5. Superior spiracular slit on left posterior spiracle.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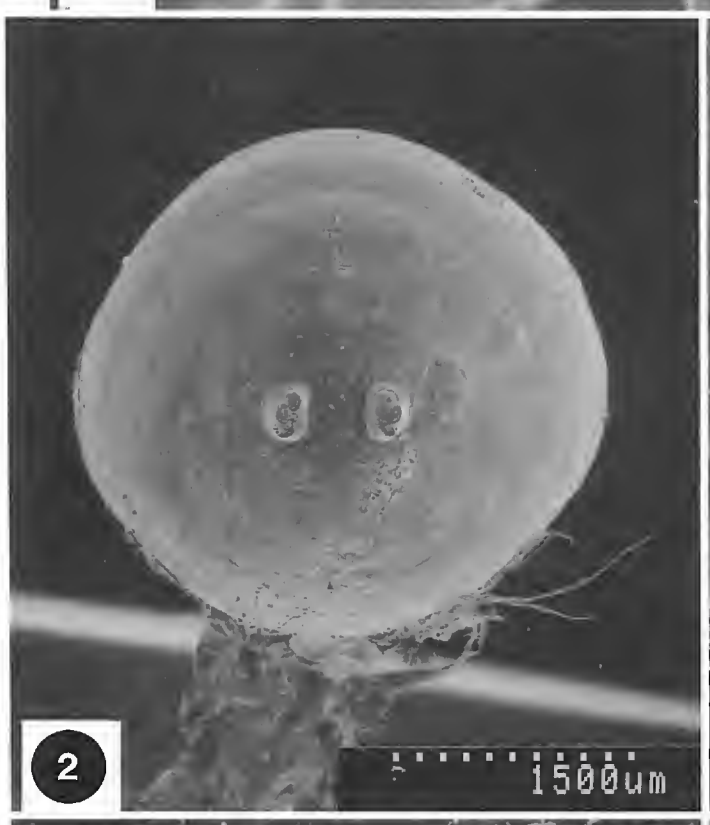
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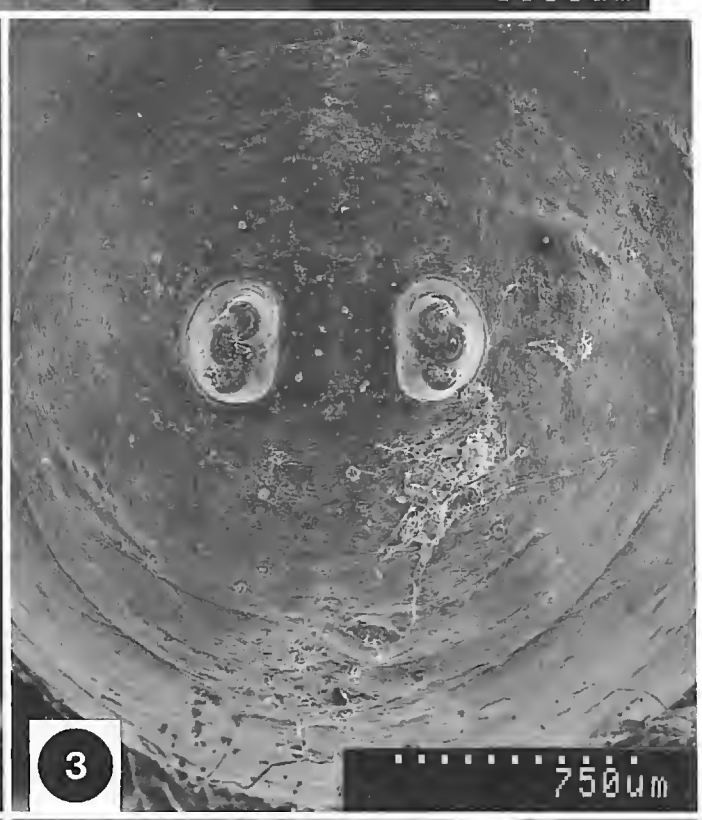
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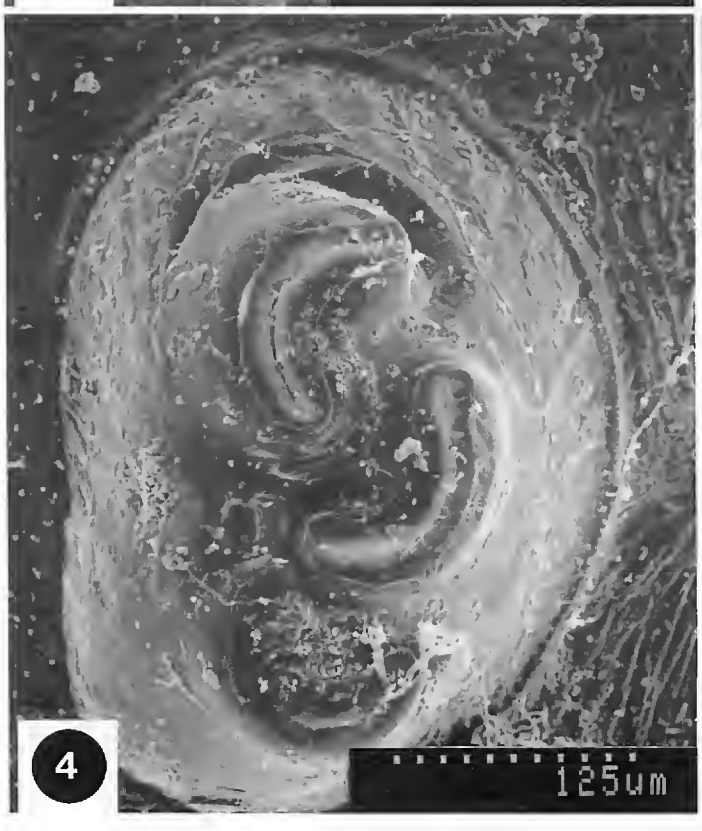
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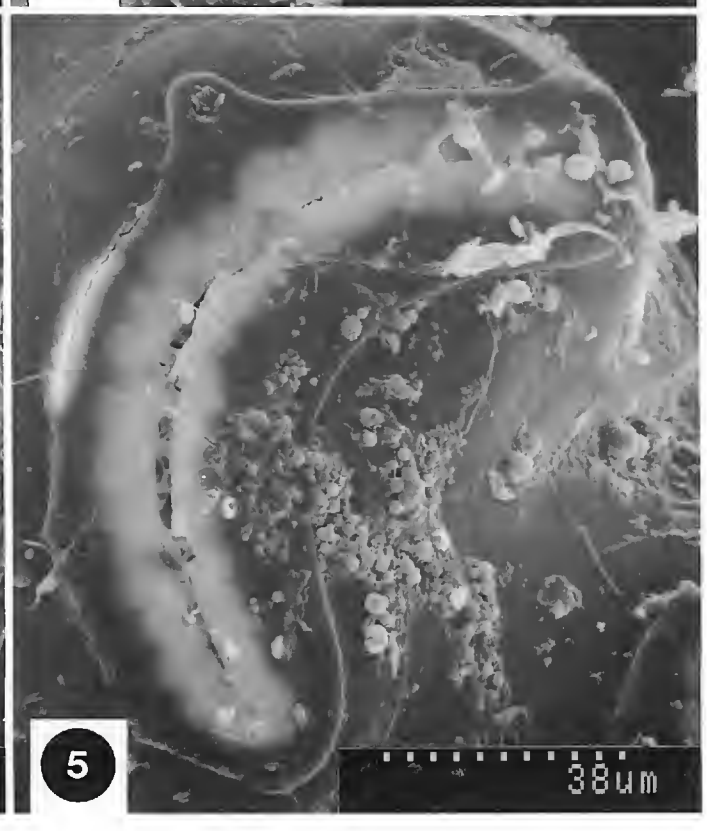
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The puparium was placed about 1 cm from a small piece of moistened tissue inside a clean covered plastic container. In this artificial environment, an adult female fly emerged at approximately 1000 h (PDT) on 29 Sep 1990. It remained teneral for three days, with its wings not fully expanded when killed. PHA subsequently identified it as *Dichocera* sp. Description of the puparium is as follows: length 8.5 mm, diameter 3.0 mm, smooth, subshining, red-brown; 10 segments subtly delineated but distinctly discernable (Fig. 1); faint depression on caudal segment around spiracular plate (Figs. 2, 3); posterior spiracles protuberant (height approximately 0.2 mm), conical, shiny black (Fig. 1), and approximately 0.36 mm apart at base (Figs. 2, 3); three crescent-shaped slits on each spiracle (Figs. 4, 5).

Material Examined.—Ceuthophilus utahensis, NEVADA. *LINCOLN CO.:* Rainbow Canyon near Elgin, 18 Aug 1990, G. Lowe.

Rearing in New York

Correspondence in 1968 and 1969, between Robert E. Silberglied and PHA, concerning several tachinid rearings included a specimen of *Dichocera.* At that time PHA was preparing a manuscript on the hosts of North American Tachinidae, and Silberglied generously gave him permission to include the rearings in the host catalog. Because unpublished rearings could not be included in the catalog, we present this *Dichocera* record here.

In 1967, at Ithaca, Tompkins County, New York, Silberglied reared *Dichocera* probably *lyrata* Williston, determined by Curtis W. Sabrosky, from a nymphal *Ceuthophilus guttulosus guttulosus* Walker.

Discussion

La Rivers' (1948: 708) conjecture that *C. utahensis* would likely occur in Nevada is confirmed by Lowe's collection of the host and by the collection of a series of six additional specimens (five females, one male) of the gracilifemoral "*utahensis*" phase made concurrently at the same locality by Stanley C. Williams, Lowe, and JSC. The male and two females of this series were parasitized by mites. The collection site was a habitat of thickets at the base of Rainbow Canyon near Meadow Valley Wash, along Route 317 (el. 1100–1200 m). This habitat, range, and spotty distribution are consistent with those mentioned by Hubbell (1936: 68–80) and La Rivers (1948: 708).

Acknowledgment

We thank Robert C. Bechtel (Nevada Department of Agriculture, Reno) for field guidance as well as supplying research material; Vincent F. Lee (California Academy of Sciences, San Francisco) for editorial advice; Graeme Lowe (Monell Chemical Senses Center, Philadelphia) for providing the host specimen; Curtis W. Sabrosky (Systematic Entomology Laboratory, SEA, U.S. Department of Agriculture, Washington, D.C.) for identifying the *Dichocera* from New York; Robert E. Silberglied posthumously for his *Dichocera* rearing record; Darrell Ubick (CAS) for assistance with the illustrations; and Stanley C. Williams (San Francisco State University) for research guidance and assistance in the field.

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AN EPIGEAN *TYRANNOCHTHONIUS* FROM HAWAII (PSEUDOSCORPIONIDA: CHTHONIIDAE)

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Abstract.—*Tyrannochthonius swiftae* NEW SPECIES was found in Ohia litter on the island of Kauai. It is similar to *T. pupukeanus* Muchmore from the island of Oahu, but is not at all cave-adapted.

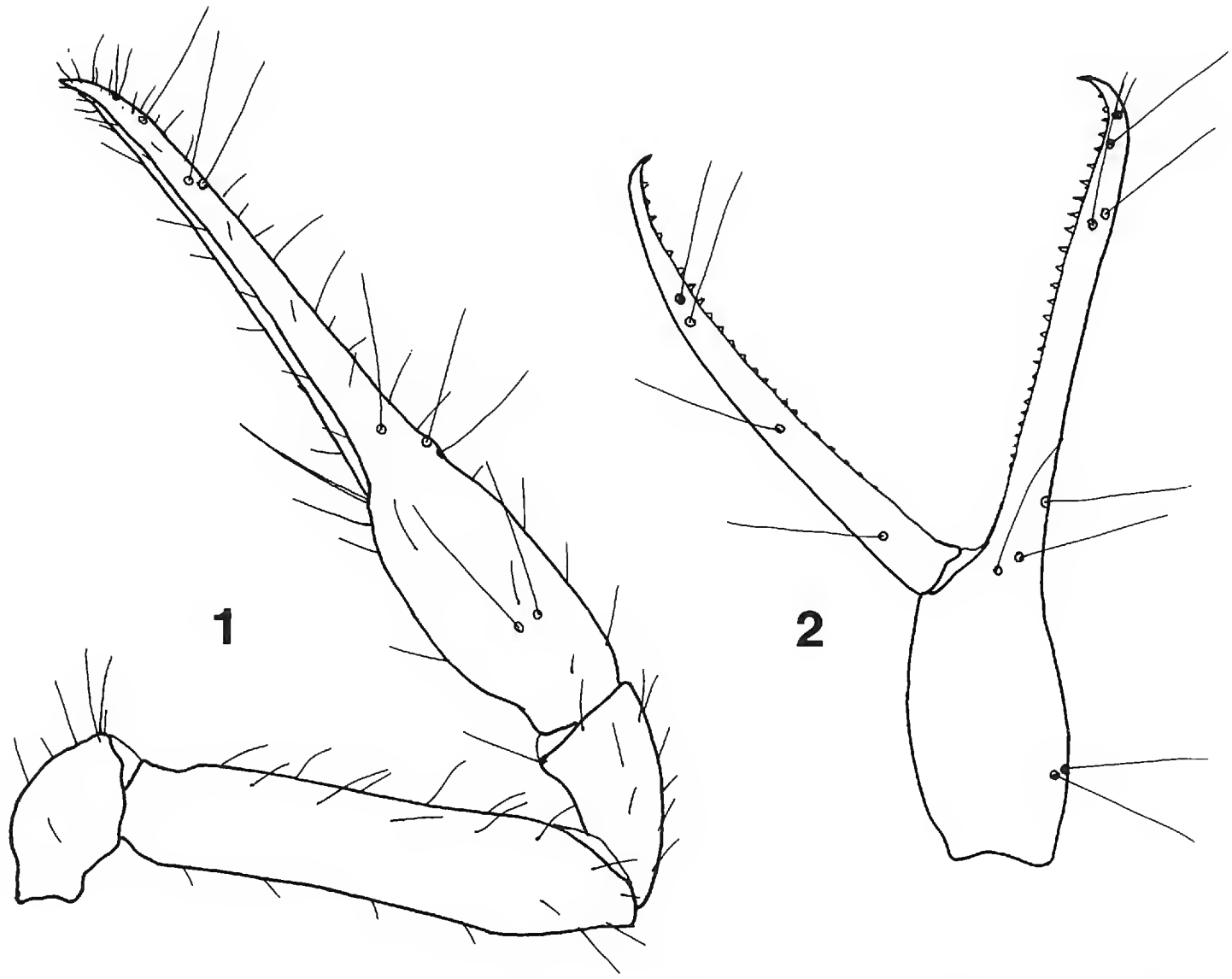
Key Words.—Arachnida, Pseudoscorpionida, Chthoniidae, *Tyrannochthonius swiftae* NEW SPECIES, epigean

Through the efforts of F. G. Howarth and his colleagues, representatives of three troglobitic species of *Tyrannochthonius* have been found in the Hawaiian islands, *T. howarthi* Muchmore (1979) from Ainahou Petroglyph Cave on Hawaii Island, *T. pupukeanus* Muchmore (1983) from Pupukea Lava Tube on Oahu Island, and *T. stonei* Muchmore (1989) from Kalu Au Au Dripping Cave on Maui Island. These species are all definitely cave-adapted, being pallid, with reduced eyes and attenuated appendages. It must be agreed that they originated from one or more epigean ancestors, but, until recently, no such "normal" *Tyrannochthonius* was known from any of the Hawaiian islands. Urged on by my repeated pleas to search for litter-dwelling pseudoscorpions by Berlese separation, Sabina Swift of the Bishop Museum has finally collected a single male of a typical, epigean species of the genus on Kauai Island; it is new and is described here.

TYRANNOCHTHONIUS SWIFTAE MUCHMORE, NEW SPECIES
(Figs. 1, 2)

Type Data.—Holotype male. HAWAII: *KAUAI:* Hono O Na Pali NAR, 1305 m, Ohia soil and litter, 19 Nov 1990, collected by Sabina F. Swift. Type in the Bishop Museum, Honolulu (BPBM 15046).

Description.—*Male.* All parts straw colored. Carapace about square in dorsal view; surface smooth; epistome small, triangular, with 2 flanking setae; 4 corneate eyes; setae long and prominent; chaetotaxy d4d-4-4-2-2, the dwarf setae (d) lying anterior to eyes. Abdomen typical; tergal chaetotaxy 4:4:4:4:4:5:5:5:5:4:T2T:0; sternal chaetotaxy 10:[4-4]:(3)5-5/16(3):(4)6(4):10:9:9:9:9:8:0:2. Chelicera 0.75× as long as carapace; hand with 5 setae; flagellum of ca. 8 pinnate setae; fixed finger with ca. 8 teeth, distal one largest; movable finger with ca. 10 small teeth; galea represented by a very low elevation; serrula exterior of 19 or 20 blades. Palp rather long and slender (Fig. 1); femur 1.2× and chela 1.8× as long as carapace. Trochanter 1.65×, femur 4.4×, tibia 1.75× and chela 5.25× as long as broad; hand 1.7× as long as deep; movable finger 1.95× as long as hand. Surfaces smooth; setae slender; 1 prominent long, heavy seta on medial side of chelal hand at base of fixed finger. Trichobothria as shown in Fig. 2; *sb* slightly nearer to *st* than to *b*. Fixed finger with 27 spaced teeth, tall and sharp distally, low and rounded proximally, and with 1 or 2 intercalated microdenticles distally; movable finger with 15 pointed teeth and 8 low rounded denticles proximally, and no microdenticles. Legs generally typical, but rather robust; apex of coxa I with a prominent rounded projection; coxal chaetotaxy 2-2-1:3-0:2-2(1)-CS:2-3:2-3; setae on apex of palpal coxa long, subequal; each coxa II with 7 or 8 terminally incised coxal spines (CS). Leg IV with entire femur 2.45 and tibia 4.1× as long as deep; tactile setae on tibia and both tarsi. *Measurements.* Body length 1.45 mm. Carapace length 0.435 mm. Chelicera length 0.33 mm. Palpal trochanter 0.18/0.11 mm; femur 0.53/0.12 mm; tibia 0.22/0.125 mm; chela



Figures 1, 2. *Tyrannochthonius swiftae* NEW SPECIES. Figure 1. Dorsal view of right palp. Figure 2. Lateral view of left chela.

0.79/0.15 mm; hand 0.265/0.155 mm; movable finger 0.52 mm long. Leg IV: entire femur 0.495/0.205 mm; tibia 0.33/0.08 mm.

Female.—Unknown.

Diagnosis.—A small species in the Hawaiian fauna, about the same size as *T. pupukeanus,* from which it differs in having four definitely corneate eyes and more robust appendages (palpal femur L/B = 4.4, compared with 4.8-5.15 for *T. pupukeanus*).

Etymology.—The species is named for S. Swift, who collected the type specimen.

Distribution.—Known only from the type locality.

Remarks.—The discovery of the specimen described above confirms the presence of epigean *Tyrannochthonius* in Hawaii. Continued search of the litter fauna will undoubtedly turn up representatives of the genus on all of the major islands.

Epigean species of *Tyrannochthonius* are known from various islands in the Pacific Ocean west of Hawaii, the nearest being Japan, Guam, New Guinea, Solomon Islands, New Caledonia, and Kermadec. *Tyrannochthonius swiftae* is larger than most of those species, but about the same size as *T. japonicus* (Ellingsen), from which it differs in having a distinct epistome and more slender appendages.

It is interesting that no *Tyrannochthonius* species is yet known from Pacific islands directly south or east of Hawaii until the Galapagos Islands, and none has

been reported from the eastern shore of the Pacific as far south as Colombia. This is probably due in large part to lack of collecting and study.

Material Examined.—See types.

Acknowledgment

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NEW SPECIES OF *PERDITA* (*PYGOPERDITA*) TIMBERLAKE OF THE *P. CALIFORNICA* SPECIES GROUP (HYMENOPTERA: ANDRENIDAE)

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Abstract.—Three new species of *Perdita* (*Pygoperdita*) of the *P. californica* group are described from the southwestern United States. *Perdita meconis* NEW SPECIES, from the Mojave Desert, is associated with two genera of Papaveraceae, *Argemone* and the endangered dwarf bearclaw poppy, *Arctomecon humilis* Coville. *Perdita ute* NEW SPECIES, from the San Rafael Desert of central Utah, is also associated with *Argemone.* The floral association of *P. angellata* NEW SPECIES, from the Colorado Plateau of northern Arizona, is unclear. A key to males is presented.

Key Words.—Insecta, Andrenidae, *Perdita,* Papaveraceae, *Argemone, Arctomecon*

Recent collections of pollinators that were made in connection with studies on the pollination of the endangered dwarf bearclaw poppy, *Arctomecon humilus* Coville, yielded a new species of *Perdita* (*Pygoperdita*) Timberlake. It is described here to make the name available for those studies. Two additional closely related species, one needed for a study in progress on the fauna of the San Rafael Desert, Utah, are also described.

Males of the three species described here, together with *P. argemones* Timberlake, form a subgroup of the *P. californica* species group of *P.* (*Pygoperdita*) that can be distinguished from all other members of the *P. californica* group by the structure of tergum 7 (T7). In these species, the apical lobes of T7 are wide (nearly horizontal), the lateral preapical angles are acute, and there is no transverse preapical carina separating the base of the segment from the apical lobes.

Characterization of the females is difficult. There is currently no way to distinguish between females of the *P. interrupta* Cresson and *P. californica* species groups (Timberlake 1956). So it should not be surprising that no unique combination of characters could be found to distinguish females of this subgroup from other species of the *P. californica* group. Females of all four species can be separated from most other *P.* (*Pygoperdita*) by the combination of obscure facial fovea, sparse scutal punctation, distinctly maculated metasoma, and a complete basitibial plate on the hind leg. However, *P. cowaniae* Timberlake, *P. duplonotata* Timberlake, *P. fallugiae* Timberlake, *P. distropica* Timberlake, *P. mohavensis* Timberlake, and *P. robustula* Timberlake also possess these traits. Therefore, no key to the females is presented here; rather the position of each species in Timberlake's 1956 key is given.

KEY TO MALES

1. Facial marks yellow; galea lightly shagreened 2
– Facial marks white; galea polished 3
2(1). Frons, scutum shagreened anteriorly; metasoma dark with yellow markings; apical lobes of T7 thickened apically ..... *meconis* NEW SPECIES

– Frons, scutum polished anteriorly; metasoma uniformly with a red hue, except for small dark marks; apical lobes of T7 not thickened apically ... . *argemones* Timberlake

3(1). Facial fovea dull; scutum uniformly green; light maculations of metasoma broad, on T2–3 encircling oval lateral spots; apical lobes of T7 not thickened apically ..... *ute* NEW SPECIES

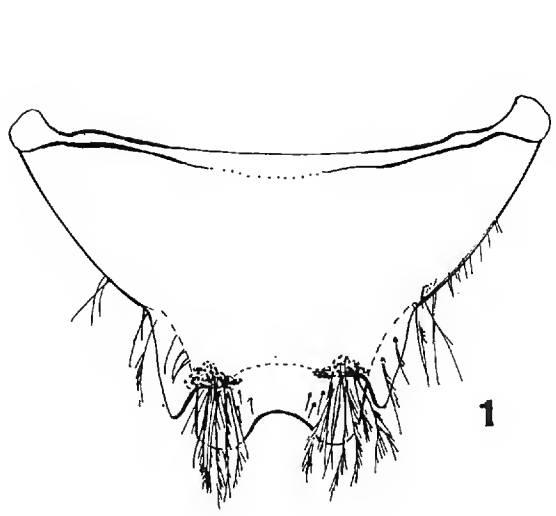
– Facial fovea shiny; scutum centrally black with purple reflections; maculations of metasoma narrow, on T2–3 not encircling oval lateral spots; apical lobes of T7 thickened apically ..... *angellata* NEW SPECIES

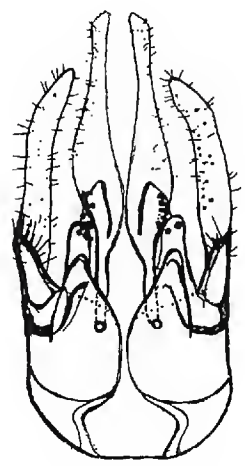
Perdita meconis, NEW SPECIES
(Figs. 7–9, 12)

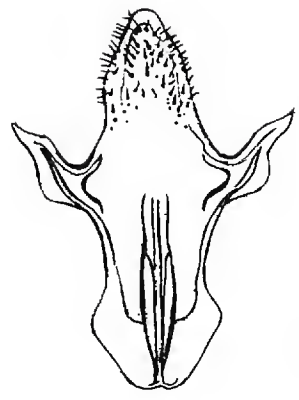
Types.—Holotype male. UTAH. *WASHINGTON Co.:* Warner Ridge, Beehive Dome, 19 May 1988, 8:30–9:00 AM, *Arctomecon humilis* Coville, B. Snow. Holotype deposited in USDA Bee Biology and Systematics Collection, Logan, Utah. Paratypes: CALIFORNIA. *SAN BERNARDINO Co.:* Cottonwood Wash, 768 m (2520 ft), T9N R12E Sec. 3, 10 May 1982, *Argemone,* T. Griswold, 5 males, 1 female; same except 2 Jun 1980, no floral record, 1 female; Kelso Dunes, 664 m, (2180 ft), T10N R13E Sec. 7, 15 May 1980, mating pair, T. Griswold, 1 male, 1 female; same except *Argemone,* 14 males; Kelso Dunes, 655 m (2150 ft), T10N R13E, 2 May 1980, *Argemone,* T. Griswold, 4 males; Winston Wash, 588 m (1930 ft), T10N R12E Sec. 3, 15 Apr 1980, *Argemone,* T. Griswold, 5 males. UTAH. *WASHINGTON Co.:* Same data as holotype, 1 male, 2 females; same except 20 May 1988, 2 males, 3 females; same except 20 May 1988, 8:00–8:30 AM, 1 male, 1 female; same except 20 May 1988, 9:00–9:30 AM, 1 male, 1 female; same except mating pair, 18 Apr 1989, 8–10 AM, 1 male, 1 female; same except 24 Apr 1989, 11:30–11:40 AM, 1 female; same except 24 Apr 1989, 10:25–10:30 AM, 1 male. Paratypes deposited in USDA Bee Biology and Systematics Collection, Logan, Utah, and University of Kansas, Lawrence.

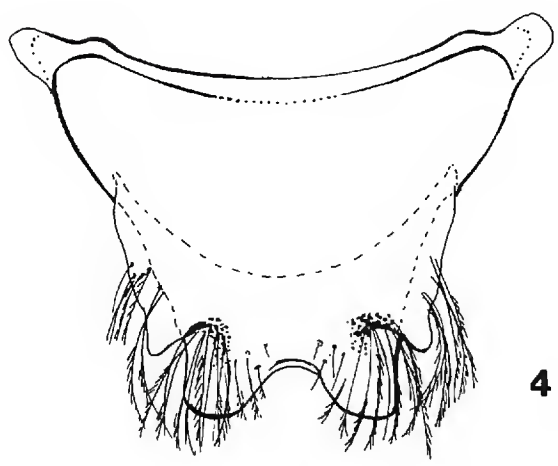
Male. Length 5 mm. Forewing length 4 mm. Head and mesosoma dark green except: propodeum blue-green; pale yellow on mandible, labrum, face below level of antenna, ventral triangular area on gena, submedial transverse line on pronotal collar, pronotal lobe. Antenna yellow below, brown above. Legs black except: pale yellow on femora apically, anterior stripe on fore- and midtibia, fore- and midtarsi; hindtarsi dark brown. Wings hyaline, veins milky white except subcosta brown. Metasoma with T1 dark green turning brown on posterior margin; T2 with basal yellow stripe narrowly broken medially, pair of lateral very dark brown oval spots joined medially by narrow brown stripe, posterior third of segment amber; T3 similar but oval spots less well defined, brown stripe evanescent; T4 amber except for ill-defined, lighter brown oval spots; T5–7 amber. S1 black; S2–6 amber. Frons strongly shagreened, moderately covered with fine punctures. Mesosoma lightly shagreened except shiny medial portion of scutum and scutellum; scutal punctures fine, sparse especially medially. Head broader than long, inner orbits parallel. Facial fovea dull, obscure. Galea lightly shagreened, as long as eye length, pointed apically. T7 as in Fig. 7, apical lobes oblique, almost vertical, in posterior view, apically thickened. S8 as in Fig. 9. Genitalia as in Fig. 8.

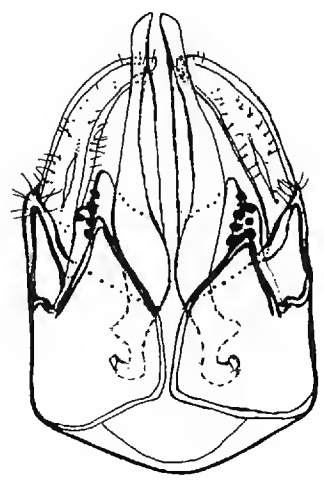
Female.—Length 6.5–7 mm. Forewing length 4.5–5 mm. Color as in male except pale yellow markings of head and mesosoma restricted to mandible, apical spot on labrum, clypeus except for pair irregular, often interrupted, vertical lines, pair very narrow supraclypeal lines, triangular paraocular area. Legs dark brown except for pale yellow on apex of fore- and midfemora and anterior stripe on foretibia. Metasomal terga dark brown except with green caste on T1, T2 with basal stripe narrowly interrupted medially, T3–4 similar but with progressively wider marks; T5 mostly yellow except for basolateral spot and subapical area (Fig. 12). Sterna amber-yellow except S1 brown, S2–4 with diffuse lateral brown spots. Punctation and sculpture as in male. Head distinctly wider than long. Clypeus

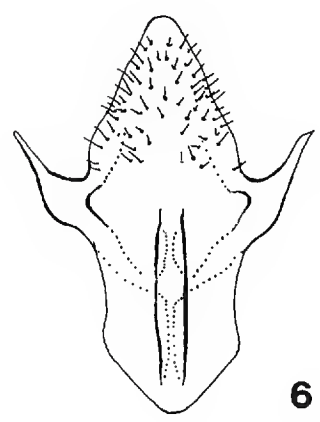


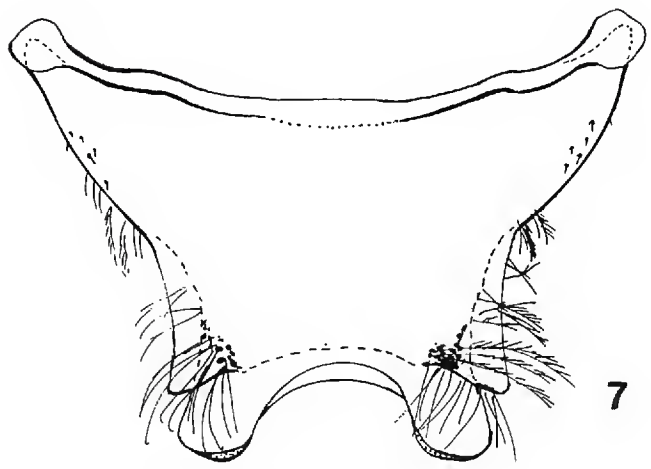


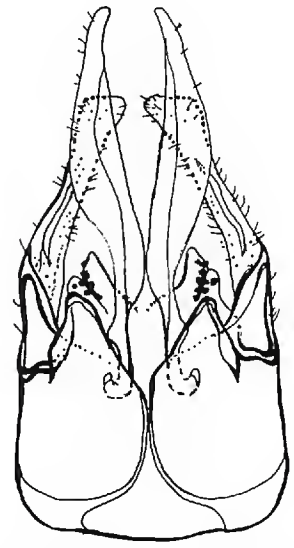


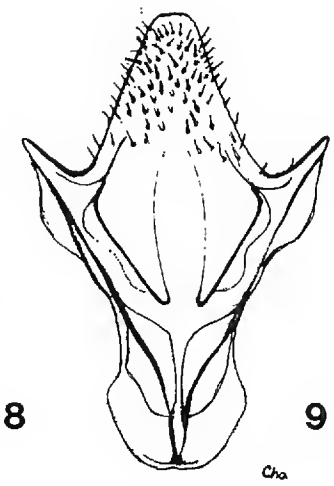










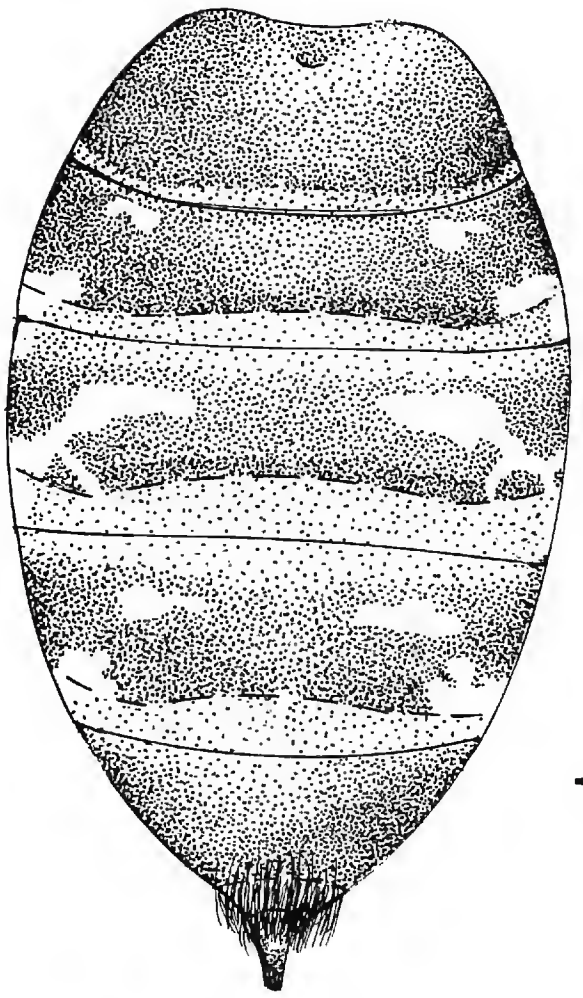


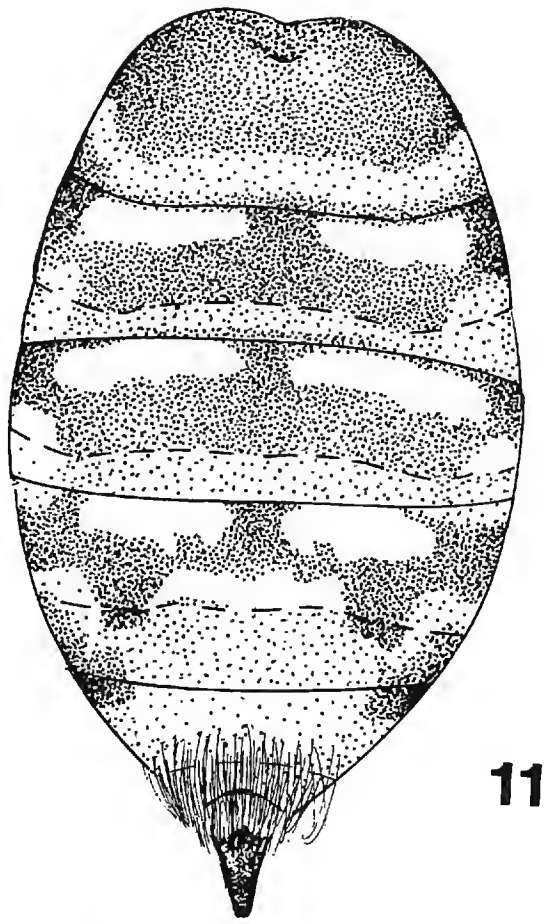
Figures 1–9. Male metasomal structures. Figure 1. *Perdita ute,* T7 in dorsal view. Figure 2. *Perdita ute,* genitalia in dorsal view. Figure 3. *Perdita ute,* S8 in ventral view. Figure 4. *Perdita angellata,* T7 in dorsal view. Figure 5. *Perdita angellata,* genitalia in dorsal view. Figure 6. *Perdita angellata,* S8 in ventral view. Figure 7. *Perdita meconis,* T7 in dorsal view. Figure 8. *Perdita meconis,* genitalia in dorsal view. Figure 9. *Perdita meconis,* S8 in ventral view.

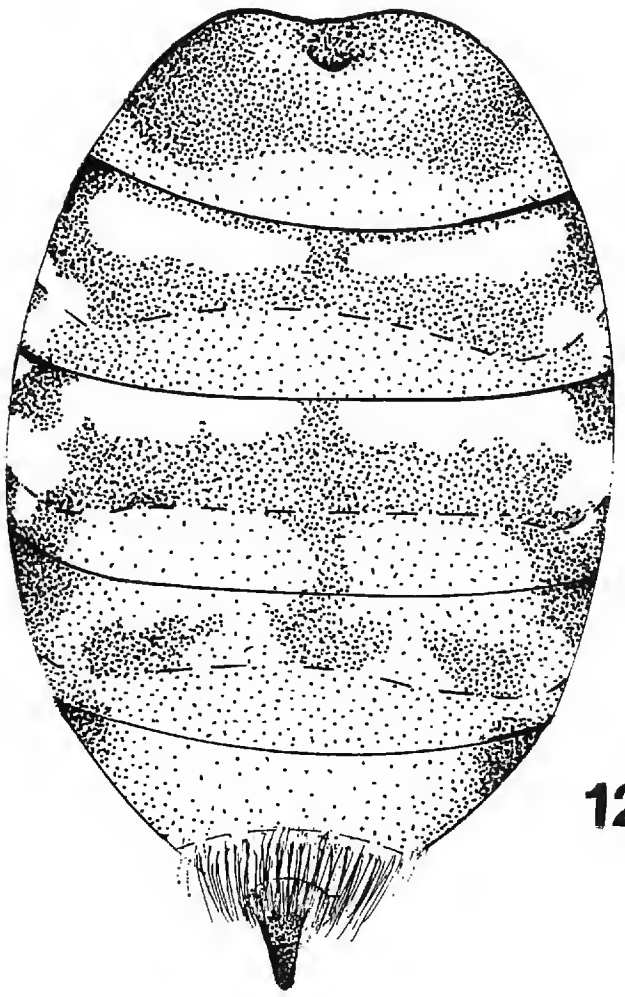
dentate adjacent to labrum. Facial fovea linear, extending from level of lower margin of antennal socket to approximately half distance between antennal socket and median ocellus. Pygidial plate rather abruptly narrowed apically, strongly curved ventrally in lateral view.

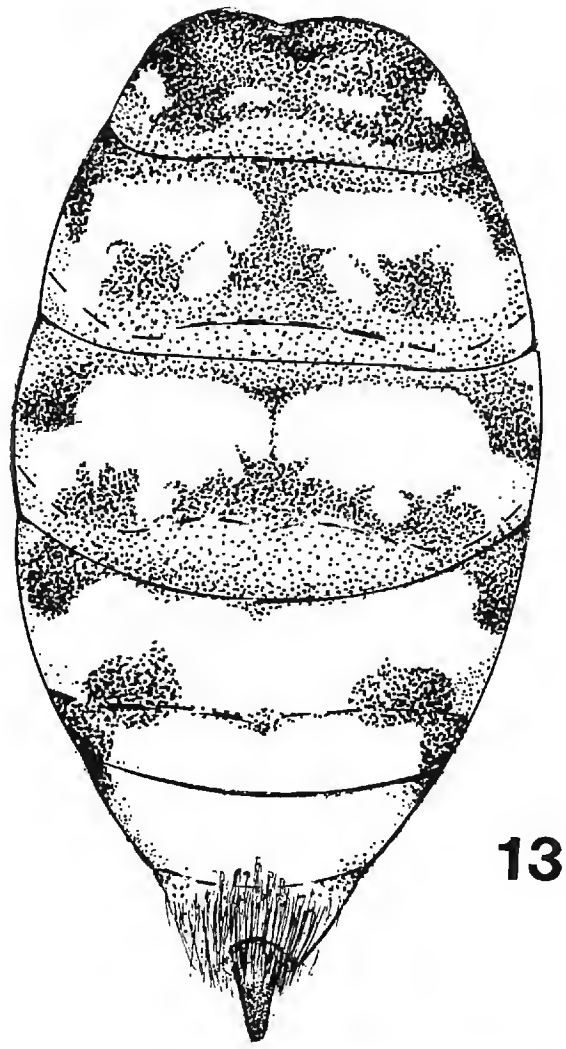
Diagnosis.—See key.

Variation.—Males range in size from 4.5–5.5 mm long. Extent of maculations varies in males. Some individuals have the paraocular mark reduced adjacent to the subantennal suture. General metasomal coloration is darker in some individuals.









Figures 10–13. Female metasoma, dorsal view showing markings. Figure 10. *Perdita angellata.* Figure 11. *Perdita argemones.* Figure 12. *Perdita meconis.* Figure 13. *Perdita ute.*

Etymology.—From the Latin "mecon," meaning poppy, because this bee is apparently limited in pollen collection to Papaveraceae.

Distribution.—Known only from the eastern Mojave Desert, where it is associated with *Arctomecon* and *Argemone* (Papaveraceae).

Discussion.—In the key to *P.* (*Pygoperdita*) (Timberlake 1956), males of *P. meconis* key to couplet 73, where they do not agree well with either part of that couplet. The female keys to couplet 23, where it may be distinguished from the subspecies of *P. wyomingensis* Cockerell (as *P. sculleni* Timberlake subspecies; see Timberlake 1968) by the following: longer mouthparts, scutum lightly shagreened anteriorly, scutal punctation more dense, T4 mostly and T5 entirely yellow.

Material Examined.—See types.

Perdita ute, NEW SPECIES
(Figs. 1–3, 13)

Types.—Holotype male. UTAH. *EMERY Co.:* 5.1 air km (3.2 mi) NE Little Gilson Butte, 1524 m (5000 ft), 3 Jun 1981, F. D. Parker. Holotype deposited in USDA Bee Biology and Systematics Collection, Logan, Utah. Paratypes all: UTAH. *EMERY Co.:* same data as holotype, 3 males, 14 females; same except, 3 Jun 1991, *Argemone corymbosa* Greene, T. Griswold, 2 males; same except 30 May 1991, 1 male; near Little Gilson Butte, 1554 m (5100 ft), 3 Jun 1991, *Argemone corymbosa,* T. Griswold, 4 males; same except, 13 Jun 1991, 1 female; E edge San Rafael Reef, 3.2 km (2 mi) S Interstate Hwy-70, 1347 m (4420 ft), 3 Jun 1991, T. Griswold, 1 female. Paratypes in USDA Bee Biology and Systematics Collection, Logan, Utah, and University of Kansas, Lawrence.

Male.—Length 4.5 mm. Forewing length 4 mm. Head and mesosoma dark blue-green except: cream-colored markings on mandible, labrum, clypeus except for pair small dark dots, subantennal area, pair spots on supraclypeal area, elongate triangular ventral area on gena, small spot on pronotal lobe. Antenna pale yellow below, dark brown above. Legs dark brown except: pale yellow on femora apically, fore- and midtibia except posterior longitudinal stripe, narrow ventral stripe on posterior tibia, fore- and midtarsi; hindtarsi light brown. Wings hyaline, veins off-white except subcosta dark brown. Metasoma dark brown (except T1 almost entirely dark blue-green), with pale yellow marks as follows: T1 on extreme apicolateral margin, T2 wide basal stripe very narrowly interrupted medially, narrow subapical line medially, small subapical patch laterally; T3 like T2 but light areas coalescing to form triangular medial and oval lateral dark spots; T4 as in T3 but dark lateral spot not margined posteriorly by thin yellow line; T5 with wide V-shaped medial mark and lateral spot, T6 subapical margin; T7 amber. S1–6 with subapical light bands. Frons strongly shagreened, moderately covered with fine punctures. Mesosoma lightly shagreened except scutellum shiny medially; scutal punctures fine, sparse especially medially. Head broader than long, inner orbits parallel. Facial fovea dull, obscure. Galea polished, nearly as long as eye length, apically pointed. T7 as in Fig. 1, apical lobes oblique, almost vertical in posterior view, apically not thickened. S8 as in Fig. 3. Genitalia as in Fig. 2.

Female.—Length 5.5 mm. Forewing length 4.5 mm. Color as in male except quadrangular area posteriorly on scutum, scutellum black; cream markings restricted to mandible, labrum laterally, clypeus except pair vertical stripes, triangular paraocular area. Legs dark brown except pale yellow on apices of femora, anterior portion of fore- and midtibia. T1 dark blue-green except for 2 pair pale yellow spots apically; T2–5 pale yellow except: white medially on T4, light brown basally and apically, dark brown oval spots apicolaterally on T2–4 and subapical area medially on T2–3 (Fig. 13). Sterna amber except for diffuse pale yellow transverse stripes on S3–4. Punctation and sculpture as in male. Head distinctly wider than long. Clypeus dentate adjacent to labrum. Facial fovea linear, extending from level of middle of antennal socket to approximately half distance between antennal socket and median ocellus. Pygidial plate evenly narrowed apically, slightly curved ventrally in lateral view.

Diagnosis.—See key.

Variation.—Light metasomal markings of one male more extensive than those of holotype. Females vary slightly in extent of metasomal maculations.

Etymology.—Named for the Ute Indians, who inhabited the San Rafael Desert.

Distribution.—Known only from the sand dune areas of the San Rafael Desert, Colorado Plateau.

Discussion.—Males key to couplet 73 in the key to *Perdita* (*Pygoperdita*) (Timberlake 1956) where they do not agree well with either option. The female keys to couplet 22 (if you assume the black on the scutum to be limited, as in *P. duplonotata* Timberlake) where it differs from both *P. nitens* Timberlake and *P. duplonotata* by the continuous, or at most very narrowly interrupted, light metasomal bands. The abdominal markings of *P. ute* are quite similar to those of *P. argemones* (Fig. 11), but the background color of the first few terga is black, not dark brown, and the light markings of T2–4 are larger, with the transverse basal marks usually joining the posterolateral ones.

Material Examined.—See types.

Perdita angellata, NEW SPECIES
(Figs. 4–6, 10)

Types.—Holotype male. ARIZONA. *COCONINO Co.:* 32.2 km (20 mi) N Cameron, 3 May 1972, *Sphaeralcea,* F. Parker, P. Torchio, G. Bohart. Paratypes, same data as holotype, 2 males, 1 female. Holotype and paratypes in USDA Bee Biology and Systematics Collection, Logan.

Male.—Length 5.5 mm. Forewing length 4.5 mm. Head with frons and vertex olive green; gena, except ventrally, dark green; paraocular area above white mark dark blue; mandible except apically, labrum, clypeus except for pair dark dots, emarginate supraclypeal mark, subantennal area, quadrangular mark on paraocular area with short narrow extension along eye, small triangular mark on lower gena white. Antenna yellow below, brown above. Mesosoma dark green except for quadrangular purplish area posteriorly on scutum, darker bronze scutellum. Wings hyaline, veins light brown except subcosta dark brown. Legs brown, except yellow apically on femora, and anteriorly on fore- and midtibia, fore- and midtarsi yellow-brown. Terga dark brown except T1 with greenish reflections, pale yellow markings on lateral corners of T1–5 and linear, medially interrupted, transverse basal bands on T2–4. S1 dark brown, S2–6 yellow-brown. Frons strongly shagreened, moderately covered with fine punctures. Mesosoma lightly shagreened except shiny medial portion of scutum and scutellum; scutal punctures fine, sparse especially medially. Head broader than long, inner orbits slightly converging above. Facial fovea shiny, distinct. Galea polished, as long as eye length, pointed apically. T7 as in Fig. 4, apical lobes oblique in posterior view, thickened apically. S8 as in Fig. 6. Genitalia as in Fig. 5.

Female.—Length 6.5 mm. Forewing length 4.5 mm. Color as in male except paraocular area less strongly blue, white markings of head and mesosoma restricted to mandible basally, lateral quadrate mark on clypeus, triangular paraocular mark. Legs dark brown except for pale yellow on apex of fore- and midfemora and anterior stripe on foretibia. Terga brown except: T2 with irregular, narrow basal stripe widely interrupted medially, small apicolateral spot; T3 similar but with wider regular basal mark joining apicolateral spot; T4 as in T2 except basal stripe not as narrow, not irregular; T5 with small apicolateral spot. Sterna brown. Punctation and sculpture as in male. Head distinctly wider than long. Clypeus dentate adjacent to labrum. Facial fovea linear, extending from level of lower margin of antennal socket to midpoint between antennal socket and median ocellus. Pygidial plate evenly narrowed apically, slightly curved ventrally in lateral view.

Diagnosis.—See key.

Variation.—Extent of facial maculations is reduced in one paratype. The basal maculations of the metasomal terga are also reduced in the paratype males.

Etymology.—From the Latin "angellus," small angle, for the distinctive small lateral angles of male T7 which distinguish this subgroup from other *P.* (*Pygoperdita*).

Distribution.—Known only from the southern portion of the Colorado Plateau in northern Arizona.

Discussion.—Males of *Perdita angellata* key to couplet 73 in Timberlake's 1956 key to the species of *Perdita* (*Pygoperdita*), where they do not agree well with either option. The female keys to couplet 22 (if the first half of couplet 11 is chosen), where it differs from both *P. nitens* Timberlake and *P. duplonotata* Timberlake by the completely black medial portion of the clypeus, the reduced markings of T4 and the absence of light markings on T5. If the second half of couplet 11 is chosen, it keys to *P. mohavensis* Timberlake in couplet 35, where it differs by its shorter tongue.

Material Examined.—See types.

Acknowledgments

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Scientific Note

MIMOSESTES NUBIGENS (MOTSCHULSKY) ESTABLISHED IN CALIFORNIA (COLEOPTERA: BRUCHIDAE)

Mimosestes nubigens (Motschulsky) was recently sent to us for determination; these were reared from the seeds of *Acacia farnesiana* (L.) Willdenow from Borrego, San Diego County, California. This is the first record of this bruchid being collected well into California. Although *M. nubigens* was reported from Calexico, California (Kingsolver, J. M. & C. D. Johnson. 1978. USDA Tech. Bull., 1590), it was not considered to be well established in California because Calexico is on the border with Mexico. Because *A. farnesiana* is a popular ornamental plant that is used widely in California, the bruchid should be expected to attack its seeds in other areas of the state.

An area of a freeway median (I-40) from 8–12.8 km (5–8 mi) SE of Needles, San Bernardino County, California has been planted with *A. farnesiana,* apparently as an ornamental plant and to prevent erosion. Since December, 1974, and most recently on 11 Mar 1991, the seeds of these plants were sampled several times for the presence of bruchids, but no *M. nubigens* have been reared from them. On the contrary, *Mimosestes amicus* (Horn) was reared from its seeds collected in December, 1974 (Kingsolver & Johnson 1978). *Mimosestes amicus* only occasionally feeds in the seeds of this acacia, and its presence in that locale can be accounted for by the nearby palo verde (*Cercidium floridum* Bentham), its more favored host. Seeds collected on 11 Mar 1991 have eggs glued to them, which we believe to be *Stator limbatus* (Horn), also a bruchid predator of seeds of *C. floridum.* No adults emerged from them, presumably because seeds of *A. farnesiana* have toxins or other inhibitors that prevent *S. limbatus* from feeding, even in the laboratory (Johnson, C. D. 1981. Environ. Entomol., 10: 857–863).

Mimosestes nubigens is also established in Hawaii, Arizona, Texas, Florida, and has a distribution to Brazil (Kingsolver & Johnson 1978).

Material Examined.—*Mimosestes nubigens*: CALIFORNIA. *SAN DIEGO Co.*: Borrego (1325 Borrego Valley Rd), 23 Jan 1991, ex seeds *Acacia farnesiana.*

Acknowledgment.—We thank Margaret Johnson for assistance in the field and Richard M. Persky for sending the specimens to us.

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Received 30 April 1991; accepted 16 July 1991.[1]

[1] This manuscript was misplaced during handling by the editor—Ed.

PAN-PACIFIC ENTOMOLOGIST
69(2): 191–192, (1993)

Book Review

Hanski, Ilkka & Yves Cambefort (Eds.). 1991. Dung Beetle Ecology. Princeton University Press, Princeton, New Jersey. xiii, 481 p., illus. (ISBN 0-691-08739-3) $60.00.

This book, with its brief title and dust jacket illustration of a world globe covered with dung beetles, is a surprisingly complete review of a vast subject. The specialized subject of the book is carefully placed in the context of general ecological principles, and the evolution and systematics of scarab beetles.

The editors have done an excellent job of organizing and structuring the book. There are three parts: (1) Introduction, (2) Regional Dung Beetle Assemblages, and (3) Synthesis. In twenty chapters, with a total of fifteen contributors, these topics are covered with a satisfying thoroughness. For example, the regional coverage does not leave out any major geographic area or faunal region. There is a smoothness from chapter to chapter that presents a unified whole belying the multiple authorship.

The seemingly unpleasant subject of animal excrement and the organisms that feed on it, or live in it, is actually made interesting in this book. A non-specialist with a general interest in ecology will find it readable and informative. The introduction discusses the ephemeral and patchy nature of the dung habitat and the problems presented to organisms that exploit it. After discussing the general fauna of dung, the authors justify focusing on only one component: the scarab dung beetles. According to the authors, dung beetles are the dominant fauna in dung and "comprise a distinct guild of their own and exhibit the strongest interspecific interactions among themselves." Given the rich variety and abundance of mammalian dung, the next issue is the reason for the dominance of only a few subfamilies of one family of beetles. Here, the authors discuss the preadaptation of humus feeding scarabs that evolved prior to the dominance of mammals (but what fed on dinosaur dung?). As large, herbivorous and omnivorous mammals evolved, the scarabs were ready to move into the new resource and were able to outcompete other insects.

The book is well illustrated with tables, graphs and diagrams. The many methods of resource exploitation by dung feeding scarabs are thoroughly explored. A unique index is particularly noteworthy. Every genus of dung beetle is listed with the number of species known, tribe, and pages referred to in this book. Absence of a page reference to a genus is an indicator of a lack of published information on the genus.

A systematist may get picky about the lack of indication of authorities for identification, or place of deposit of voucher specimens. However, a review work of this nature should not be expected to contain such detailed information that would unnecessarily expand its size and cost. Tables of genera and species in the appendices do have author citations. The classification of the Scarabaeoidea adopted is one favored by European workers, in which sixteen families of dung beetles are recognized. Most American workers recognize only one family (Scarabaeidae).

Holm and Marais in their recent work on the Fruit Chafers of Southern Africa argue strongly against the splitting of Scarabaeidae into multiple families.

Dung Beetle Ecology is a significant contribution to the literature of ecology and evolution. Its price is not out of line with current trends. It could be successfully utilized as a supplementary text in college courses.

Kirby W. Brown, *San Joaquin County Agricultural Commissioner's Office, P.O. Box 1809, Stockton, California 95201.*

PAN-PACIFIC ENTOMOLOGIST
69(2): 192, (1993)

Book Review

Evenhuis, Neal L. (Ed.). 1989. Catalog of the Diptera of the Australasian and Oceanean Regions. Bishop Museum Press and E. J. Brill, Honolulu, Hawaii, 1155 p. Price $85 (ISBN-0-930897-37-4).

This work is an important milestone toward the complete cataloging of all the species of Diptera in the world. The only zoogeographical regions yet to be finished are the Palaearctic and Neotropical.

This catalog covers Australia, Tasmania, New Guinea, New Zealand and the Pacific islands of Hawaii, Guam, eastern Indonesian Archipelago to French Polynesia and Easter Island. In Appendix I, it lists taxa from Antarctica and the surrounding subantarctic islands. Fossil Diptera of Australasia and Oceania are covered in Appendix II.

Each taxon is classified under family, genus and species, with other supergeneric names given where appropriate. In many cases synonymies are listed for genera and species. The large Literature Cited section is a source of additional information. An adequate index gives valid species names, synonyms and higher categories.

The author provides a very helpful section describing and mapping the many far-flung islands covered in this catalog, giving the most up-to-date name for each.

Much credit is due Neal Evenhuis, for seeing the need for this work, for his assigning the various dipterous families to fifty-three taxonomists throughout the world, and for his superb job of coordinating all of the accumulated information into a very usable catalog. The contributing taxonomists are from Australia, Brazil, Canada, Czechoslovakia, Denmark, England, France, Germany, Japan, Netherlands and the United States.

This work documents our present knowledge of the named species of Diptera of the Australasian and Oceanean Regions, and provides an excellent base to which future taxa can be added.

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PAN-PACIFIC ENTOMOLOGIST
69(2): 193, (1993)

Book Review

Armitage, Brian J. 1990. Diagnostic Atlas of North American Caddisfly Adults. 1. Philopotamidae (2nd ed.). The Caddis Press. Athens, Alabama. 72 p.

A worthwhile book with useable illustrated keys, diagnostic descriptions and illustrations of the genitalia of the males and, when known, the female. However in the rewrite an error crept in. In the first edition, *Chimarra angustipennis* was noted as occurring in California, but not here. This was compounded by the synymizing with it of *C. siva* with its Calif. type locality. The other problem was the inadvertent absence of *Dolophilodes andora, D. columbia* and *Wormaldia laona* (Denning, D. G. 1989. "Eight new species of Trichoptera." Pan.-Pacif. Entomol., 75: 123–131).

The work is a major convenience for researchers, an aid in faunal surveys and will permit beginners ready entry to this group. It is available from author at Ohio Biological Survey, Ohio State Univ. 1315 Kinnear Rd., Columbus, Ohio 43212-1192

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PAN-PACIFIC ENTOMOLOGIST
69(2): 194–198, (1993)

THE PAN-PACIFIC ENTOMOLOGIST, FORMATS: TAXONOMIC MANUSCRIPTS AND LOCALITY DATA

Taxonomic Format

The *Pan-Pacific Entomologist* requires taxonomic articles to conform to a standardized format and paragraph sequence that promotes a uniform appearance and order within the journal. The taxonomic format applies to any manuscripts that: (a) are taxonomic in nature, providing or discussing nomenclatural reassignments, synonymies, formal descriptions, or diagnoses, or (b) cite locality data for specimens or geographic information for types. The taxonomic format and paragraph order is listed below:

(1) Taxonomic Name heading: (*Required initial heading for section. Centered heading.*)

Name underlined, with taxonomic author(s), followed by a new status descriptor in capital letters (i.e., NEW GENUS, NEW SPECIES, NEW STATUS, NEW COMBINATION), where appropriate. When citing species names that have been previously reassigned to new genera, place only the taxonomic authors name in parentheses but not the date, if cited, of the species description [i.e., Essigella californica (Essig), 1909; not (Essig, 1909) or (Essig 1909)]; for any author citations that include the year, list the reference in the Literature Cited section. Examples:

Ralus thermophilus Geptor, Holling & Zalick, NEW SPECIES

Ralus philpoti (Donker), 1967, NEW COMBINATION

(2) Synonymy listings. (Optional. Left hanging paragraph.)

These paragraphs end in NEW SYNONYMY, when appropriate. List all citations in the Literature Cited section. If citing geographic data (i.e., type locality) associated with a name, use the locality data format (below). Depository abbreviations may be used for any types for synonyms mentioned under synonymy listings. Avoid discussions of synonyms under synonymy listings; if they must be discussed, do so in a Synonyms or Discussion paragraph after the Diagnosis paragraph. Synonymy examples:

Ralus thermadorus Gustof, 1955: 304-305. Type locality: CALIFORNIA. El DORADO Co.: Placerville. Holotype deposited BM[NHl. NEW SYNONYMY

Ralus hobarti Anderson, 1923: 34-36.

Ralus querteri (Zippler), 1912. Lectotype: AUSTRALIA. NEW SOUTH WALES: Newcastle, 11 Dec 1889, deposited USNM. NEW SYNONYM

(3) Types paragraph. (*Required paragraph before description if a new taxon is being originally described,* but optional if only a new form [morph, sex, etc.] is described for an existing taxon. Indented paragraph format. The Types paragraph is designated "Type-Species" for a genus description, and then lists the generotype.)

All type data must: (a) conform to the locality data format [see Material Examined paragraph and locality data format below]; or (b) alternatively, for holo-, allo-, lecto- or neotypes [not paratypes], data may be quoted [within quotation marks] from the data label. Spell out the depository for holo-, allo-, lecto- or neotypes and list the city in which it occurs; depositories for paratypes may be indicated by abbreviations that are defined earlier in the Methods sections. List *all* types, including paratypes, in the Types paragraph. Use a format for this paragraph that is reasonably similar to the following:

Types.—Holotype, female; data: CALIFORNIA. SAN BERNARDINO Co.: 3 km S of Anytown, 2200 m el, 16 Sep 1977, A. H. Geptor, Pinus lambertiana Douglas; deposited: British Museum (Natural History), London. Paratypes: same data as holotype, 30 females, 6 males; deposited: U.S. National Museum of Natural History, Washington, D.C.

(4) Description paragraph(s). (*Required paragraph(s) for formal description statements for any new or existing taxon,* but optional if no formal description statement is desired for an existing taxon [e.g., a taxonomic review]. Indented paragraph format [reduced to 8 pt type in the journal].)

Use a single, separate paragraph for the description of each sex, morph or life stage; do not describe various body parts in separate paragraphs. Alternatively, a general (unisex) description, occurring as one paragraph, may be followed by separate paragraphs for males and females, noting only their differences. Maintain the same order for morphological sequences among descriptions of multiple taxa. Define any specialized abbreviations in the Methods section.

Description.—Description requirements: (A) Description in telegraphic style [minimum use of words, especially connectives]. (B) Avoid "-ish" endings for colors, instead describe colors more accurately [i.e., not "reddish brown" but "red-brown" or "brown with a light red hue," not "blackish" but "black" "with faint black cast"]. (C) Describe dimension comparisons or ratios in quasi-formula format using decimals and "x" between descriptors [i.e., "wing width 3.5 x length" rather than "wing width three and one-half times its length"]. (D) Use Arabic numerals for all numbers, including those under ten [i.e., "3-5 setae," "2-58 pores," "4 mm long," "setal number formula 2:4:4:5:11," "abdominal segment 4"]; alternatively, if desired, Roman numerals may be used for body segments of components [i.e., "abdominal segment IV," "antennal segment II"]. (E) Fractions should be expressed as word equivalents or decimals [i.e., "0.25" or "one-quarter," not "1/4"], and should have "one-" inserted where it is implied [i.e., "on distal one-third" preferably to "on distal third"]. (F) Avoid English directional descriptors, using Latin instead [i.e., "mesal" or "medial," not "inner"; "distal" or "lateral," not "outer"; "dorsal" or "ventral," not "upper" or "lower"]. (G) Place measurement units after each measurement, do not state "all measurements in mm" and then list only numbers [i.e., "leg lengths: femur 5.0 mm, tibia 3.0 mm"; not "leg lengths (mm): femur 5.0, tibia 3.0"].

(5) Diagnosis paragraph: (*Required paragraph after description if a new taxon is being originally described,* but optional if only a new form [e.g., sex, morph, stage] is described for an existing taxon. Indented paragraph format.)

Diagnosis.—The diagnosis, labeled as such, for newly described species should state, using nontelegraphic style, only those traits necessary to distinguish the new species. For example: "Ralus thermophilus can be distinguished from all other Ralus by its unique combination of . . ." or "Ralus thermophilus very closely resembles R. strobus Alexander, but can be distinguished by its . . ." Do not incorporate non-diagnosis discussions in the diagnosis. If a key is provided in the manuscript, you may chose to simply state "See key" in the Diagnosis paragraph, rather than repeat the diagnostic features there.

(6) Various miscellaneous paragraph(s): (Optional. Indented paragraph format.)

Discussion.—These optional side-headed paragraphs (e.g., [in preferred order] "Synonyms.-," "Distribution.-," "Hosts.-," "Discussion.-," "Etymology.-," etc.) may be added after the Diagnosis paragraph, to discuss and draw attention to particular information. Because purely diagnostic statements go in the Diagnosis paragraph, mention of diagnostic traits in discussion paragraphs may be redundant unless other qualities (e.g., apomorphy, plesiomorphy) of the traits are mentioned or discussed there.

You may use one or more paragraphs with a "Discussion.-" or "Remarks.-" side-heading label under the centered section heading for the taxonomic name. Note, however, that if the discussion is long or wide-ranging, it may be more appropriate to create a separate Discussion section, with a centered heading, after the taxonomic section of the manuscript. If you chose to use a separate enlarged Discussion section later in the manuscript, it may be appropriate to use paragraph side-headings within it, to designate information from various taxa or subjects.

Whether either discussion paragraph(s) in a taxonomic section, or a separate Discussion section later, are used, do not list data for a particular specimen in the text. (This is because specimen data must conform to the locality data format, which is awkward within text.) If you must refer to a specimen using its locality, do so generally and give reference to its data citation in the Material Examined paragraph (i.e., ". . . but the male from Redwood Creek, California [see Material Examined] . . ." It is permissible, however, to generally refer to locations in the text without evoking the locality data format (e.g., "We collected additional specimens near Hatfield Creek, Gunnison Co., Colorado.").

If you comment on the etymology of the name, create a separate paragraph labeled "Etymology.-" as the last in this sequence of miscellaneous paragraphs, and place it immediately before

the Material Examined paragraph. Do not place gratuitous remarks in an Etymology paragraph, put them in the Acknowledgment section at the end of the manuscript.

(7) Material Examined paragraph: (*Required terminal paragraph* [reduced to 8 pt type in journal] *for section. Indented paragraph format.*)

Material Examined.—(See example of Material Examined paragraph below.). This paragraph is necessary, whether material in addition to that contained in the Types paragraph was examined or not. If only types were examined, their data is listed under Types, and the Material Examined paragraph should state simply "see Types."

Other Conventions for Taxonomic Articles

Abstracts.—All new taxa or taxonomic reassignments that are mentioned in the abstract must be followed by the appropriate new status descriptor in capital letters (i.e., NEW SPECIES, NEW GENUS, NEW SYNONYMY, etc.)

Depository Abbreviations.—Abbreviations for specimen depositories (e.g., museums, personal collections) may be used, and are preferred for non-types. Place abbreviations for depositories (including mention of their city) in a separate, appropriately labeled paragraph at the end of the Methods (or, in its absence, Introduction) section. Do not incorporate depository abbreviations in the Acknowledgement section. Note that depository information (including city) must be fully written-out for holo-, allo-, lecto-, or neotypes in the Types paragraph, but that paratype depositions noted there may use abbreviations; mention of depositories for the types of synonyms in the synonymy listings should use abbreviations.

Keys.—Keys are optional, but if provided, they must meet the following criteria. Keys must be dichotomous, and have "back-tracking" notation immediately after each couplet number. Couplet statements must be reasonably uniform, telegraphic, and comparative between opposing couplets, where possible; statements should follow the description requirements (above). Where new taxa are keyed out, follow their name with the appropriate new status descriptor in capital letters. Couplet example:

2a (1b) Thorax black; wing length < 3.0 x width; labium with 4-6 sharp-tipped setae. . . R. cobblus
2b Thorax white; wing length > 3.5 x length; labium with 7-15 incrassate setae. . . . . R. thermophilus NEW SPECIES

Locality Data Format

All locality data associated with specimens (except types) must occur in a separate Material Examined paragraph that ends the paragraph series for the section for a given taxonomic name; data for types [holo-, allo-, lecto-, neo-, paratypes] must occur in the Types paragraph (see taxonomic format), but all other material is listed in the Material Examined paragraph. In Scientific Notes involving new records or hosts, the data paragraph, usually labeled "Records.-," occurs at the end of the note.

The *Pan-Pacific Entomologist* uses a particular, order-dependant telegraphic format for locality data to minimize the necessary printing of geopolitical entities and information in the data block, as follows:

For all data:

(1) List *country* first, in all capital letters, followed by a period [.] (i.e., "USA." or "CANADA."). When more than one country is listed in a given data block. List the countries *in alphabetical order* in the telegraphic format, *except that U.S.A. occurs first in the data block* [its format is treated differently, see (2a, 2′) below]. If only U.S.A. data is present in the data block, omit indication of the country. Mention a country only once in the telegraphic format.

For U.S.A. data (50 states only, treat non-state political associates [e.g., Guam, Virgin Islands] as other countries):

(2a) Denote *states* in all capital letters, followed by a period [.] (i.e., "CALIFORNIA."). List states *in alphabetical order,* and mention a state only once in the telegraphic format.

(2b) Next denote *counties* (or equivalents) in all capital letters and underlined [to indicate italics], followed by "Co." and a colon [:] (i.e., "SACRAMENTO Co.:"). List counties *in alphabetical order* after their state, and mention a county only once. *It is the responsibility of the author to list all counties, even if they do not occur on data labels*; consult an appropriate atlas/map. If

the county cannot be ascertained, list the data under "COUNTY UNKNOWN:" at the end of the string for the given state.

For countries other than U.S.A.:

(2′) List *next largest political area designation below federal level* [i.e., Canadian *provinces,* Mexican *states,* Japanese *perfectures*] in all capital letters and underlined [to indicate italics], followed by a colon [:] (i.e., "SONORA:" or "ALBERTA:"). List these geopolitical subdivisions *in alphabetical order* after their country, and mention each only once. *It is the responsibility of the author to list all appropriate foreign subdivisions, even if they do not occur on data labels*; these subdivisions can usually be found in Webster's New Geographic Dictionary (Merriam-Webster Publishers, Springfield, Massachusetts) or on an appropriately detailed local atlas/map. If the subunit cannot be ascertained, list the data under "PROVINCE [or STATE, etc., as appropriate] UNKNOWN:" at the end of the string for the given country.

For all data:

(3) For that local portion of the locality data that is subordinate to the level of a U.S. county or a major foreign gopolitical subdivision, list the local descriptor items (location, date, collector, host, etc.) separated by commas [,], and separate information from various locations by semicolons [;]. When the local data for a given county or foreign subdivision has been completed, end in a period [.] and begin the next larger (alphabetized) division (i.e., country, state, county). Minimize repeating redundant local locality information inasmuch as clarity can be maintained and length can be shortened; this requires planning the data order for efficient listing. For example, you may replace redundant descriptors with "same except," "same loc." or similar notations (e.g., ". . . ; 10 km S of South Lake Tahoe, hwy 50, 2 Jul 1977; same loc., 4 Aug 1983; . . .").

(A) For the local location, use the format "5 km E *of* Palo Alto," including "of," not "5 km E Palo Alto" ["East Palo Alto" may be a place!] *All distances and elevations cited must be in metric, even if they are not so on data label and the author must convert.* If you want to list distances in miles or elevations in feet (as "ft" not "'"), place these non-metric measurements within parentheses immediately after their metric conversions [i.e., "5 km (3 mi) E of Anywhere, 3050 m (10,000 ft)"]; *do not include English measurements without metrics.* Omit terminating periods after abbreviations for locations or their descriptors (e.g., hwy, mts, cyn, nr, jct); omit initial capital letters for these also, unless a direction or proper name is involved (e.g., N, E, SW, Mt Rushmore, Haines Jct).

(B) For dates, use three Roman letter abbreviations for months, with day before month, and entire year after month [i.e., "25 Jun 1985"].

(C) Include any information on collector, data number, or host association after the location and date. (If the host is mentioned for the first time in the article, it must have the spelled out taxonomic author cited.) When listing an abbreviated host genus, or a person name, retain periods after the abbreviations (e.g, *P. ponderosa,* F. W. Ringer).

(D) If the number of specimens, sexes or morphs, or an abbreviation of their depository is to be included for a data label, place these last, just before the terminating semicolon (or period) for the data.

Example of data format and Material Examined paragraph:

Material Examined.—USA. CALIFORNIA. CALAVERAS Co.: 18 km (10.8 mi) E of Arnold, 1680 m (5516 ft), 17 Sep 1977, A. H. Geptor, P. lambertiana Douglas, 1 female. SAN BERNARDINO Co.: San Bernardino Mts, 3 km S of Jenks Lake, 2200 m, 16 Aug 1977, A. H. Geptor, P. lambertiana, 14 females; 5 km NW of Gregory, 1490 m, 17 Aug 1977, F. W. Holling, P. ponderosa Lawson, 16 females. OREGON. JACKSON Co.: 15 km S of Union Creek, hwy 62, 850 m, 5 Apr 1978, F. W. Holling, P. lambertiana, 3 females. AUSTRALIA. AUSTRALIAN CAPITAL TERRITORY: Canberra, 8 Sep 1983, D. S. Lee, 4 males. NEW SOUTH WALES: Newcastle, 8 Oct 1974, J. Cashner (CSIRO). WESTERN AUSTRALIA: Perth, 9 Nov 1976, A. J. Rammery, 6 males; same loc., 12 Nov 1976, S. W. Rammery, 7 females. CANADA. ALBERTA: 6 km N of Edmonton, 12 Jun 1983, D. Kinny, Picea sp. BRITISH COLUMBIA: 21 km S of 100 Mile House, hwy 97, 910 m, 13 Jul 1978, P. contorta Douglas, J. T. Sorensen (78G125), 3 females; 40 km E of Prince George, hwy 16, 14 Jul

1978, 8 females (deposited BM[NH]); 5 km N of Spuzzum, hwy 1,13 Jul 1978, P. monticola Douglas, 6 females. INDIA. MADHYA PRADESH: Mandla, 28 Jun 1988, 4 males; 3 km E of Jabalpur, 30 May 1989, P. S. Bashu; Itarsi, 2 Sep 1957, 3 females (deposited USNM). MAHARASHTRA: 2 km S of Wardha, 6 Feb 1945, D. Waspal. ITALY. TOSCANA: Siena, 12 Jun 1966, T. Peller, 6 males, 3 females. MEXICO. CHIHUAHUA: El Carrizo, 14 Aug 1945. JALISCO: 1 km N of Tomatlan, 13 May 1979. OAXACA: Choapan, 6 Dec 1957, F. George; Tlaxiaco, 23 Sep 1966, K. Gunner. NEW ZEALAND. CANTERBURY: Ashburton, 14 Oct 1971, D. S. Keller; 15 km W of Rangiora, 12 Dec 1956, W. W. Lessa; same loc., 14 Jan 1978, O. P. Hue. OTAGO: Alexandra, 7 Jun 1955, F. Doncaster. TARANAKI: Waitara, no date. PEOPLE'S REPUBLIC OF CHINA. FUJIAN: 2 km S of Nanping, 7 Oct 1956, Y.-L. Wong, 7 females, 2 males. SHANDONG: Xintai, 1 Feb 1978, W.-Y. Chu; 3 km E of Jimo, 23 Sep 1983, W.-Y. Chu.

PAN-PACIFIC ENTOMOLOGIST
Information for Contributors

See volume 66 (1): 1–8, January 1990, for detailed general format information and the issues thereafter for examples; see below for discussion of this journal's specific formats for taxonomic manuscripts and locality data for specimens. Manuscripts must be in English, but foreign language summaries are permitted. Manuscripts not meeting the format guidelines may be returned. Please maintain a copy of the article on a word-processor because revisions are usually necessary before acceptance, pending review and copy-editing.

Format. — Type manuscripts in a legible serif font IN DOUBLE OR TRIPLE SPACE with 1.5 in margins on one side of 8.5 × 11 in, nonerasable, high quality paper. THREE (3) COPIES of each manuscript must be submitted, EACH INCLUDING REDUCTIONS OF ANY FIGURES TO THE 8.5 × 11 IN PAGE. Number pages as: title page (page 1), abstract and key words page (page 2), text pages (pages 3+), acknowledgment page, literature cited pages, footnote page, tables, figure caption page; place original figures last. List the corresponding author's name, address including ZIP code, and phone number on the title page in the upper right corner. The title must include the taxon's designation, where appropriate, as: (Order: Family). The ABSTRACT must not exceed 250 words; use five to seven words or concise phrases as KEY WORDS. Number FOOTNOTES sequentially and list on a separate page.

Text. — Demarcate MAJOR HEADINGS as centered headings and MINOR HEADINGS as left indented paragraphs with lead phrases underlined and followed by a period and two hypens. CITATION FORMATS are: Coswell (1986), (Asher 1987a, Franks & Ebbet 1988, Dorly et al. 1989), (Burton in press) and (R. F. Tray, personal communication). For multiple papers by the same author use: (Weber 1932, 1936, 1941; Sebb 1950, 1952). For more detailed reference use: (Smith 1983: 149–153, Price 1985: fig. 7a, Nothwith 1987: table 3).

Taxonomy. — Systematics manuscripts have special requirements outlined in volume 69(2): 194–198; if you do not have access to that volume, request a copy of the taxonomy/data format from the editor before submitting manuscripts for which these formats are applicable. These requirements include SEPARATE PARAGRAPHS FOR DIAGNOSES, TYPES AND MATERIAL EXAMINED (INCLUDING A SPECIFIC FORMAT), and a specific order for paragraphs in descriptions. List the unabbreviated taxonomic author of each species after its first mention.

Data Formats. — All specimen data must be cited in the journal's locality data format. See volume 69(2), pages 196–198 for these format requirements; if you do not have access to that volume, request a copy of the taxonomy/data format from the editor before submitting manuscripts for which these formats are applicable.

Literature Cited. — Format examples are:

Anderson, T. W. 1984. An introduction to multivariate statistical analysis (2nd ed). John Wiley & Sons, New York.

Blackman, R. L., P. A. Brown & V. F. Eastop. 1987. Problems in pest aphid taxonomy: can chromosomes plus morphometrics provide some answers? pp. 233–238. *In* Holman, J., J. Pelikan, A. G. F. Dixon & L. Weismann (eds.). Population structure, genetics and taxonomy of aphids and Thysanoptera. Proc. international symposium held at Smolenice Czechoslovakia, Sept. 9–14, 1985. SPB Academic Publishing, The Hague, The Netherlands.

Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in *Aedes albopictus*. Evolution, 42: 895–899.

Sorensen, J. T. (in press). Three new species of *Essigella* (Homoptera: Aphididae). Pan-Pacif. Entomol.

Illustrations. — Illustrations must be of high quality and large enough to ultimately reduce to 117 × 181 mm while maintaining label letter sizes of at least 1 mm; this reduction must also allow for space below the illustrations for the typeset figure captions. Authors are strongly encouraged to provide illustrations no larger than 8.5 × 11 in for easy handling. Number figures in the order presented. Mount all illustrations. Label illustrations on the back noting: (1) figure number, (2) direction of top, (3) author's name, (4) title of the manuscript, and (5) journal. FIGURE CAPTIONS must be on a separate, numbered page; do not attach captions to the figures.

Tables. — Keep tables to a minimum and do not reduce them. Table must be DOUBLE-SPACED THROUGHOUT and continued on additional sheets of paper as necessary. Designate footnotes within tables by alphabetic letter.

Scientific Notes. — Notes use an abbreviated format and lack: an abstract, key words, footnotes, section headings and a Literature Cited section. Minimal references are listed in the text in the format: (Bohart, R. M. 1989. Pan-Pacific. Entomol., 65: 156–161.). A short acknowledgment is permitted as a minor headed paragraph. Authors and affiliations are listed in the last, left indented paragraph of the note with the affiliation underscored.

Page Charges. — PCES members are charged $30 per page. Members without institutional or grant support may apply to the society for a grant to cover up to one half of these charges. Nonmembers are charged $60 per page. Page charges do not include reprint costs, or charges for author changes to manuscripts after they are sent to the printer. Contributing authors will be sent a page charge fee notice with acknowledgment of initial receipt of manuscripts. At that time, they may apply to the *Treasurer*, using provided forms, for partial waiver of page charges.

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THE GENUS *TIBILIS* STÅL IN MEXICO (HETEROPTERA: PENTATOMIDAE)

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Abstract.—The genus *Tibilis* Stål is reported from Mexico for the first time with a provenance of the Lacandon Jungle of Chiapas. *Tibilis* is a South American genus with one species extending into Panama and Costa Rica. The Chiapanecan species is described as new, differentiated primarily by the male and female genitalia.

Key Words.—Insecta, Pentatomidae, stinkbug, taxonomy, Mexico, *Tibilis*

The pentatomine genus *Tibilis* Stål (1858 [1860]) contains ten nominal species all from South America with one species, *Tibilis parva* (Distant 1893), extending into Panama and Costa Rica. *Tibilis* belongs to section 3 of the tribe Pentatomini, possessing an elevated metasternum apposed by a basal abdominal spine. A key to this group of genera was provided by Rolston et al. (1980).

Tibilis has not been reviewed or revised, thus there are no keys or modern descriptions for any of the species except *T. parva.* Ruckes (1960) redescribed *T. parva,* which he transferred to *Tibilis* (from *Brachystethus* Laporte), when he described a new genus and species, *Paratibilis confusus,* from Mexico. *Paratibilis* is closely related to *Tibilis,* differing by the metasternum that is obtusely carinate rather than flat-topped and pentagonal. Other differences described by Ruckes (1960), and later by Grazia & Barcellos (1991), are the bucculae that are uniform in height in *Paratibilis,* but elevated anteriorly in *Tibilis,* and the juga that are convergent before the tylus in *Tibilis,* whereas in *Paratibilis,* the juga do not surpass the tylus. Grazia & Barcellos (1991) redescribed *Paratibilis confusus* Ruckes, comparing it to *Tibilis subconspersa* Stål, the type of the genus.

The most recently named species of *Tibilis* were described by Bergroth (1914) and Breddin (1903, 1914). Bergroth stated that the differences between his new species (*T. compascens* Bergroth and *T. laeviventris* Bergroth) and the type species, *Tibilis subconspersa* Stål, were the relative lengths and coloration of the antennal segments. Breddin did not compare his new species to any of those previously described. Neither Breddin nor Bergroth made mention of the genitalia. Our examination of material representing *Tibilis parva* and two other South American species, one of which we believe to be *T. subconspersa,* indicates that the critical differences between species in this genus are found to be in the genitalia. We do not consider differences in coloration or the proportions of the antennal segments to be dependable for the separation of species in the Pentatomidae.

In the absence of a revisionary study and review of the types, it is not possible to determine South American specimens with certainty. However, in the collection of the Universidad Nacional Autonoma Mexico (UNAM), there is a long series

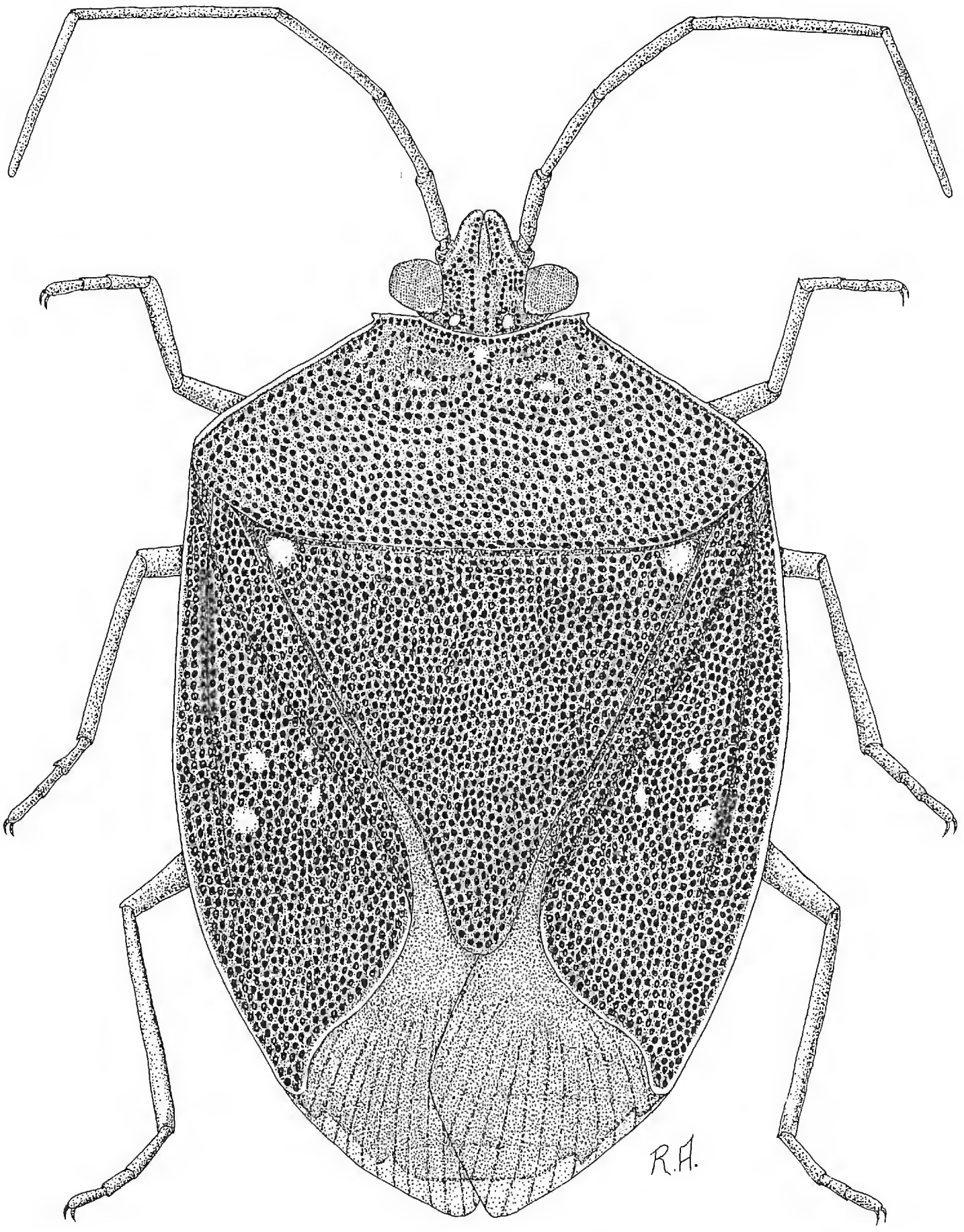
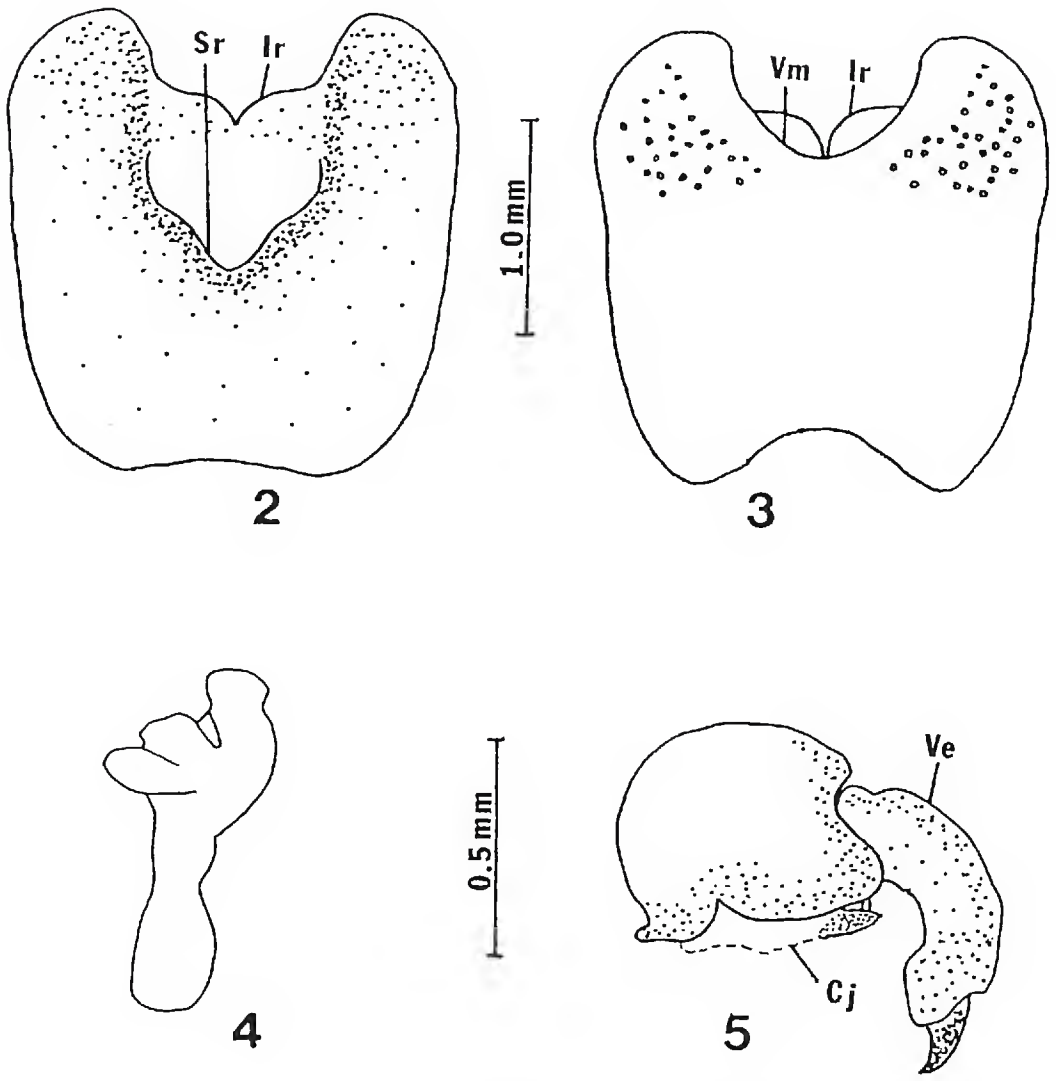


Figure 1. *Tibilis chiapensis* Thomas & Brailovksy, NEW SPECIES.

of specimens from the Lacandon Jungle of Chiapas, Mexico. The presence of this genus in Mexico is of considerable interest, because the North American pentatomine fauna is quite well known. An examination of the genitalia of these specimens indicates that they are quite distinct from *Tibilis parva* and from the South American specimens available to us. For these reasons, and because of its disjunct distribution, we describe the Chiapas species as new.

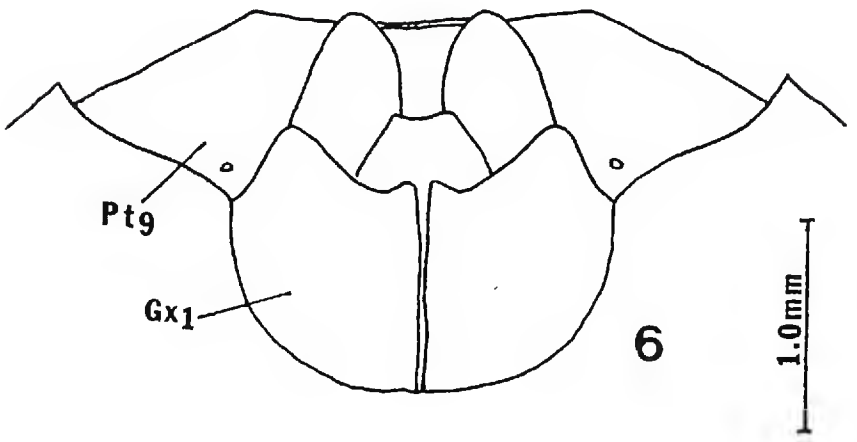


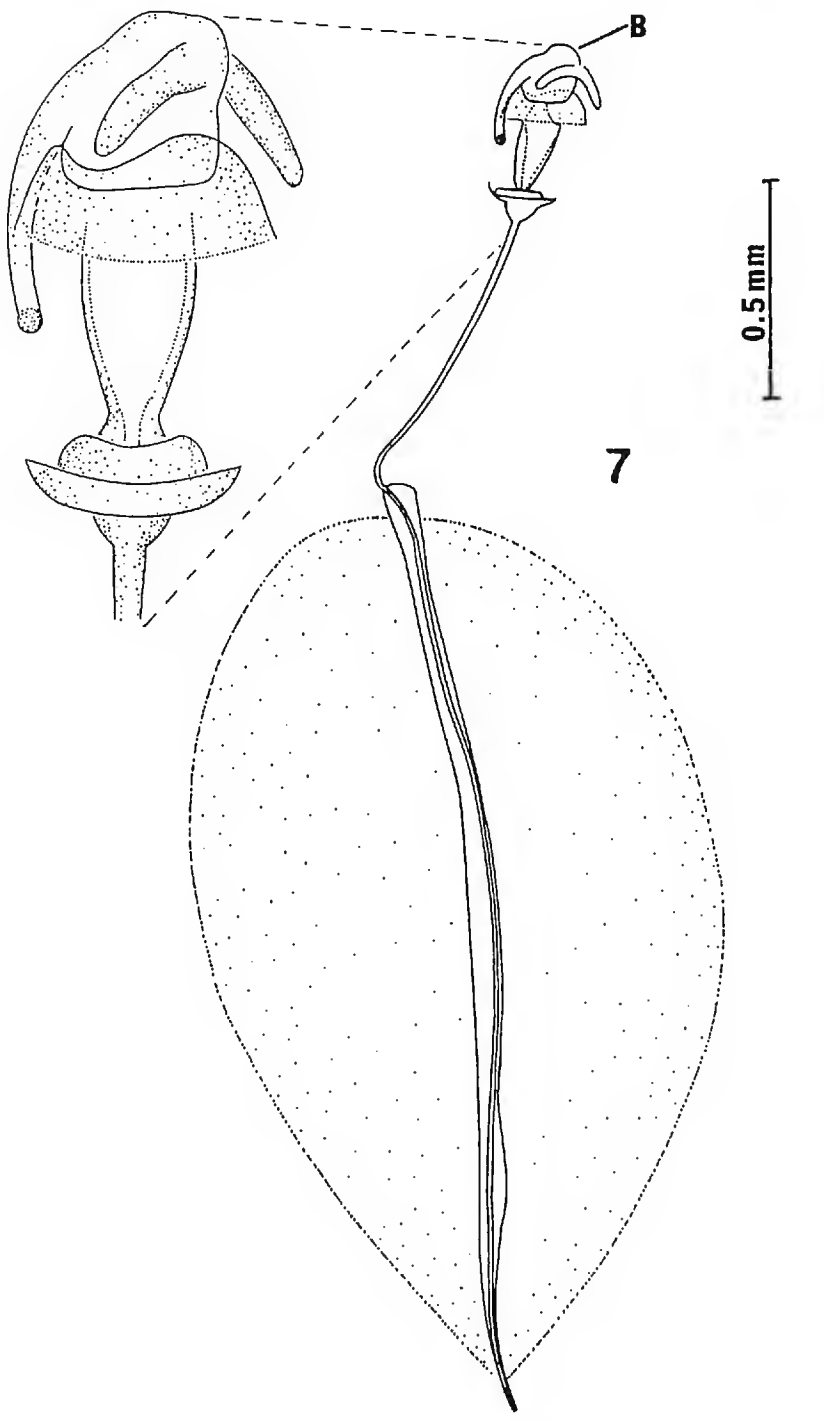
Figures 2–5. Male genitalia of *Tibilis chiapensis.* Figure 2. Pygophore, dorsal view. Figure 3. Pygophore, ventral view. Figure 4. Left Paramere, mesial view. Figure 5. Aedeagus, lateral view. Abbreviations: Ir = inferior ridge, Sr = superior ridge, Vm = ventral margin.

Tibilis chiapensis, Thomas & Brailovsky, new species
Figs. 1–7

Types.—Holotype, male; data: MEXICO. *CHIAPAS:* Bonampak, 23–25 May 1984, Adolfo Ibarra. Holotype deposited in the Universidad Nacional Autonoma Mexico (UNAM), Mexico D.F. Paratypes: 1 male and 1 female with same data as holotype deposited in collection of D. B. Thomas (DBT). Other paratypes: MEXICO. *CHIAPAS:* Bonampak (Ruinas de Bonampak), 2–4 May 1978, H. Brailovsky & E. Barrera, 9 males, 20 females (UNAM); Bonampak (Ruinas de Bonampak), 20–25 May 1984, E. Barrera, M. Garcia & A. Ibarra, 40 males, 56 females (UNAM), 1 male, 1 female (DBT), 1 male, 1 female (L. H. Rolston), 1 male, 1 female (D. A. Rider), 1 male, 1 female (J. E. Eger). Agua Azul, 22 May 1979, L. Rivera, 1 female (UNAM). Agua Azul, 1 May 1978, E. Barrera, 1 female (UNAM).

Description.—Male. Form ovate, depressed. Dorsal color appearing brown, the result of dense, contiguous red-brown punctures. Each basal angle of scutellum with round, yellow callus (Fig. 1). Length 12 mm, width across pronotum 6.5 mm. *Head:* Dorsum tan with red-brown punctures in irregular, longitudinal lines. Juga convergent anteriorly, margins outlined in red-brown. Ocelli large; intraocellar distance approx. 2× width of ocellus. Eyes bulbous, intraocular distance approx. 1.5× width of eye. Apex of antennal segment I extends past tips of juga; segments with minute brown punctures; segment V bicolor, basal one-third yellow, apex tan; segments IV and V longest, subequal in length, segment I shortest, II slightly longer than I. Bucculae apparently uniting though nearly





Figures 6–7. Female genitalia of *Tibilis chiapensis*. Figure 6. External terminalia. Figure 7. Spermatheca and spermathecal pump. Abbreviations: B = bulb of spermathecal pump, Gx1 = first gonocoxite, Pt9 = ninth paratergite.

obsolescent behind. Apex of rostrum attaining only to mesocoxae, segment I not attaining cervix. *Thorax:* Anterolateral pronotal margin subrectilinear with narrow calloused bead. Humeral angles rounded, not produced. Apex of scutellum subacute. Posterior margin of corium arcuate to lateral margin which terminates in short abrupt angle intruding on membrane; latter infuscated. All pleura, including evaporatorium, dark punctate. Scent gland ruga elongate, sinuate, reaching approx. three-fourths distance from ostiole to metapleural margin. Mesosternum with thick, obtusely produced carina projecting anteriorly between procoxae; posteriorly contiguous with elevated pentagonal metasternum. Metasternum deeply notched posteriorly. Femora densely spotted with brown. Tibia prismatic in cross-section. *Abdomen:* Venter yellow-tan with dense brown freckling. Spiracular openings large, margins ringed with dark brown. Sternite III (second visible) with forwardly protruding spine directed into metasternal notch. Connexiva dark brown with mesial spot on outer margin of each segment; angles not produced but minutely black tipped. *Genitalia:* Pygophore with small dorsal opening; superior ridge broadly, sinuately v-shaped (Fig. 2), evanescing laterally and not continuous with inferior ridge or ventral margin; latter broadly, deeply u-shaped in ventral view (Fig. 3); inferior ridge erectly, thinly carinate, with narrow, v-shaped, mesial emargination. Paramere with trilobate head (Fig. 4), lobes folded toward one another. Aedeagus with large, pendulous, sclerotized vesica. Membranous conjunctiva with semisclerotized penial lobes ventral in position with penisfilum short, projecting ventrally between conjunctival lobes (Fig. 5).

Female.—Genitalia. Basal plates (first gonocoxites) with posterior margins sinuately lobed, mesial angles angularly produced; spiracles present on ninth paratergites (Fig. 6). Bulb of spermathecal pump with 2 short and 1 long digitiform appendages (Fig. 7).

Diagnosis.—The new species differs from *T. subconspersa* by having a proportionately smaller head as well as differences in the male and female genitalia. From the other species examined, the only significant differences appear in the genitalia. In *T. parva,* the ventral margin of the male pygophore has a deeply and narrowly u-shaped emargination instead of the open v-shaped margin seen in *T. chiapensis.* The posterior margins of the female basal plates are concavely sinuate in *T. chiapensis,* but the margin is straight or weakly convex in *T. parva.*

Variation.—The type series is quite uniform with only slight differences in size and color. Females are slightly larger (by about 1 mm) than males.

Distribution.—The two localities in the type series are 125 km apart in the state of Chiapas. Both localities are lowland tropical rain-forest.

Etymology.—The species is named for the Mexican state of Chiapas.

Material Examined.—Known only from the type series.

Acknowledgment

We thank Richard Ashley for the habitus drawing of the new species.

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NEW NEOTROPICAL AMISEGINE WASPS (HYMENOPTERA: CHRYSIDIDAE)

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Abstract.—Eleven new Amiseginae are described from the Neotropical Region, including nine species of *Adelphe*: *A. argentea* NEW SPECIES, *A. dominicana* NEW SPECIES, *A. hansoni* NEW SPECIES, *A. limonae* NEW SPECIES, *A. meridae* NEW SPECIES, *A. minuta* NEW SPECIES, *A. nitida* NEW SPECIES, *A. paralaevis* NEW SPECIES and *A. ziva* NEW SPECIES, and two of *Amisega*: *A. geminata* NEW SPECIES and *A. gloriosa* NEW SPECIES. *Duckeia vagabunda* Kimsey is now recorded from Costa Rica in addition to the original collection site in Mexico.

Key Words.—Hymenoptera, Chrysididae, Amiseginae, *Adelphe, Amisega,* Neotropics

Amisegine chrysidids are found in very few insect collections around the world, and even those that have them generally have a small number of representatives. Despite this apparent rarity, these wasps may actually be common in some situations. The redoubtable efforts of Lubomir Masner, and the intensive sampling of the Costa Rican wasp fauna, organized by Ian Gauld, Dan Janzen and Paul Hanson, have shed some light on the actual size of this group.

There seem to be two basic factors involved in the discrepancy between the commonness in collections versus nature. The first has to do with search images. Most collectors simply never see these wasps. Female amisegines tend to spend most of their time, in or on, the leaf litter searching in cryptic situations for the walking stick host eggs; whereas males rest on or fly among, low vegetation. The second factor involves collecting techniques. Masner uses pan traps and modified malaise traps, and Gauld and Hanson also use malaise traps. Appropriately situated, both techniques are very effective at catching amisegine wasps.

In the Western Hemisphere, the extent of the amisegine fauna has been underestimated. Prior to the survey of the Costa Rican Hymenoptera, only two *Amisega* and three *Adelphe* species were recorded from that country. The survey has revealed two more undescribed species of *Amisega* and six of *Adelphe,* as well as a species of *Duckeia, D. vagabunda* Kimsey, recorded previously only from Mexico. As a result, the revisions of *Adelphe* (Kimsey 1986) and *Amisega* (Kimsey 1987), which included species keys, are clearly inadequate based on the material described here.

Masner's collecting has revealed a great deal of island endemism in *Adelphe.* Every Caribbean island that he has sampled has turned up one or more endemic species. If this is typical, then given the diversity of genera in southeast Asia, the species diversity there is probably even greater than in the Caribbean.

Once sufficient numbers of these taxa are described it should be possible to trace the evolutionary relationships among them with more accuracy than has been done by Kimsey & Bohart (1991). In particular it will be very interesting to examine the evolutionary relationships among the *Adelphe* species on Caribbean islands and the mainland, to see how these wasps, with poor dispersal capabilities, managed to colonize so many islands.

Although there are female specimens of *Adelphe* collected at some of the localities listed here, it has proven impossible, so far, to definitively associate them with any of the males. Therefore, at this point the females for the *Adelphe* species described here are unknown.

Depositories and Abbreviations.—The majority of specimens described below are from the Canadian National Insect Collection, Ottawa, Ontario (OTTAWA). The remainder are deposited in the Bernice P. Bishop Museum, Honolulu, Hawaii (HONOLULU), National Museum of Natural History, San José, Costa Rica (SAN JOSE), and the Bohart Museum of Entomology, University of California, Davis (DAVIS). Two abbreviations are used throughout the descriptions as units of distance: MOD = midocellus diameter and PD = puncture diameter.

ADELPHE ARGENTEA, NEW SPECIES
(Fig. 1)

Type.—Holotype male: DOMINICAN REPUBLIC. *PEDERNALES PROV.:* 9.5 km N of Cabo Rojo, Jul 1990, L. Masner. Deposited in the Canadian National Collection, Ottawa.

Male.—(Holotype). Body length 3.5 mm. Face (Fig. 1) with dense shallow punctures, 0.1–0.3 PD apart; scapal basin with broad ovoid zone of cross-ridging; mandibles with 2 apical teeth; clypeal apex thickened, forming nearly a right angle in profile; subantennal distance 1.2 MOD; malar space 3.5 MOD; postocular distance 1 MOD; occipital carina well-developed but not flared; flagellomere I length 3.5× breadth; flagellomere II 2.6× as long as broad; mesopleuron evenly and densely punctate, punctures 0.2 PDs apart; scrobal sulcus entirely lacking; metanotal disk 5× as broad as long; propodeal dorsomedial enclosure coarsely cross-ridged; posteromedial enclosure polished, irregularly and sparsely punctate, punctures occurring mostly dorsally, lateral tooth small and obtuse. Ocular setae 0.4 MOD long. Head, thorax and abdomen black; scape brown with red accent; flagellum and pedicel dark brown; legs red, except hindtibia, hindtarsi and hindfemoral apex dark brown. Body with extensive erect silvery setae. Flagellar setae very short and dense, 0.2 MOD long.

Diagnosis.—The lack of a scrobal sulcus and silvery vestiture will immediately distinguish *A. argentea* NEW SPECIES from other *Adelphe* species. *Adelphe argentea* does not appear to be closely related to any other *Adelphe.*

Material Examined.—See type.

ADELPHE DOMINICANA, NEW SPECIES
(Fig. 2)

Type.—Holotype male: DOMINICAN REPUBLIC. *PEDERNALES PROV.:* 14.5 km N of Cabo Rojo, Jul 1990, 165 m, arid scrub, L. Masner. Deposited in the Canadian National Collection, Ottawa.

Male.—(Holotype). Body length 4.5 mm. Face (Fig. 2) densely punctate, with punctures 0.1–0.5 PD apart; scapal basin smooth without cross-ridging, with few scattered punctures; mandibles with 2 apical teeth; clypeal apex thickened, forming nearly a right angle in profile; subantennal distance 1 MOD; malar space 3.8 MOD; postocular distance 1.5 MOD; occipital carina complete but not flared; flagellomere I length 4.7× breadth; flagellomere II 2.3× as long as broad; mesopleuron polished with few scattered punctures, 1–4 PD apart; scrobal sulcus 8× as long as broad; metanotal disk 3× as broad as long; propodeal dorsomedial enclosure densely cross-ridged; posteromedial enclosure smooth with punctures clumped along dorsal margin, lateral tooth tiny, low obtuse angle. Ocular setae 0.5 MOD long. Head, thorax and abdomen black with faint coppery tints on face; entire antennae black; legs brown, trochanters and tibiae paler and somewhat red. Body with extensive erect pale setae. Flagellar setae 0.1 MOD long.

Diagnosis.—The long flagellomere, I, short malar space, long narrow scrobal sulcus of *A. dominicana* suggest a close relationship with *A. mexicana* Mocsary, and to a lesser extent with *A. puertoricana* Kimsey and *A. cubana* Kimsey. Diagnostic features for *A. dominicana* NEW SPECIES, which will separate it from related species, include: metanotal disk 3× as wide as long, subantennal distance 1 MOD and flagellar setae very short and dense.

Material Examined.—See type.

Adelphe hansoni, NEW SPECIES
(Fig. 3)

Type.—Holotype male: COSTA RICA. *SAN JOSE PROV.:* Parque Nacional Braulio Carrillo, 8 km NE of Tunel, 1100 m, 15 May 1988, P. Hanson. Deposited in the Bohart Museum of Entomology, University of California, Davis.

Male.—(Holotype). Body length 2.5 mm. Face (Fig. 3) highly polished, punctures shallow and scattered, 2–4 PD apart; scapal basin smooth and polished without striae, rugae or punctures; mandibles with 2 apical teeth; subantennal distance 2 MOD; clypeal apex thickened, forming nearly a right angle in profile; malar space 4 MOD; postocular distance 1.7 MOD; occipital carina complete and not flared; flagellomere I length 3.7× breadth; flagellomere II 2.5× as long as broad; mesopleuron polished and impunctate; scrobal sulcus 5× as long as broad; metanotal disk 1.8× as broad as long; propodeal dorsomedial enclosure with narrow zone of cross-ridging on either side of smooth medial welt, flanked laterally by another equally wide impunctate welt; posteromedial enclosure irregularly rugose, lateral tooth prominent and acute. Ocular setae 0.8 MOD long. Head and thorax black, dorsum with bronzy tints; abdomen brown with red accent, paler basally; scape and pedicel yellow; flagellum black; legs including coxae yellow. Body with extensive erect black setae. Flagellar setae 0.8 MOD long.

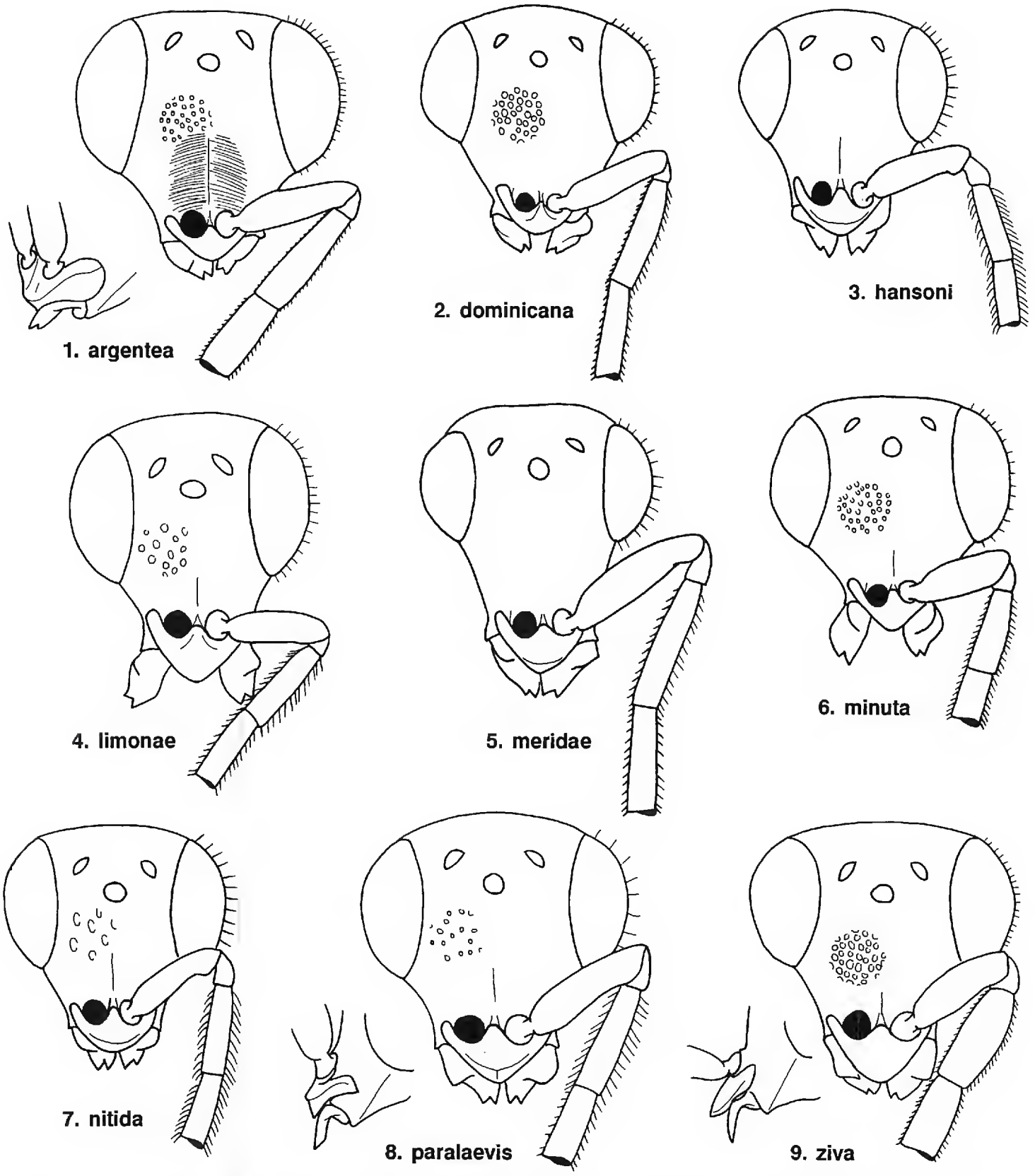
Diagnosis.—This species can be immediately distinguished by the long malar space and subantennal distance. Additional diagnostic features include the bronzy dorsum and yellow legs, scape and pedicel. *Adelphe ziva* from Jamaica has similar facial and antennal dimensions but differs substantially in color and the length of the ocular and flagellar setae.

Material Examined.—See type.

Adelphe limonae, NEW SPECIES
(Fig. 4)

Type.—Holotype male: COSTA RICA. *LIMON:* 7 km SW of Bribri, 50 m, Sep 1989, P. Hanson. Holotype deposited in the Bohart Museum of Entomology, University of California, Davis. Paratypes: 9 males (SAN JOSE, DAVIS): 4 males: same data as holotype except Jan–Feb 1990; 3 males: 4 km SW of Bribri, Sep–Nov 1989, P. Hanson; 2 males: Limón, Parque Nacional Tortuguero, Est. 4–esquinas, 0 m, Jun–Aug 1989, Solano.

Male.—(Holotype). Body length 4 mm. Face (Fig. 4) polished with shallow punctures about 1 PD apart; scapal basin polished with narrow strip of cross-ridging on either side of midline; clypeal apex nearly flat in profile, not thickened or forming right angle; mandibles with 2 apical teeth; subantennal distance 1.7 MOD long; malar space 2.4 MOD; postocular distance 1.2 MOD; occipital carina well developed but not flared; flagellomere I length 3× breadth; flagellomere II 2.5× as long as broad; mesopleuron polished with scattered small punctures between 2 and 4 PDs apart; scrobal sulcus 4.3× as long as broad; metanotal disk 3.5× as broad as long; propodeal dorsomedial enclosure cross-ridged; posteromedial enclosure polished and only punctate marginally, lateral tooth small and subacute. Ocular setulae 0.5 MOD long. Head, thorax and abdomen black with red accent on basal abdominal



Figures 1–9. Front view of male face, *Adelphe* species. Punctation and setation only shown on right side. Oblique (1a), or lateral (8a, 9a) views of clypeus, mandible and malar space.

tergum; face, vertex, pronotum, scutum, scutellum and metanotum with strong brassy highlights; pedicel red; flagellum dark brown; legs including coxae yellow. Body with extensive erect black setae. Flagellar setae 0.9 MOD long.

Diagnosis.—Although *A. limonae* NEW SPECIES is one of the *Adelphe* species with cross-ridging in the scapal basin, including *A. argentea, A. confusa* Kimsey, *A. masneri* Kimsey, *A. paradoxa* (Ducke), *A. robusta* Kimsey and *A. jamaicensis* Kimsey, it differs from the rest by having a shorter malar space, longer subantennal distance, and longer first flagellomere.

Material Examined.—See types.

Adelphe meridae, NEW SPECIES
(Fig. 5)

Type.—Holotype male: VENEZUELA. *MERIDA:* El Valle, 15 km NE of Mérida, 2400 m, 24 Jun–2 Jul 1989, S. and J. Peck. Deposited in the Canadian National Collection, Ottawa.

Male.—(Holotype). Body length 3 mm. Face (Fig. 5) polished and nearly impunctate; scapal basin polished without punctures, striation or rugae; mandibles with 2 apical teeth; clypeal apex thickened, forming nearly a right angle in profile; subantennal distance 2 MOD; malar space 4.4 MOD; postocular distance 3 MOD; occipital carina not unusually enlarged or flared; flagellomere I length 4.5× breadth; flagellomere II 3.5× as long as broad; mesopleuron polished and essentially impunctate; scrobal sulcus 5× as long as broad; metanotal disk slightly longer than broad; propodeal dorsomedial and posteromedial enclosures smoothly polished and impunctate, lateral tooth a low obtuse angle. Ocular setae sparse about 0.4 MOD long. Head and thorax black; antenna dark brown; legs brown with yellow accent. Body with sparse erect yellow setae. Flagellar setae 0.6 MOD long.

Diagnosis.—Unusual features of *A. meridae* NEW SPECIES include the unusually long malar space, smoothly polished face, essentially impunctate mesopleuron and long flagellomeres. This species most closely resembles *A. laevis* Kimsey, *A. cubana* and *A. puertoricana,* but can be distinguished by the features listed above as well as the darker scape and pedicel, smooth propodeal posterior enclosure and narrower scrobal sulcus.

Material Examined.—See type.

Adelphe minuta, NEW SPECIES
(Fig. 6)

Type.—Holotype male: DOMINICAN REPUBLIC. *PEDERNALES PROV.:* 9.5 km N of Cabo Rojo, Jul 1990, desert, L. Masner. Deposited in the Canadian National Collection, Ottawa. Paratypes: 9 males, same data as holotype (OTTAWA, DAVIS).

Male.—(Holotype). Body length 2.5 mm. Face (Fig. 6) strongly narrowed across antennal sockets, with large shallow punctures 0.3–1 PD apart; scapal basin smooth without cross-ridging or striation; mandibles with one primary apical tooth on inner angle, outer margin ending in right angle, not actually tooth-like; clypeal apex thickened, forming nearly right angle in profile; subantennal distance 1.2 MOD; malar space 4.6 MOD; postocular distance 1 MOD; occipital carina narrow only slightly flared; flagellomere I length 2.6× breadth; flagellomere II 1.8× as long as broad; mesopleuron polished with few scattered small punctures; scrobal sulcus parallel sided, 10× as long as broad; metanotal disk 3× as broad as long; propodeal dorsomedial enclosure polished with fine rugae laterally; posteromedial enclosure polished with scattered shallow large punctures, lateral tooth a short obtuse angle. Ocular setae short and relatively dense, 0.6 MOD long. Head, thorax and abdomen black; scape and legs, rest of antenna black. Body with extensive erect pale setae. Flagellar setae, short and dense, 0.2 MOD long.

Diagnosis.—This is the smallest species of *Adelphe* described to date. It is similar to *A. calvata* Kimsey, a Brasilian species, but can be distinguished by the eyes having setulae, a longer postocular distance, flagellomere I shorter and II longer, the mandible not obviously bidentate, and the metanotal disk considerably wider than long. The closest relative of *A. minuta* NEW SPECIES appears to be *A. insula* Kimsey. However, it can be distinguished from *A. insula* by the longer

malar space, shorter flagellomere I, the oddly dentate mandible, and the propodeal enclosure not cross-ridged.

Material Examined.—See types.

ADELPHE NITIDA, NEW SPECIES
(Fig. 7)

Types.—Holotype male: COSTA RICA. *LIMON:* 4 km NE of Bribri, 50 m, Sep-Nov 1989, P. Hanson. Deposited in the National Museum of Natural History, San José, Costa Rica. Paratypes 10 males (COSTA RICA, DAVIS, OTTAWA): 2 males, same data as type; 1 male: *ALAJUELA PROV.:* San Pedro del la Tigra, Cacao, 200 m, Jan–Feb 1990; 2 males: *HEREDIA PROV.:* Chilamate, 75 m, May 1989; 1 male: *LIMÓN PROV.:* 16 km W of Guápiles, 400 m, Apr 1989; 1 male: *PUNTARENAS PROV.:* Golfo Dulce, 3 km S of Rincón, 10 m; 2 males: San Vito, Jardin Botanico Las Cruces, May 1988, 1200 m; 1 male: Parque Nac. Corcovado, Est. Sirena, 50 m, Apr–Aug 1989.

Male.—(Holotype). Body length 2.5 mm. Face (Fig. 7) smooth with shallow punctures, 0.5–2.0 PD apart; scapal basin smooth, without cross-ridging or striation; mandibles with two apical teeth; clypeal apex thickened, forming nearly a right angle in profile; subantennal distance 1 MOD long; malar space 3.5 MOD; postocular distance 1.5 MOD; occipital carina narrow and only slightly flared; flagellomere I length 3.5× breadth; flagellomere II length 2.5× breadth; mesopleuron polished, with very few tiny punctures; scrobal sulcus 5× as long as broad; metanotal disk 3× as broad as long; propodeal dorsomedial and posteromedial enclosures smooth, lateral tooth small and acute. Ocular setae 0.6 MOD long. Head and thorax black with faint green to coppery tints; antenna dark, except scape with yellow accent; legs including coxae pale yellow. Body with erect dark setae. Flagellar setae 0.8 MOD long. Paratypes body length 2.5–3.0 mm, otherwise closely resemble holotype.

Diagnosis.—This small sized species appears most closely related to *A. paralaevis,* based on the smooth scapal basin, long first flagellomere, long malar space, nearly impunctate mesopleuron and smooth propodeal enclosures. It can be distinguished from this and other species by the additional characteristics: metanotal disk more than twice as broad as long, pale scape, subantennal distance 1 MOD long, and green-coppery tinted dorsum.

Material Examined.—See types.

ADELPHE PARALAEVIS, NEW SPECIES
(Fig. 8)

Type.—Holotype male: COSTA RICA. *PUNTARENAS PROV.:* Monteverde Reserve, 16 Aug 1986, 1500 m, L. Masner. Deposited in the Canadian National Collection, Ottawa.

Male.—(Holotype). Body length 4.5 mm. Face (Fig. 8) highly polished, punctures shallow and 0.5–1 PD apart; scapal basin smoothly polished and impunctate; mandibles with 2 apical teeth; clypeal apex thickened, forming nearly a right angle in profile; subantennal distance 1.7 MOD; malar space 3 MOD; postocular distance 2 MOD; occipital carina well developed, angulate dorsolaterally; flagellomere I length 4× breadth; flagellomere II 2.5× as long as broad; mesopleuron polished with scattered punctures anteriorly, 1–3 PD apart; scrobal sulcus 4× as long as broad; metanotal disk 1.3× as broad as long; propodeal dorsomedial enclosure polished and faintly wrinkled; posteromedial enclosure with dense nearly contiguous punctures, lateral tooth large and apically rounded. Ocular setae 0.7 MOD long. Head and thorax black with green tints; abdomen brown-yellow; entire antenna black; legs including coxae yellow-brown. Body with extensive erect black setae. Flagellar setae 0.5 MOD long.

Diagnosis.—The smooth scapal basin and long flagellomere I place *A. paralaevis* NEW SPECIES in the group of species characterized by these features, including: *A. antennalis* Kimsey, *A. cubana, A. dominica, A. mexicana, A. nitida, A. metallica* (Kieffer), *A. meridae, A. laevis, A. brasiliensis* Kimsey and *A. puertoricana.* However, *A. paralaevis* has a longer malar space and subantennal distance than any of these other species. In addition, the posteromedial propodeal enclosure is densely punctate and antenna is dark brown to black.

Material Examined.—See type.

Adelphe ziva, NEW SPECIES
(Fig. 9)

Type.—Holotype male: JAMAICA. St. Andrew Park, Fairy Glade Trail to Catherines Peak, 8 Dec 1975, G. F. Hevel. Deposited in the U.S. National Museum, Washington, D.C.

Male.—(Holotype). Body length 4 mm. Face (Fig. 9) with dense, nearly contiguous, shallow punctures; scapal basin barely indicated, punctures only slightly farther apart than on frons, no cross-ridging; mandibles with 2 apical teeth; clypeal apex nearly flat in profile, not thickened or nearly forming a right angle; subantennal distance 2.5 MOD; malar space 3 MOD; postocular distance 2 MOD; occipital carina complete but not flared; flagellomere I length 3.5× breadth and dilated medially; flagellomere II 2.5× as long as broad; mesopleuron with shallow punctures anteriorly, 0.2–0.5 PD apart; scrobal sulcus 8× as long as broad; metanotal disk 2× as broad as long; propodeal dorsomedial enclosure faintly wrinkled medially, without cross-ridging; posteromedial enclosure smooth and polished without medial ridge or welt, lateral tooth low and obtuse. Ocular setae 0.3 MOD long. Head and thorax black with silvery blue tints; abdomen black except with red accent basally; scape yellow, pedicel and flagellomeres black; legs including coxae pale yellow, except darker on hindfemoral-tibial joint and hindtarsi. Body with extensive erect silvery setae. Flagellar setae 0.2 MOD long.

Diagnosis.—*Adelphe hansoni* and *A. ziva* appear to be most closely related based on the combination of the length of flagellomere I, long subantennal distance and malar space and metanotal disk about twice as long as wide. *Adelphe ziva* NEW SPECIES can be distinguished from *A. hansoni* by the punctate mesopleuron, long narrow scrobal sulcus, thoracic dorsum with silvery blue tints and pedicel dark.

Material Examined.—See type.

Amisega geminata, NEW SPECIES

Types.—Holotype female: COSTA RICA. *GUANACASTE PROV.:* Pitilla, 9 km S of Santa Cecilia, 700 m, Jun 1989, I. Gauld. Deposited in the National Museum of Natural History, San José, Costa Rica. Paratypes: 3 males and 3 females (SAN JOSE, DAVIS), same data as holotype.

Female.—(Holotype). Body length 3.5 mm. Scapal basin with smooth impunctate medial area without cross-ridging or striatiform punctures; frons and vertex with small contiguous punctures; malar space 1.2 MOD long; eye widest medially; flagellomere I 3.2× as long as broad; flagellomere II 2× as long as broad; pronotum, scutum, scutellum and metanotum covered with deep contiguous punctures; mesopleuron covered with large nearly contiguous deep punctures, with striatiform punctures above scrobe; propodeal enclosures polished and impunctate, dorsal enclosure faintly wrinkled; terga I–II polished with few widely scattered tiny punctures; terga III–IV with posterior band of tiny punctures associated with sparse fringe of setae. Vertex, pronotum, scutum, scutellum and metanotum bright coppery red; face, propleuron, gena and mesopleuron black with bronze tints; rest of thorax and propodeum black, propodeum dorsally with green tints; abdomen brown with red accent and

with black dorsally; coxae, trochanters, midfemur, basal one-half of hindfemur and base of hindtibia orange, rest of legs dark brown; antenna black, except flagellomeres I–V with green tints; wings with two faint brown bands, one basal and the other subapical.

Male.—Body length 3–3.5 mm. Similar to female except: malar space 1.5 MOD long, wing banding even fainter; face and pronotum green; vertex, scutum medially, scutellum, metanotum and dorsal propodeal enclosure blue; rest of body including legs and antennae dark brown to black.

Diagnosis.—This species superficially resembles both *A. cooperi* Krombein and *A. gloriosa* because of the striking coloration. However, it is smaller than both of these species. It can be distinguished from *A. cooperi* by the polished dorsal propodeal enclosure, relatively impunctate posterior enclosure, and lack of a posterolateral scutal tooth. Unlike *A. gloriosa, A. geminata* NEW SPECIES has the wings faintly banded, the thorax primarily black not red, and the scapal basin has a polished and impunctate medial area.

Material Examined.—See types.

Amisega gloriosa, NEW SPECIES

Types.—Holotype female: GUATEMALA. *ZACAPA DEPARTMENTO:* San Lorenzo, 1800 m, 9–11 Jul 1986, L. LeSage. Deposited in the Canadian National Collection, Ottawa. Paratypes: 1 female and 8 males, same data as holotype (OTTAWA, DAVIS).

Female.—(Holotype). Body length 5 mm. Face with fine contiguous punctures; scapal basin faintly cross-striated medially; frons, vertex and gena appearing granular; malar space 0.7 MOD; eye in lateral view widest medially; flagellomere I 4× as long as broad; flagellomere II 2× as long as broad; pronotum, scutum, scutellum and metanotum covered by fine contiguous punctures; notauli obsolescent; mesopleuron completely covered with coarse contiguous punctures, even above scrobe; dorsal propodeal enclosures smooth and impunctate; posterior propodeal enclosures smooth with scattered punctures; tergum I with transverse band of tiny punctures along posterior margin; tergum II with tiny punctures clumped anteriorly with impunctate medial stripe; terga III–IV with tiny nearly contiguous punctures and dense setae in transverse band across posterior one-half of tergum. Frons, vertex, pronotum, scutum, scutellum and metanotum bright coppery-red; gena and ventral surface of head with green cast; rest of thorax and coxae non-metallic red; femora inner surface red, outer surface dark brown to black with green tints; tibiae and tarsi brown; antennae dark brown with some green tints; wings with two dark brown bands, one subbasal and one subapical; tergum I brown with red accent basally, rest of abdomen black with green tints.

Male.—Similar to female except: body length 4.5–5 mm, body color entirely black with green tints, including legs and antennae, and wings faintly banded.

Diagnosis.—As discussed under *A. geminata* this species shares its striking dorsal coloration with *A. geminata* and *A. cooperi.* It can be distinguished by the darkly banded wings, non-metallic red thoracic sides and venter, scutal posterolateral corners not projecting, scapal basin not polished, notauli obsolescent, and the propodeal enclosures not finely striate.

Material Examined.—See types.

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AN UNUSUAL NEW TIPHIID GENUS FROM PERU AND A KEY TO THE AMERICAN GENERA OF TIPHIINAE (HYMENOPTERA)

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Abstract.—A new genus and species of tiphiid wasp in the subfamily Tiphiinae, *Megatiphia fuscata,* is described, and an illustrated key to the tiphiine genera of the Western Hemisphere is given, including: *Tiphia, Paratiphia, Mallochia, Krombeinia, Neotiphia, Epimodiopteron* and *Megatiphia.*

Key Words.—Insecta, Tiphiidae, Tiphiinae, *Tiphia, Paratiphia, Mallochia, Krombeinia, Neotiphia, Epomidiopteron*

Although tiphiid wasps are large bodied and often colorful insects, they are inconsistently collected, perhaps due to considerable endemism and/or seasonality. The tiphiid fauna of South America is particularly poorly known, especially in the oriente region. Although there have been a number of extensive collections of insects made in eastern Peru, few specimens have been made available for study. Material seen from this region indicates that there is a great deal of endemism on the Amazonian slopes of the Andes.

Members of the subfamily Tiphiinae are characterized by features discussed by Kimsey (1991). These features include: the occasionally enlarged tegula, the mesosternum with a large generally flattened plate separating the mesopleural lamellae, females with the marginal cell open, and the miditibia with one spur.

There are seven genera of tiphiines in the Western Hemisphere. Of these only *Tiphia, Mallochia, Epomidiopteron* and *Megatiphia* (described here) occur in South America. *Mallochia* has only been recorded from Argentina and southern Brazil. The dominant tiphiine genus in South America is *Tiphia.* Although Allen (1972) published a key to the tiphiines of the Americas, his key is poorly illustrated, difficult to use and does not include *Megatiphia.* Therefore, a revised key is given below.

KEY TO THE WESTERN HEMISPHERE GENERA OF TIPHIINAE

1. Tergum I smooth, without transverse carina 2
– Tergum I with transverse carina submedially (Fig. 4) 4
2(1). Sternum I with small ventral hook or projection near base, hindtibia with small fovea subapically on inner surface (Fig. 9) ..... *Megatiphia,* NEW GENUS
– Sternum I without ventral hook or projection (Fig. 4), hindtibia without fovea on inner surface 3
3(2). Oral fossa plus lateral oral plate narrower than long (as in Fig. 3), male sternum V with small lateral denticle, male sternum VI apical margin notched, appearing trilobate (as in Fig. 8) ..... *Mallochia* Allen
– Oral fossa plus lateral oral plate considerably wider than long (as in Fig.

2), male sternum V without lateral denticle, male sternum VI apical margin evenly curved without lateral notch ..... *Tiphia* Fabr.

4(1). Tergum I with flat ovoid lateral patches (Fig. 4), male sternum VII, enlarged and cupping the apical tergum ..... *Paratiphia* Sichel

– Tergum I without flat ovoid lateral patches, male sternum VII not enlarged or cupping the apical tergum (except in *Epomidiopteron*) 5

5(4). Propodeum without transverse carina isolating dorsal from posterior surface (Fig. 7), body with distinctive yellow markings (Fig. 7), forewing with 3 submarginal cells, tergum I broadly joined to II (Fig. 7), male sternum VII apical rim not laterally notched, expanded dorsally and cupping the apical tergum ..... *Epomidiopteron* Romand

– Propodeum with transverse carina separating dorsal from posterior surface (as in Fig. 5), body without yellow markings, forewing with 1 or 2 submarginal cells, terga I and II constricted at their juncture, male sternum VII apical rim notched laterally, appearing almost trilobate (Fig. 8) 6

6(5). Terga II-V with broad, highly polished, asetose and translucent apical band (Fig. 8) ..... *Neotiphia* Malloch

Terga II-V without distinct apical band ..... *Krombeinia* Pate

Megatiphia, NEW GENUS
(Figs. 1, 2, 5, 6, 9, 10)

Type species.—*Megatiphia fuscata,* NEW SPECIES.

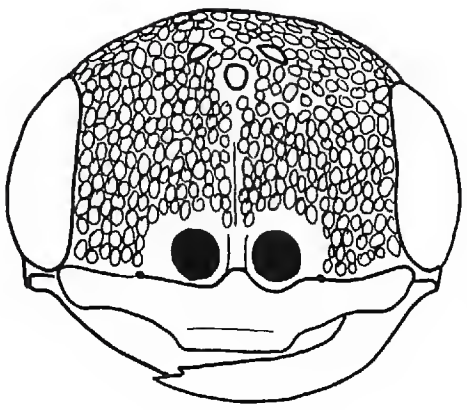
Female.—Oral fossa region delimited by carina, broader than long (Fig. 2); maxillary palpus with 6 articles; labial palpus with 4 articles; genal bridge bulging in lateral view (Fig. 10); pronotum with transverse carina well developed, extending downwards laterally (Fig. 10); mesopleuron with omaulus (Fig. 10); tegula subovoid, only slightly longer than broad, inner margin produced into a posterior angle; hindcoxa without dorsal carina; mesosternum bulging medially, with submedial lateral tooth (Fig. 6); forewing with 2 submarginal cells (Fig. 10); propodeum with transverse and vertical lateral carinae separating posterior propodeal surface (Fig. 5); midtibia without subapical fovea on inner surface; hindtibia with subapical elliptical fovea on inner surface (Fig. 9); gastral segments: tergum I without transverse carina or oval flat lateral patches; sternum I with subbasal projection; terga I and II strongly constricted at their juncture; terga II–V without discrete, polished apical band; sternum VI slightly emarginate apicomedially.

Diagnosis.—See Key.

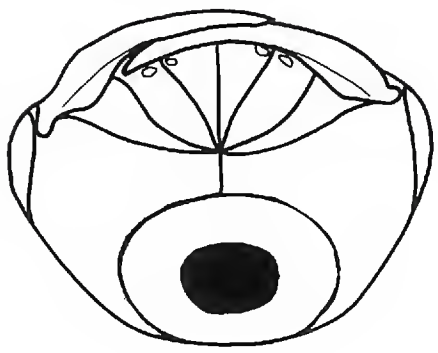
Discussion.—This genus is a rather extremely modified member of the subfamily Tiphiinae, based on the broadly elevated mesosternum that separates the mesopleural lamellae, the flat antennal sockets, single midtibial spur, and marginal cell open in the female. *Megatiphia* appears to be most closely related to *Tiphia,* mostly based on the absence of characteristics found in *Paratiphia, Mallochia, Neotiphia* and *Krombeinia,* including the carinate first gastral tergum and tergal bands. Males of this genus probably lack a cupped or trilobate sternum VII, as do those of *Tiphia. Megatiphia* can be distinguished from *Tiphia* by the highly modified mesosternum, first gastral sternum with a projection, and the hindtibia with a subapical fovea.

Etymology.—*Mega*—large, *tiphe*—insect, Gr, f.

Material Examined.—See type species.



1. Megatiphia



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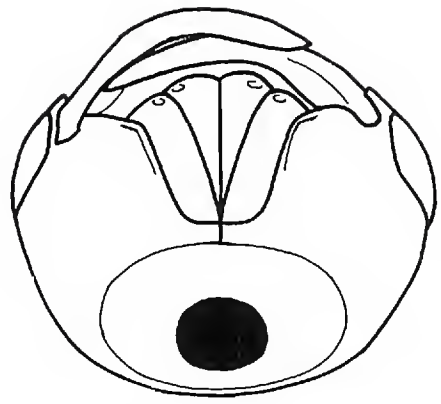

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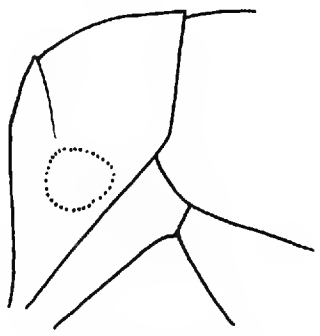

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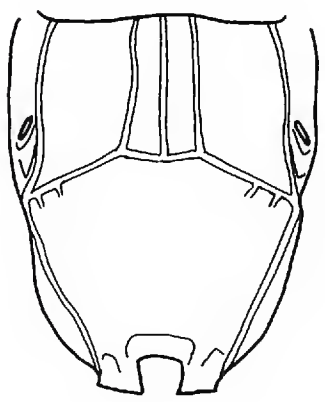

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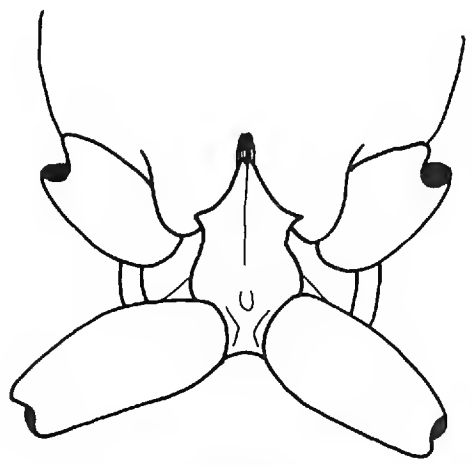

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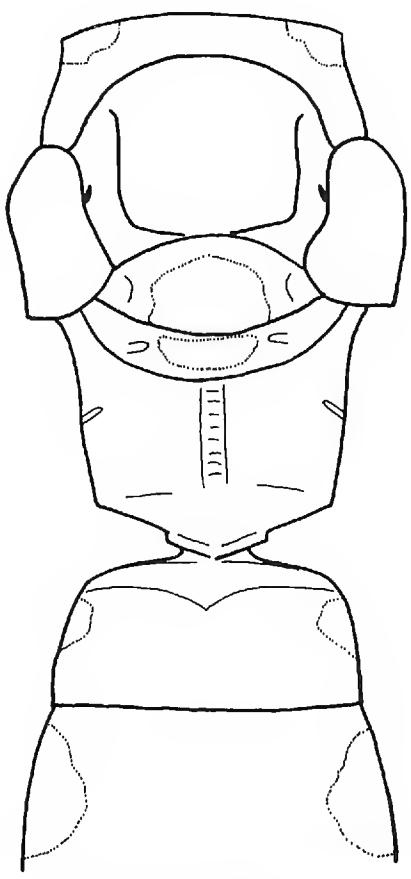
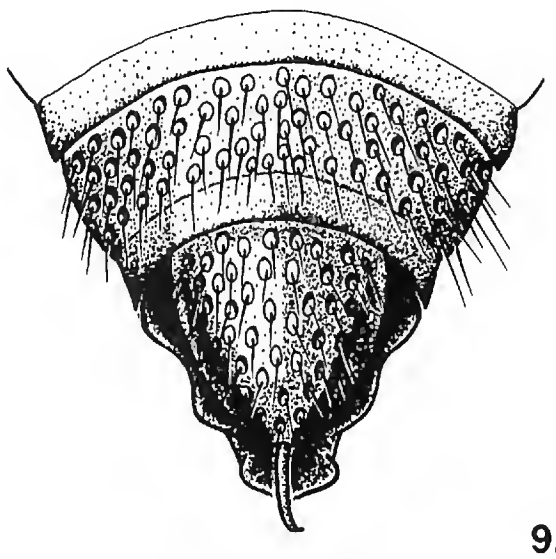
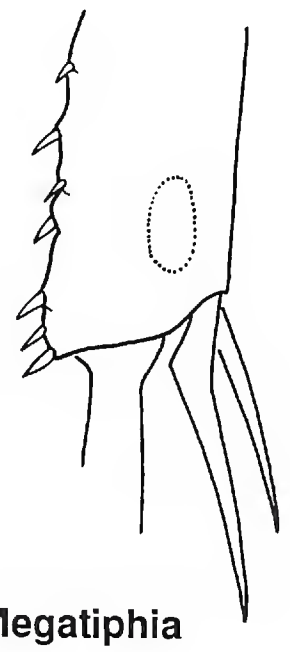


7. Epomidiopteron



8. Neotiphia



9. Megatiphia

Figures 1–9. Figure 1. Front view of female face. Figures 2–3. Ventral view of head, females. Figure 4. Lateral view of basal abdominal segments, male. Figure 5. Posterior view of propodeum, female. Figure 6. Ventral view of mesothorax, female. Figure 7. Dorsal view of thorax and basal abdominal segments, with head and wings removed, female. Figure 8. Dorsal view of apical abdominal segments of male. Figure 9. Inner surface of apex of hindtibia of female. Figures 1, 2, 5, 6, 9. *Megatiphia fuscata.* Figure 3. *Paratiphia robusta* Cameron. Figure 4. *Paratiphia neomexicana* Cameron. Figure 7. *Epomidiopteron julii* Romand. Figure 8. *Neotiphia sulcata* Roberts.

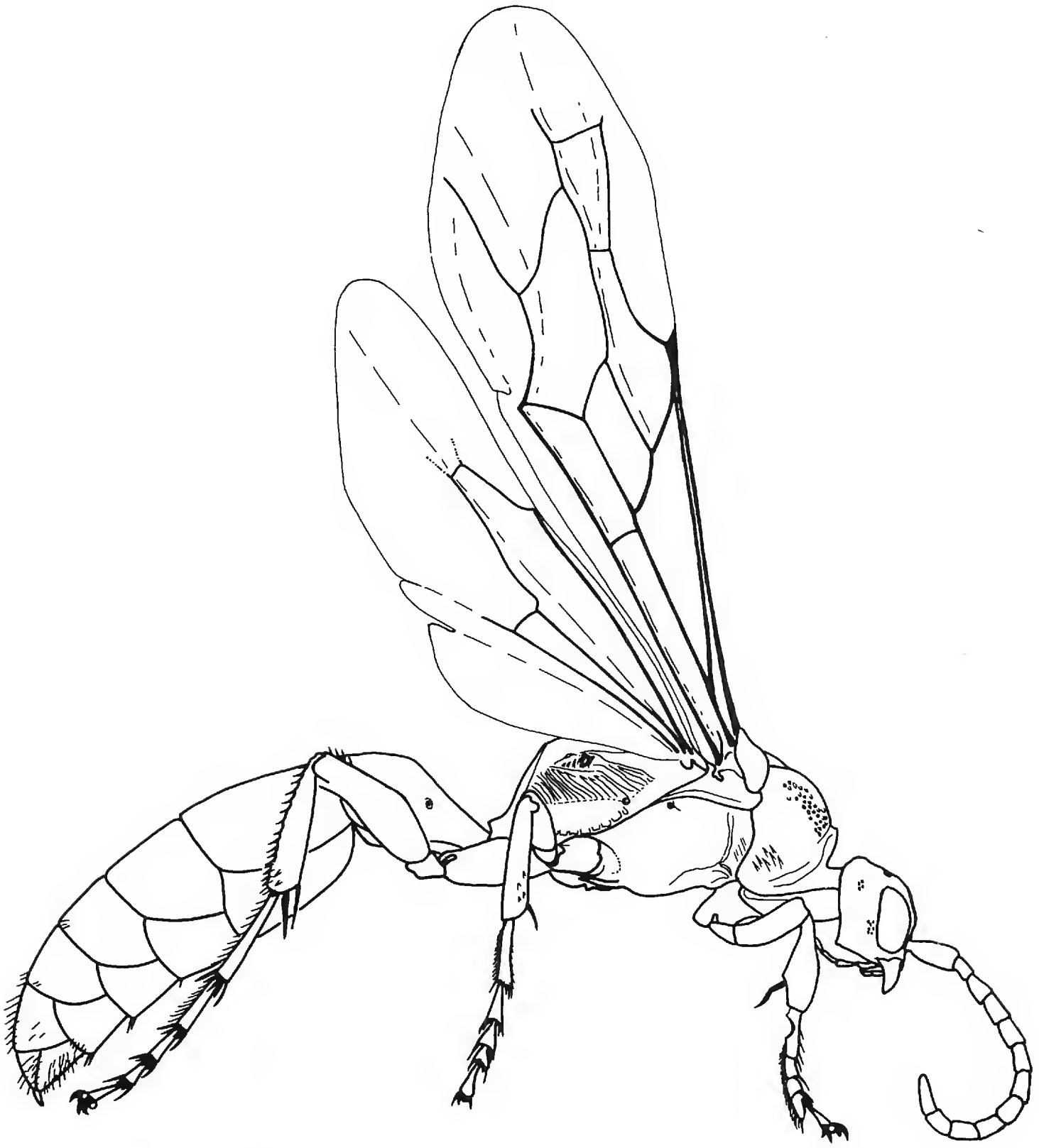


Figure 10. Lateral view of *Megatiphia fuscata,* female.

Megatiphia fuscata, NEW SPECIES

Type.—Holotype female. PERU. *JUNIN PROV.:* Chanchamayo, 4 Mar 1949, J. Schunke. Holotype deposited in the U.S. National Museum, Washington, D.C. Paratype female: same data as holotype, except collected 31 Jan 1949 (U.S. National Museum).

Female.—(Holotype). Body length 27 mm; forewing 20 mm. Face (Fig. 1) broader than long with coarse contiguous punctures on frons, vertex and gena; clypeus broadly truncate, apex 4× midocellus diameter (= MOD) wide; malar space 0.7 MOD long; subantennal distance 3 MOD long; labial palpi 4-segmented; maxillary palpi 6-segmented; body (Fig. 10); flagellomere I length 1.6× breadth; flagellomere II 1.5× as long as broad; mesopleuron with fine dense appressed silvery pubescence anteriorly before omaulus, medially with coarse contiguous punctures, with polished impunctate welt before scrobe, posteriorly below scrobe with nearly contiguous tiny punctures and appressed pubescence;

pronotum with sharp transverse and lateral anterior carina, notum polished anteriorly with large punctures 0.5–1 puncture diameter apart, posteriorly impunctate; scutum impunctate except medially with large punctures clumped posteromedially; scutellum polished and impunctate medially with large nearly contiguous punctures sublaterally; metanotum polished, nearly impunctate; propodeum shagreened and dull, with 3 parallel medial carinae, spiracle enclosed by 2 subparallel lateral carinae, posterior surface delimited by transverse dorsal and lateral carinae, laterally below spiracle with coarse crossridges; abdominal segments highly polished with sparse setae subapically, densest on apical sternum. Body slender, and shiny black; wings fuscous and nearly opaque.

Diagnosis.—Because this is the only species currently placed in *Megatiphia,* it is difficult to differentiate between generic and specific characters. The highly polished and nearly asetose black body and dark wings are distinctive features of this species, as are the short flagellomeres and impunctate abdominal segments.

Material Examined.—See types.

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TWO NEW NORTH AMERICAN SPECIES OF THE TRIBE PEMPHREDONINI (HYMENOPTERA: SPHECIDAE: PEMPHREDONINAE)

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Abstract.—Two new species in the sphecid subfamily Pemphredoninae are described: *Pemphredon bocae,* NEW SPECIES and *Cemonus menkei,* NEW SPECIES. These are from western U.S. and eastern U.S., respectively.

Key Words.—Sphecidae, Pemphredoninae, *Pemphredon, Cemonus*

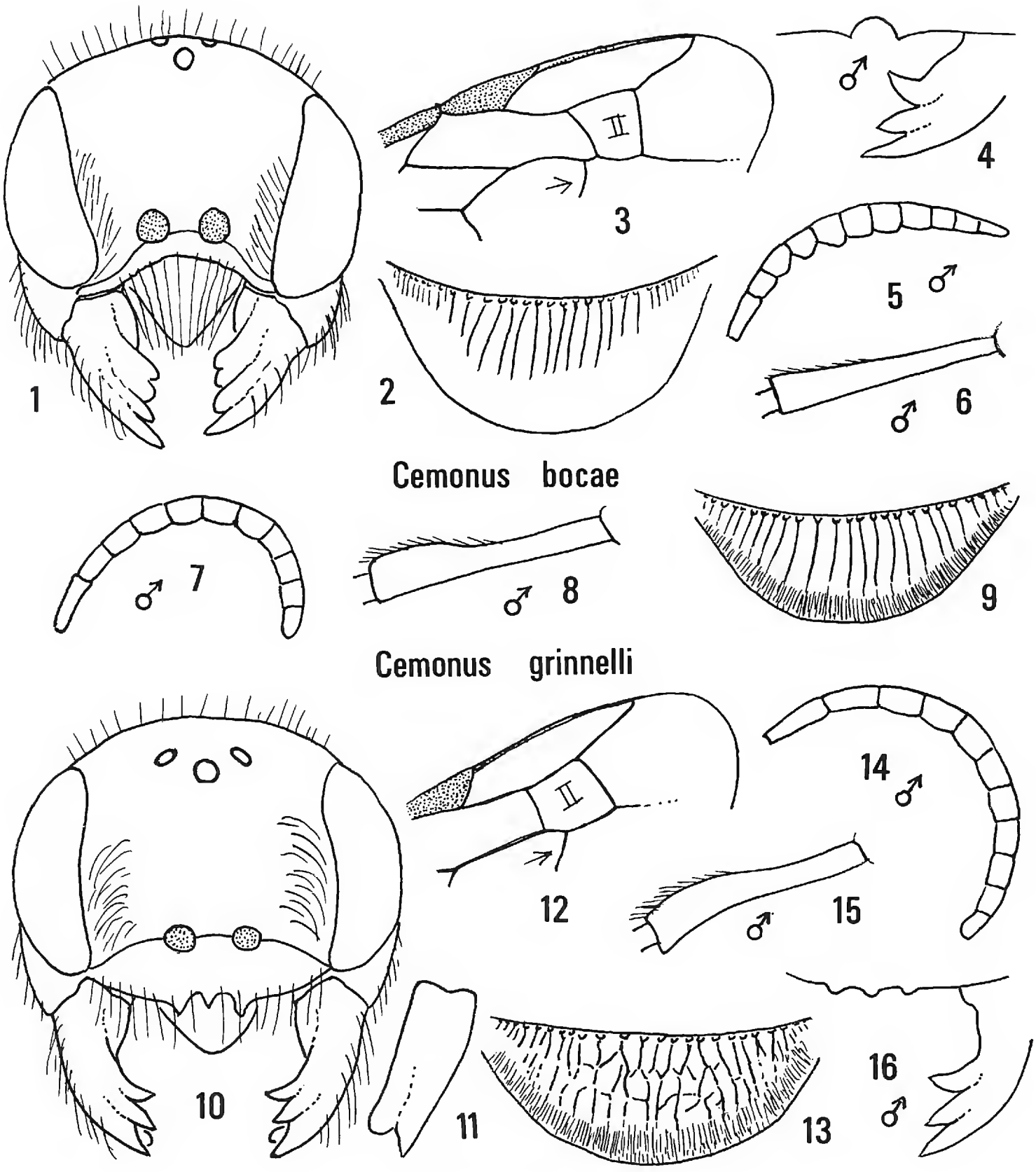
The tribe Pemphredonini contains a number of genera, two of which are *Pemphredon* and *Cemonus.* They have often been placed as subgenera under the former name. However, the two entities appear to be separate phylogenetically, and they can be distinguished by the reception of the second recurrent vein of the forewing at, or before, the proximal end of submarginal cell II in *Cemonus,* and well beyond in *Pemphredon* (compare Figs. 3 and 12). One species in each genus is presented below.

CEMONUS BOCAE, NEW SPECIES
Figs. 1–6

Types.—Female holotype. CALIFORNIA. *NEVADA Co.:* Boca, 12 Aug 1974, R. M. Bohart. Holotype deposited in the Bohart Museum of Entomology, University of California, Davis. Paratypes: 1 male, 6 females, data: CALIFORNIA. *MONO Co.:* Mill Creek Canyon, 26 Aug 1979, M. Wasbauer, P. Adams, 2 females. *NEVADA Co.:* same data as holotype, 1 female. *PLACER Co.:* nr Tahoe City, 29 Jun 1979, P. Adams, 1 female. *SIERRA Co.:* Sierraville, 28 Jun 1966, R. L. Brumley, 1 male; same locale, 14 Jul 1958, R. M. Bohart, 1 female. IDAHO. *BUTTE Co.* (?): Little Cottonwood Creek, Craters of the Moon National Monument, 13 Aug 1965, D. S. Horning Jr., 1 female. (Paratypes to be distributed in the future.)

Female.—Holotype length 7.5 mm; black wings slightly and evenly stained. Pubescence pale, that from clypeus and propodeum long. Punctation fine and close on frons, but becoming widely separated by extensive polished areas on vertex; punctation fine, but sparse on scutum, moderate on propodeum beyond enclosure, coarse on mesopleuron, but becoming polished posteriorly and ventrally as well as on propodeal enclosure posteriorly (Fig. 2). Mandible with 4 dorsal teeth, basal 2 almost completely fused (Fig. 1); clypeus with apical margin very broadly emarginate, rim almost reaching antennal sockets (Fig. 1); vertex dimpled behind ocellar triangle; propodeal enclosure with about 20 fine and close longitudinal ridges (Fig. 2); pygidial plate a nearly even rectangle, 2× as long as broad.

Male.—Length 7 mm; wings, punctation, dimpled vertex, color and propodeal sculpture as in female. Facial pubescence dense, silvery. Mandible with most basal tooth enlarged and slightly angled inward (Fig. 4); flagellomeres III–VII strongly swollen beneath giving a serrated appearance (Fig. 5); clypeal apex narrowly, deeply, and roundly emarginate (Fig. 4); midbasitarsus straight, and gradually enlarged from base (Fig. 6).



Figures 1–16. Front view of head, punctation omitted. Figure 11. Mandible, side view. Figures 2, 9, 13. Propodeal enclosure. Figures 3, 12. Apical forewing venation (arrow indicates second recurrent vein). Figures 4, 16. Clypeal apex (silvery setae omitted) and mandible dentition. Figures 5, 7, 14. Flagellum in profile. Figures 6, 8, 15. Midbasitarsus in profile. Male figures indicated and based on paratypes, remainder are based on female holotypes. Illustrations not drawn to scale.

Diagnosis.—*Cemonus bocae* NEW SPECIES is easily identified in the female by the peculiar retracted clypeus (Fig. 1). Both sexes have a vertex dimple. The male of *C. grinnelli* (Rohwer) is quite similar to male *C. bocae* in clypeal shape and in conformation of the propodeal enclosure. However, in *C. bocae* the vertex

dimple, more strongly serrate flagellum, and straight midbasitarsus are diagnostic. Compare Figs. 5 with 7, 6 with 8, and 2 with 9 for these contrasts.

Material Examined.—See types.

Pemphredon menkei, NEW SPECIES
Figs. 10–16

Types.—Female holotype. MARYLAND. *MONTGOMERY Co.:* Colesville, 15 Sep 1974, A. S. Menke. Holotype deposited in the Bohart Museum of Entomology, University of California, Davis. Paratypes: 9 males, 12 females, data: DISTRICT OF COLUMBIA. Washington, 15 May 1944, G. E. Bohart, 5 males. MARYLAND. *MONTGOMERY Co.:* same locale as holotype, various dates from 21 Sep 1974 to 8 May 1976, A. S. Menke, 3 males, 9 females; Plumber's Island, 13 Jun 1961, K. V. Krombein, 1 male. MINNESOTA. *HUBBARD Co.:* Park Rapids, 18 Jul 1958, A. Raske, 1 female. VIRGINIA. *FAIRFAX Co.:* Black Pond, 21 Jun 1923, R. A. St. George, 1 female. *HOCKING Co.:* (no locale) 20 Aug (no year), D. J. & J. N. Knull, 1 female. (Paratypes to be distributed in the future).

Female.—Holotype length 8 mm. Wings uniformly dusky. Pubescence pale, moderate. Punctation fine and close on frons, becoming sparse on mostly polished vertex, scutal punctures medium-sized but well separated on shagreened surface, coarse in front and fine behind on mesopleuron, propodeal side polished in front, followed by moderate punctation. Mandible evenly tridentate dorsally, apex bidentate, lower tooth enlarged and flattened (Figs. 10, 11); clypeus apicomedially with 3 sharp teeth (Fig. 10); propodeal enclosure reticulate on basal two-thirds, limited posteriorly by a longitudinally shagreened arc (Fig. 13), propodeum posteriorly finely and closely reticulate; pygidial plate with indistinct edges, slightly wedge-shaped, about 3× as long as broad.

Male.—Length 7 mm. Wings, color, punctation and sculpture as in female. Facial pubescence dense, silvery. Mandible evenly tridentate (Fig. 16); clypeal apex weakly tridentate apicomedially (Fig. 16); midbasitarsus slightly bowed in profile, enlarged in distal one-half (Fig. 15); flagellomeres moderately convex on III–VII (Fig. 14).

Diagnosis.—*Pemphredon menkei* NEW SPECIES is similar to *P. nearctica* Kohl, sharing similar clypeal dentition, mandibular structure, and punctation in general. The principal difference is the reticulate propodeal enclosure of *P. menkei* (Fig. 13) rather than the longitudinal ridging of *P. nearctica.* This character holds up well in the type series of *P. menkei* and approximately 150 specimens of *P. nearctica* that I have seen. Another more subtle, but constant, difference is the less distinctly margined pygidial plate of female *P. menkei.* The species is named for the collector, a well-known Hymenopterist, and my friend.

Material Examined.—See types.

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BIOLOGICAL STUDIES OF *HEMICOELUS GIBBICOLLIS* (LECONTE) (COLEOPTERA: ANOBIIDAE), A SERIOUS STRUCTURAL PEST ALONG THE PACIFIC COAST: LARVAL AND PUPAL STAGES

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Abstract.—*Hemicoelus gibbicollis* (LeConte) is an important structure-infesting anobiid beetle found along the coastal areas of western North America. Little had been known about this insect because the larvae escaped detection while feeding within building timbers. Radiography was used to document the development of larvae over a 2 year period. Larvae move about 1 cm each month and may spend up to 6 years feeding on wood. Wood moisture between 13 and 19% is the key element contributing to successful colonization of timbers. Symbiotic yeasts present in larval mycetomes probably aid in nutrition. No correlation was found between the number of adult exit holes and live larvae present in wood blocks.

Key Words.—Insecta, *Hemicoelus gibbicollis,* structure-infesting, larva, pupa, symbiont

Throughout many areas of the world, structure-infesting beetles in the family Anobiidae are serious pests (Hickin 1981). Larvae live within wooden timbers, producing extensive feeding galleries that result in a weakened structure. The cost of wood replacement and/or chemical control can be quite high. Despite the damage they cause, little is known about most species because of a long life cycle and difficulty in rearing.

Along coastal areas of western North America, *Hemicoelus gibbicollis* (LeConte) is the most damaging anobiid. This species occurs in >90% of infested structures in western Washington State (Suomi 1992). Although considered to be the most destructive anobiid in Washington, Oregon, California, and British Columbia (Doane et al. 1936, Linsley 1943, CIPR 1988), its biology was unrecorded. Recent estimates show the beetle is responsible for $7–8 million in wood replacement and chemical control costs annually in Washington (Suomi 1992).

Documenting the behavior of insects residing in wood is exceedingly difficult because the life stage under study is hidden from view and can be damaged if attempts are made to remove it for examination. Additionally, many wood-inhabiting insects have long life cycles, often 4–6 years or more, and do not readily lend themselves to laboratory study. Radiographic devices allow these insects to be observed without interference in their activities (Parkin 1940, Bletchly 1961, Villani & Wright 1988) and are a necessary tool for studying their habits. This, and a previous paper (Suomi & Akre 1993), describe the biology and habits of *H. gibbicollis.*

MATERIALS AND METHODS

Wood Collection.—Subflooring, primarily Douglas-fir, *Pseudotsuga menziesii* (Mirbel), infested with *H. gibbicollis* larvae was collected from western Washington

Figure 1. Radiograph of *H. gibbicollis* larvae within a structural timber.

and Oregon homes and outbuildings during June, July, and August, 1987–1991. This material was transported to the laboratory at Washington State University in sealed containers to maintain wood moisture at the higher levels found in coastal areas.

Radiography.—Wood blocks (9 cm by 9 cm by 2 cm) were cut from infested timbers and x-rayed monthly at 35 kV for 75 sec using a Faxitron Radiographic Inspection System Model 43804 (Hewlett-Packard, McMinnville, Oregon). This unit has a beryllium window which transmits "soft" radiation that is relatively harmless to biological tissues. Radiographic film (Kodak Radiographic Film, Min-R, Eastman Kodak, Rochester, New York) was exposed at room temperature, immersed in standard x-ray developer for 5 min, rinsed in distilled water, and fixed for 5 min. Radiographs were viewed on a light table and larval positions marked (Fig. 1). A 1:1 reproduction of live larvae to images was recorded on the film. Radiographs of 20 wood blocks were taken monthly for 2 years to document larval development, movement, and survival. Measurements were made with a vernier caliper with graduations of 0.05 mm. Where appropriate, data were analyzed with MEANS Procedures (SAS Institute 1985).

Wood Block Storage.—Before and after radiography blocks were stored in covered, darkened boxes measuring 38 cm by 28 cm by 15 cm with 1 cm plaster of Paris/charcoal as a substrate to maintain wood moisture between 14 and 17%. Ventilation was provided through two screen covered holes (35 mm diameter) in the top cover. Wood moisture readings were taken with a Delmhorst Model RC-1C Moisture Meter (Delmhorst Instrument Company, Boonton, New Jersey). An environmental chamber was used to maintain conditions at 65 ± 3% RH and 18 ± 1° C as commonly found in crawl spaces under buildings in western Washington.

Additional wood blocks were stored in a separate environmental chamber at 15 ± 1° C and 60 ± 1% RH which kept wood moisture levels at or below 12%. During 1990–1991, a third group of blocks was transferred in bimonthly intervals from laboratory storage to an unheated garage. Daily maximum and minimum temperatures were recorded at this location (Suomi 1992: appendix 5). Sixteen other blocks were radiographed and transferred to a 1.5° C walk-in cooler for 2, 4, 6, or 8 weeks, then returned to an environmental chamber. Wood moisture was maintained at 14–15%. Additionally, 50 wood blocks were radiographed and larvae counted to assess any correlation between number of adult exit holes and total larvae present.

First Instar Penetration Studies.—One year old Douglas-fir dimensional lumber, locally purchased, was cut into blocks (9 cm by 9 cm by 2 cm) to clearly show the demarcation between sapwood and heartwood (Miller 1987). Thirteen blocks were sanded to produce a slightly roughened surface. A camel's hair brush was used to transfer five, newly emerged *H. gibbicollis* larvae to the sapwood : heartwood demarcation of each block. A clear, polystyrene insect diet cup (4 cm tall by 4 cm diameter) was positioned over the insects and held in place with adhesive from an electric glue gun. All blocks were stored in separate, darkened enclosures and larval penetration was recorded after 7 days.

Larval Descriptions.—For descriptive studies, radiographs were marked and larvae carefully extracted from within the wood. Five immatures of different sizes were dissected to extract and photograph symbiont-containing mycetomes.

Results and Discussion

Larva.—*Hemicoelus gibbicollis* larvae are approximately 0.6 mm long, straight, and white upon emerging from the egg (Fig. 2). There is distinct body segmentation, and small legs, with one claw, are present. A single stemma is located on each side of the hypognathus head. The mandibles are heavily sclerotized and have two apical teeth. Prodorsal asperites are present on thoracic segment III and abdominal segments 1–7. These structures most likely aid larvae in adhering to and moving through galleries within wood. As larvae develop the anterior one-third becomes slightly red-brown, and the body trunk becomes more curved (Fig. 3). This color change results from the ingestion of wood and retention of fibers within the crop. Larvae possess a hydrophobic surface layer and float in water for several minutes. This layer probably protects the immature stage from high wood moisture conditions often found in damp wood. According to Böving (1954) the larva is similar to that of *Anobium punctatum* (De Geer) except for having spiracles of a different shape and a different number of prodorsal asperites. Galleries are packed with fecal pellets that are cylindrical and tapered at each end, being somewhat "gritty" in texture when rubbed between fingers.

Effect of X-rays on Insects.—Radiographic techniques have been used as a nondestructive sampling method for detecting insect activity in a variety of materials (Fisher & Tasker 1940, Milner et al. 1950, Dennis 1961, Berryman & Stark 1962, Villani & Wright 1988). X-rays have little effect on biological tissues if low energy, long wavelengths are used and critical dosages not exceeded. Daily radiographic examinations of the granary weevil, *Sitophilus granarius* L., and rice weevil, *Sitophilus oryza* L., over a two week period produced no deleterious effects

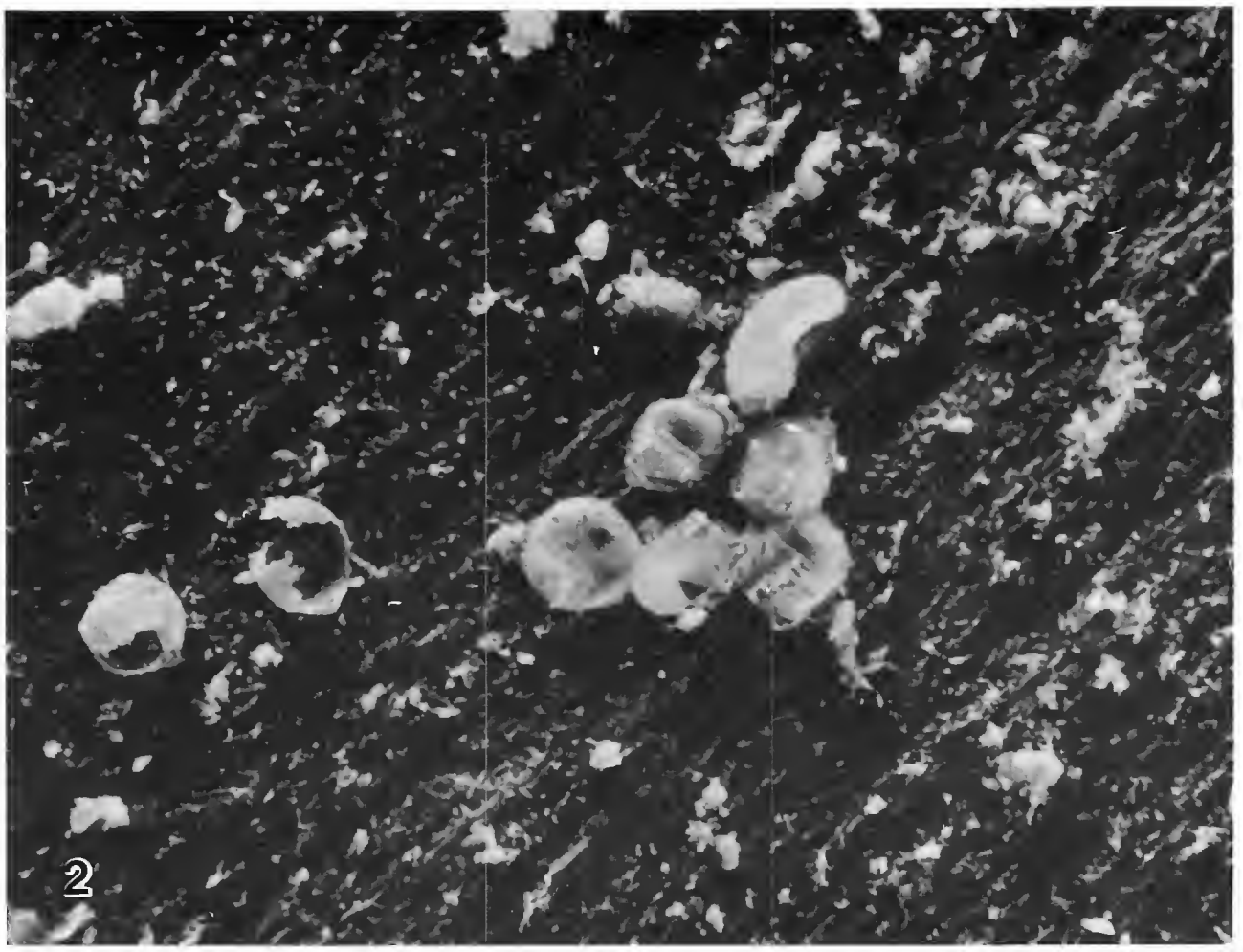

Figure 2. First instar of *H. gibbicollis*.

Figure 3. Mature *H. gibbicollis* larva.

on adults or larvae (Milner et al. 1950). Bletchly & Fisher (1957) and Bletchly & Baldwin (1962) used x-rays at dosages similar to those used in this study and saw no behavioral changes in *A. punctatum* larvae. According to Bletchly & Fisher (1957), over 70,000 roentgens are necessary to kill larvae of *A. punctatum.* Larvae in these studies were exposed to <1450 roentgens over 24 months. Adult *H. gibbicollis* emerging from blocks radiographed for these tests mated and produced viable offspring.

Larval Development and Behavior.—The number of larval instars in *H. gibbicollis* is uncertain and may vary depending on nutrition available in wood. According to Hickin (1975) the number for *A. punctatum* is not well established, but another anobiid, *Stegobium paniceum* (L.), typically has five (Hickin 1974). Böving (1954) stated that there are no major morphological changes between instars in *H. gibbicollis.* All larval sizes were often seen on radiographs of a single wood block. This most likely signifies that larvae of different generations were present although Bletchly & Farmer (1959) reported that developmental rates of *A. punctatum* differed resulting from inconsistencies of nutritional components within the same test block. Larvae were not easily observed on radiographs until they were approximately 1.5 mm long. Linscott (1971) reported that 8–18 months of development were necessary before larvae of *A. punctatum* became visible on radiographs.

Emergence time of first instars from eggs was quite variable, ranging from 27 min to over 22 h. While emerging, *H. gibbicollis* larvae consume between 25 and 75% of the chorion. Symbiotic yeasts, which are transmitted to eggs during passage through the female oviduct, are ingested by larvae in this process (Jurzitza 1979). Wood is relatively low in nutrition, particularly nitrogen (Merrill & Cowling 1966), and yeasts play a vital role in providing essential amino acids and vitamins to anobiid larvae (Pant & Fraenkel 1954, Kelsey 1958, Jurzitza 1979). These symbionts, *Symbiotaphrina* sp. (Gams & von Arx 1980), resemble yeasts isolated from the cigarette beetle, *Lasioderma serricorne* (Fabr.) and probably represent a new species (P. Dowd, personal communication). Larval dissections showed six, blue-gray, grape-like clusters (mycetomes) attached to a ring shaped structure between the crop and midgut (Fig. 4). Thin membranes loosely hold these mycetomes in place.

Upon emergence most larvae wander at least 1 cm from the oviposition site before attempting to enter the wood. Less than 20% of larvae (> 200, total observed) penetrated the substrate directly through the chorion. The greatest distance any larva moved from the oviposition to a penetration site was approximately 8 cm. Hickin (1981) noted that newly emerged *A. punctatum* larvae usually chew directly through the egg into wood, and therefore oviposition site selection by the adult female was of critical importance.

Larvae move by muscular undulations of the body that are directed from posterior to anterior. Upon locating a suitable site, first instars penetrate 2–3 mm at a 90° angle to the surface. Later instars formed feeding tunnels that followed the grain. Wood dissections and radiographs showed that larvae often fed within old galleries, changed positions through time, and widened the tunnel as their body size increased. Due to continued feeding, field collected wood was often reduced to powdery frass with little or no structural strength.

An attempt was made to promote development of *H. gibbicollis* on dog food

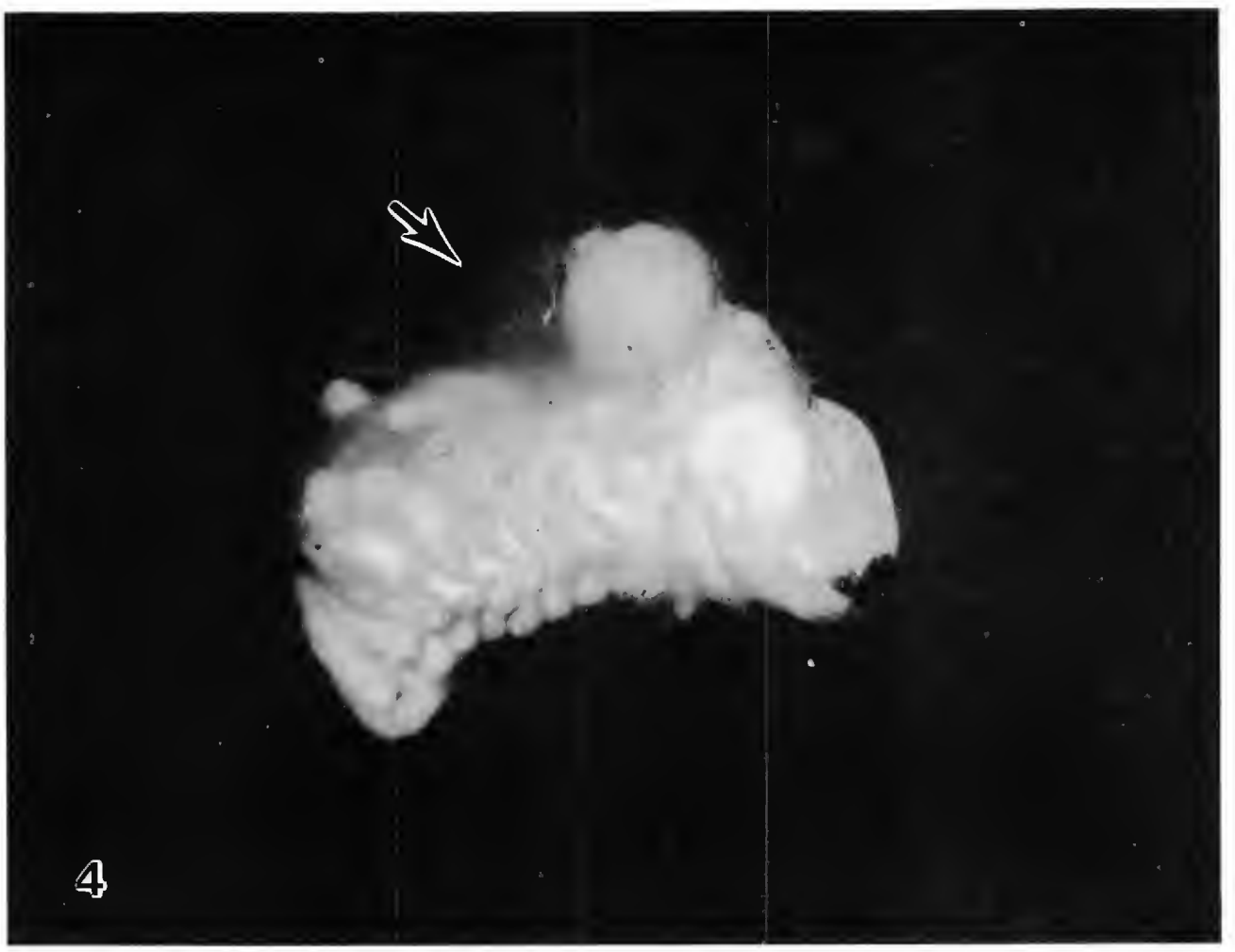

Figure 4. Mycetomes (containing symbiotic yeasts) located behind crop of *H. gibbicollis* larva.

(MiniChunks, Iams Company, Dayton, Ohio, 26% protein) and dog biscuits (Vita Bone, American Nutrition, Ogden, Utah, 20% protein), but none of the 30 larvae released on either food source survived. Other researchers have successfully reared *A. punctatum* on dog food and this dramatically decreased development time, often resulting in a 1 year life cycle (Baker & Bletchly 1966). However, high protein diets led to aberrant symbionts in the mycetomes (Berry 1976) or inconsistent responses to insecticidal treatments in subsequent generations of *A. punctatum* (Cross & Crabtree 1978).

Heartwood contains extractives that repel many insects (Miller 1987), and *H. gibbicollis* larvae were mainly found feeding within the sapwood portion of timbers. In certain instances larvae fed in heartwood, particularly if the sapwood had been depleted or if the heartwood had a moisture content of >17%. Two other wood-infesting anobiids, *A. punctatum* and *Euvrilletta peltata* (Harris), are found predominantly in sapwood as this is higher in carbohydrates and nitrogen (Becker 1942, Bletchly & Farmer 1959, Williams & Mauldin 1981). Upon emergence, most *H. gibbicollis* larvae penetrated into sapwood, but a high percentage still entered wood blocks through the heartwood. Of 65 larvae released, 46 (74.2%) were found in sapwood while 16 (25.8%) entered the blocks through heartwood. Three larvae died before penetrating the surface. Texture of wood at an entry site is probably the most important factor dictating this behavior.

Larval Populations in Wood.—Within individual wood blocks randomly cut from infested timbers, the number of *H. gibbicollis* larvae present was highly variable. Wood blocks radiographed during this research often showed extensive tunnelling by larvae, but no insects were found. On other occasions many larvae

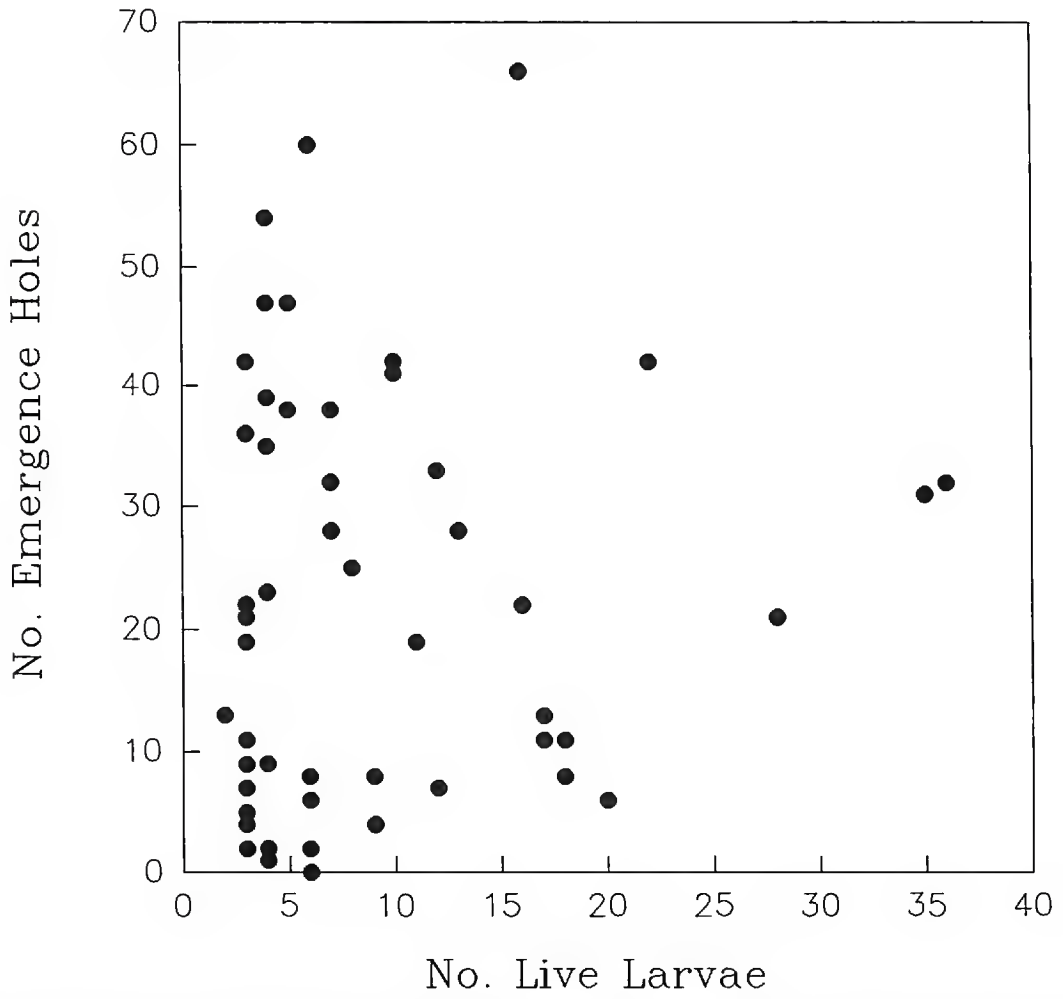

Figure 5. Number of *H. gibbicollis* adult exit holes compared to number of live larvae present in structural timbers.

were present; the maximum number found in one block was 55, which equal 631/929 cm^2 (per 1 ft^2). Williams (1973) found 72 *E. peltata* larvae/929 cm^2 in yellow poplar, *Liriodendron tulipifera* L., boards and 144 larvae/929 cm^2 in yellow poplar molding. These high numbers are relatively uncommon, but when found within structural timbers may quickly cause serious weakness. The average number of *H. gibbicollis* larvae found in a representative sample of 137 wood blocks (9 cm by 9 cm by 2 cm) was 7.3.

Although the literature is replete with statements that anobiids will only attack old, well seasoned wood (Linsley 1943, Chamberlin 1949, Ebeling 1975, Hickin 1981, Mampe 1982), this is not the case with *H. gibbicollis*. Replacement wood, attached to old infested timbers, in seven coastal homes harbored many anobiid larvae even though the wood had been in place for less than 10 years. Greater nutritional availability in wood harvested on shorter growth cycles may lead to serious anobiid problems in the future (Williams & Mauldin 1981). Bletchly (1957) demonstrated that *A. punctatum* was capable of infesting a wide variety of freshly cut hardwoods and softwoods. Williams & Mauldin (1974) reported that the anobiid *E. peltata* infested seasoned and unseasoned wood. Exit holes may not become apparent for 4–5 years and large scale infestations for 15–20 years because the holes are minute (< 2 mm) and often located in relatively inaccessible areas.

Most assessments of anobiid infestations made by the pest control industry are based on the number of adult exit holes on the wood surface. We found no correlation between the number of exit holes and larval counts within wood blocks (Fig. 5). Williams et al. (1979) supported this conclusion and further stated that the number of exit holes does not necessarily indicate that an infestation is active,

Table 1. Growth of *Hemicoelus gibbicollis* larvae within wood over a 2-year period.

Larva no.	Initial length[a]	Terminal length	Size increase	Distance moved/month
1.5-3	2.25	5.55	3.30	8.1
1.6-2	2.95	3.85	0.90	8.2
1.13-2	3.05	4.10	1.10	7.1
1.16-1	2.15	4.35	2.20	10.7
1.16-2	3.05	4.15	1.10	8.4
3.11-1	2.30	3.10	0.80	5.7
3.11-2	2.80	3.95	1.15	10.4
3.11-4	2.95	4.30	1.35	7.6
3.11-6	2.90	4.10	1.20	8.6
3.12-2	3.55	3.85	0.30	4.1
4.1-1	4.05	5.50	1.45	13.2
4.2-1	4.85	5.60	0.75	11.0
4.2-2	3.20	4.30	1.10	13.8
4.7-1	2.55	4.25	1.70	14.5
4.7-3	5.75	6.45	0.70	11.2
5.13-1	3.55	4.40	0.85	6.6
5.13-2	3.15	4.45	1.30	10.7
5.15-1	4.20	5.05	0.85	9.7
5.17-5	2.30	4.70	2.40	7.2
5.17-6	2.85	4.15	1.30	13.8

[a] Measurements in mm.

only the existence of larvae does. The best technique for determining presence of larvae is radiography.

Larvae appeared to be randomly distributed within most wood blocks. Occasionally, two or more were located within the same feeding tunnel, but most were positioned 0.5–1.0 cm apart. Generally, larvae moved 1 cm or less during a 30 day period. The maximum distance traveled by any immature was 4.4 cm over 30 days. During 24 months of radiographic observations the mean larval distance traveled was 0.95 ± 0.06 cm/month (mean ± SEM; $n = 220$, range = 0.07–4.44).

Lengths of 20 larvae were recorded at the beginning and end of a 2 year period (Table 1). These measurements were variable across the samples ($\bar{x} = 3.22 \pm 0.20$ mm). The average size increase over 24 months was 1.29 ± 0.15 mm and ranged between 0.30 and 3.30 mm. The average amount of growth each month was 0.06 mm (range = 0–0.45 mm). No correlation was noted between apparent size increase and amount of movement (Fig. 6). Activity was somewhat reduced in winter months, but larvae extracted during December, January, and February were capable of sustained movement within the frass-filled tunnels. It is unclear if a diapause is present in this species, but given year-round moderate climatic conditions in their native range, an arrested state of development is probably unnecessary.

The length of time anobiid larvae feed within wood is variable and depends primarily on available nutrition. Infested timbers collected in 1987 from a structure in western Washington continued to produce adult beetles in 1991. Radiographs showed that mature larvae were still present in late 1991. These larvae were >4 mm long and most, if not all, will probably emerge in 1992. Based on these data, the maximum time *H. gibbicollis* spends as a larva is 6 years. Williams

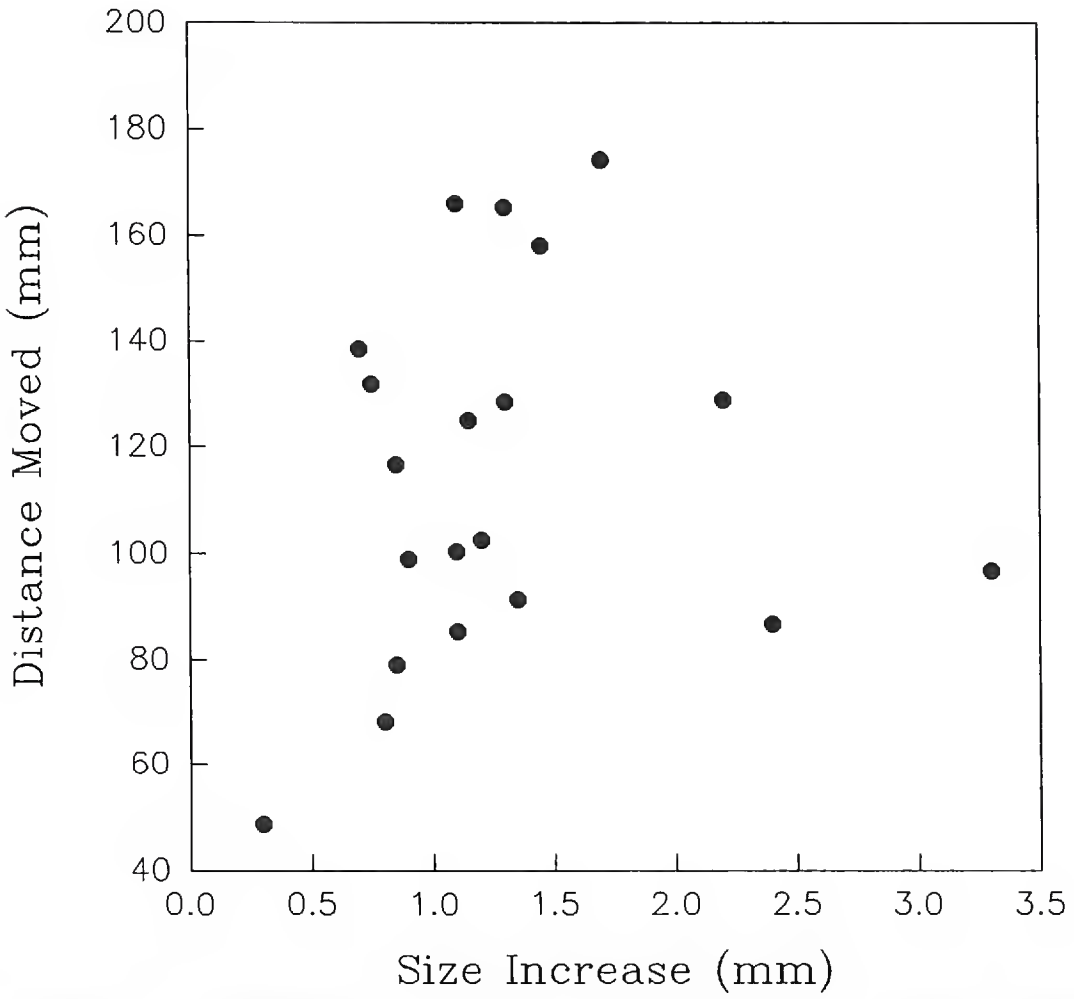

Figure 6. Growth of *H. gibbicollis* larvae related to movement within structural timbers.

& Mauldin (1981) reported the life cycle of *E. peltata* to be at least 2 years in favorable wood and possibly five in unfavorable wood. Baker & Bletchly (1966) and Hickin (1981) described the life cycle of *A. punctatum* as taking 3 years or more.

According to structural pest control operators in Washington and Oregon anobiid infestations often die out for unknown reasons, thus reducing or eliminating the need for insecticide applications. When wood nutrition becomes less available due to extensive feeding by larvae, emerging adults may choose more highly nutritious wood for oviposition (Bletchly & Farmer 1959, Bletchly & Taylor 1961). Also, anobiids are restricted from certain woods if the moisture content is above 20%, as this encourages development of *Penicillium* spp. that colonize on beetle eggs. If bark, which deters oviposition, is present on structural timbers, or if the nitrogen level has decreased substantially due to feeding by other organisms, oviposition may be significantly reduced (Robinson 1990).

When wood moisture levels were maintained at 11–12%, *H. gibbicollis* larvae did not survive longer than 18 months (Fig. 7). Smaller larvae died initially, and larger instars succumbed more slowly to the reduced wood moisture. Moore (1968) claimed that regulation of humidity (and wood moisture) alone would not be effective in controlling the initiation of an infestation by *E. peltata,* but Williams & Smythe (1978) stated that the advent of central heating and cooling in modern homes is probably the major factor in reducing anobiid infestations. Relative humidity, as it affects wood moisture, is the primary factor which influences anobiid infestations within structural timbers. Wood moisture levels between 14 and 17% are optimal for *H. gibbicollis* survival (Suomi 1992); levels above 19% resulted in development of decay fungi that effectively reduced numbers of both

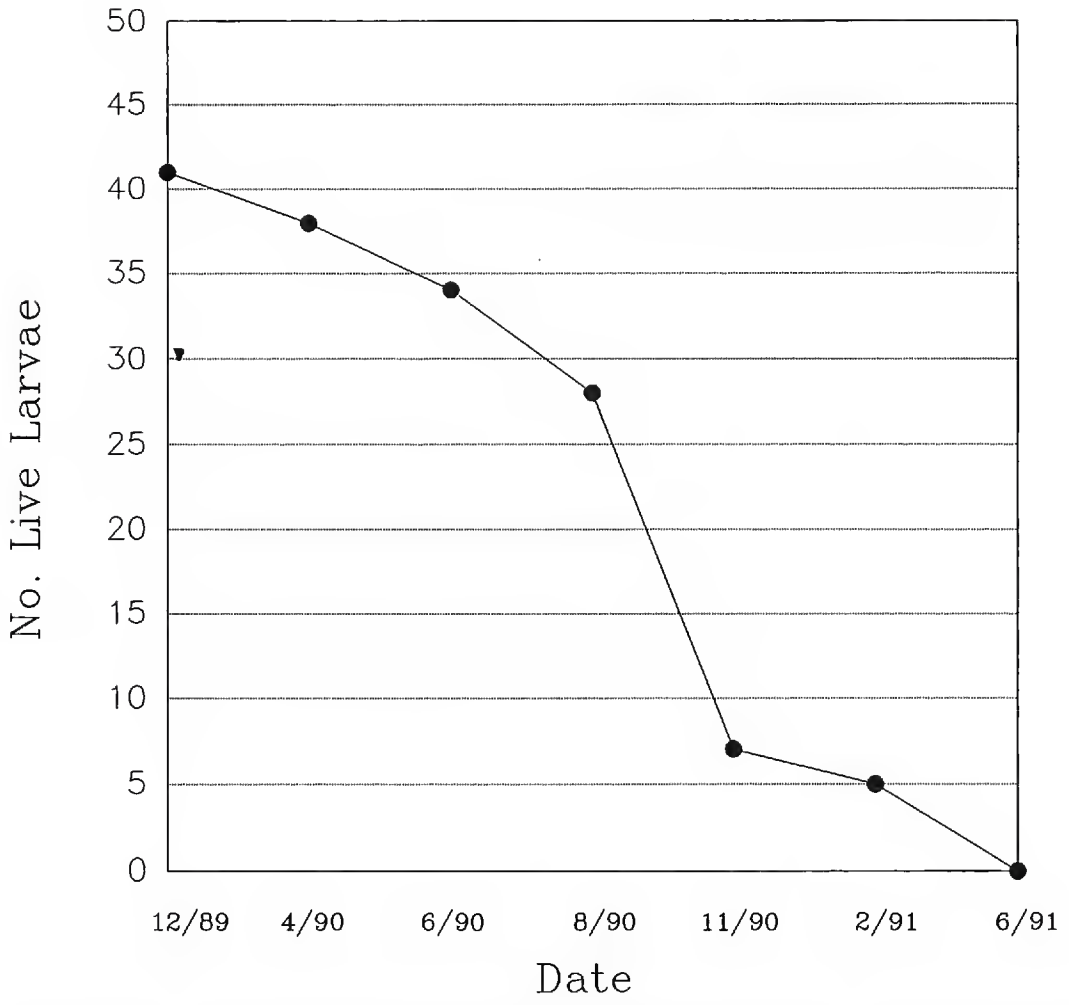

Figure 7. Survival of *H. gibbicollis* larvae in Douglas-fir blocks at 11–12% wood moisture.

eggs and larvae. Spiller (1948) also noted that *A. punctatum* survival was hindered at wood moisture levels above 20%.

In nature, *H. gibbicollis* larvae attack a wide variety of softwood and hardwood tree species (Table 2). The most accessible wood for a natural anobiid infestation are dead standing trees or stumps that remain undecayed for a minimum of 3 years, as most wood-infesting anobiids have a 3 year life cycle in nature (Berry 1976). Bletchly & Farmer (1959) demonstrated with *A. punctatum* that an increase in larval weight and survival was positively correlated with the nitrogen content of their host. Sapwood in trees is generally higher in amounts of soluble nitrogen and amino acids than heartwood (Merrill & Cowling 1966). Sapwood in contact with the ground is totally decayed in 3 years or less (Shigo 1968), so anobiids cannot complete their life cycles in this decomposing wood. The heartwood that remains is lower in nitrogen and higher in extractives which tend to repel anobiids (Parkin 1940).

Pupa.—During this research very few larvae were collected prior to pupation ($n = 4$, range = 5.3–6.1 mm, $\bar{x} = 5.7$ mm long). In two separate experiments, an attempt was made to promote pupation of *H. gibbicollis* by exposing infested wood blocks to different cooling regimes for varying lengths of time. Blocks held at 1.5° C and 14–15% wood moisture failed to produce any adult beetles during the normal emergence period. Radiographs taken 4 months and 1 year after the treatments revealed the presence of live larvae that were considerably smaller in size (up to 50% in certain cases) and showed little movement from their original positions. It is probable that these immatures were forced into a quiescent period with little or no feeding occurring, thus resulting in their reduced size.

Other infested wood blocks were placed at 2 month intervals in an unheated

Table 2. Known host tree species of *Hemicoelus gibbicollis.*

Scientific Name[a]	Common Name	Reference
Abies concolor (Gordon & Glendinning) Lindley	grand fir	Knutson 1963
Abies grandis (Douglas) Forbes	concolor fir	Knutson 1963
Acer macrophyllum Pursh	bigleaf maple	Keen 1938
Alnus rubra Bongard	red alder	Knutson 1963
Ceanothus thyrsiflorus Eschscholz	buckthorn	Knutson 1963
Corylus cornuta Marshall	hazelnut	Knutson 1963
Myrica californica Chamisso	Pacific myrtle	Suomi 1992
Picea engelmannii Parry	Engelmann spruce	Hatch 1946
Pinus monticola Douglas	western white pine	Suomi 1992
Pinus spp.	plywood	Suomi 1992
Prunus emarginata (Douglas) Walpers	bittercherry	Furniss 1939
Pseudotsuga menziesii (Mirbel) Franco	Douglas-fir	Doane et al. 1936
Quercus wislizensii DeCondolle	oak	Knutson 1963
Salix lasiandra Bentham	willow	Knutson 1963
Sequoia sempervirens (D. Don) Endlicher	redwood	Keen 1938
Taxus brevifolia Nuttall	Pacific yew	Knutson 1963
Thuja plicata Don	western red cedar	Suomi 1992
Tsuga heterophylla (Rafinesque) Sargent	western hemlock	Knutson 1963

[a] Plant names from Hitchcock & Cronquist (1973).

garage. Adults only emerged from blocks which had been moved out-of-doors 8 months prior to the normal adult emergence time in June, July, and August (Table 3). The first adult appeared during the second week of July and the last appeared in the third week of August.

French (1971) and Berry (1976) reported on the inability of *A. punctatum* to pupate under constant optimal temperatures. During this research, infested wood blocks maintained in indoor insectaries produced adult beetles every summer, but mainly from wood that had been collected the previous year. The greater the number of years that wood was kept indoors, the fewer adults emerged, even though many larvae were observed in radiographs. Berry (1976) stated that changes in moisture content or photoperiod do not induce pupation in *A. punctatum,* but

Table 3. Adult *Hemicoelus gibbicollis* emergence from wood blocks held out-of-doors, eastern Washington.

No. months	No. larvae	No. emerged (%)
2	11	0 (0)
4	12	0 (0)
6	12	0 (0)
8	18	5 (28)

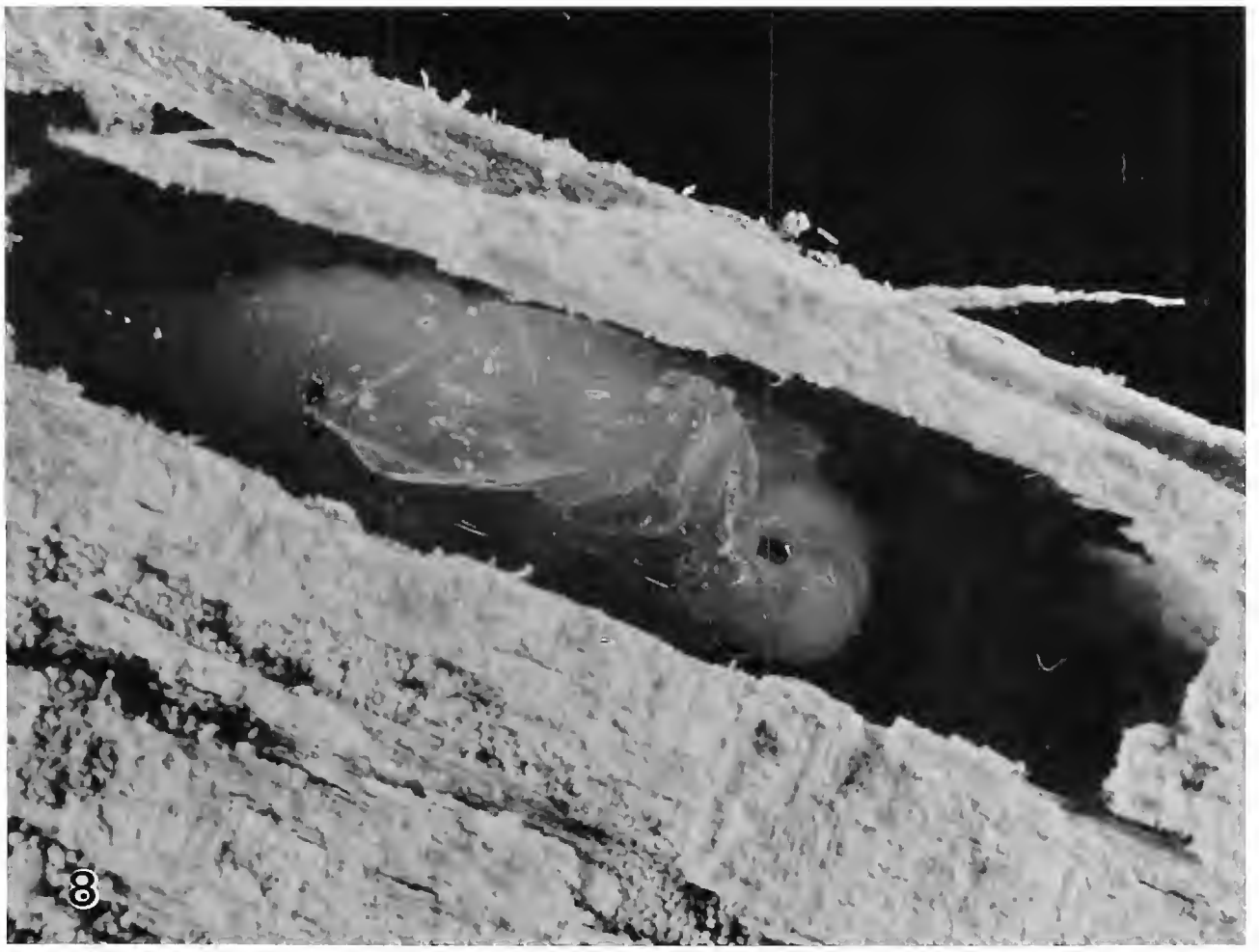

Figure 8. Pupa of *H. gibbicollis.*

rather, the pupal induction is dependent upon changes in temperature during a critical period in spring. Williams & Waldrop (1978) believe that emergence of *E. peltata* adults is synchronized by critical ambient temperature and relative humidity. With *H. gibbicollis,* it is likely that a combination of factors, including favorable temperatures, relative humidity (and thus, wood moisture), and larval size, induces pupation. To be effectively supplied with a laboratory population of these beetles, the best course is to collect infested wood and retain the material in an outdoor insectary which simulates environmental changes normally encountered by the insect.

Hemicoelus gibbicollis pupae were not easily observable by x-ray techniques. From images seen on the radiograph prior to pupation, larvae would cease moving and a decrease in length of 0.4–1.1 mm was noted. Six of 20 larvae observed eventually pupated and emerged as adults. No pupal cocoon was produced by this species. A change to the pupal form becomes imminent when a larva tunnels toward the outside surface of wood. Pupae examined were found in oval cells within 1–2 mm of the wood surface (Fig. 8). Four larvae were measured prior to pupation that ranged from 5.3 to 6.1 mm long and weighed between 8.1 and 11.0 mg. Bletchly (1953) reported average prepupal weights of 3.9 and 5.0 mg for male and female *A. punctatum,* respectively. In this same anobiid species, Berry (1976) observed successful pupation when larvae attained weights between 4 and 8 mg.

The change from larva to pupa required about 24 h and was observed on four occasions. Pupae are relatively active during this process and moved vigorously when exposed to light. Initially, pupae are white with red-brown eyes. Elytra sclerotize first, followed by the head and thorax, and finally, the abdomen. Pupae weighed between 5.2 and 7.4 mg and were approximately 4.5 mm long.

The minimum amount of time required to change from a mature larval form to a fully sclerotized adult beetle was 13 days; other pupal periods required 15, 19, and 22 days. French (1971) demonstrated that *A. punctatum* required 19–30 days to complete the pupal stage and Hickin (1975) reported the process lasted 2 to 3 weeks. In the Pacific Northwest, normal pupation for *H. gibbicollis* occurs from early May through mid-August.

Acknowledgment

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HOSTS, ADULT EMERGENCE, AND DISTRIBUTION OF THE APPLE MAGGOT (DIPTERA: TEPHRITIDAE) IN UTAH

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Abstract.—The apple maggot, *Rhagoletis pomonella* (Walsh), in Utah was reared from field infested apricot (*Prunus armeniaca* L.), chokecherry (*Prunus virginiana* L.), crabapple (*Malus* spp.), mahaleb (*Prunus mahaleb* L.), pyracantha (*Pyracantha coccinea* Roemer), ornamental hawthorn (*Crataegus monogyna* Jacquin and *C. mollis* Scheele), plum (*Prunus americana* Marshall), river hawthorn (*C. douglasii* Lindley), sweet cherry (*Prunus avium* L.), and tart cherry (*Prunus cerasus* L.) in Utah. Using 1 Mar as a starting date and an 8° C lower threshold, 50% emergence was as early as 1537 degree-days in cherry (both sweet and tart) to as late as 3773 degree-days in pyracantha. The apple maggot has been detected in most areas where river hawthorn grows in Utah, and in all major fruit growing areas, except in Washington and Wayne Counties.

Key Words.—Insecta, *Rhagoletis pomonella,* hosts, distribution, emergence, Utah

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The apple maggot (AM), *Rhagoletis pomonella* (Walsh), is indigenous to North America, where its native host is hawthorn, *Crataegus* spp. (Bush 1966). Since it was first reported in 1867 from apple, *Malus* spp. (Walsh 1867), it has been found in other North American hosts: apricot—*Prunus armeniaca* L. (Lienk 1970, Davis & Jones 1986), crabapple—*Malus* spp. (Walsh 1867, O'Kane 1914, Herrick 1920, AliNiazee & Penrose 1981, Westcott 1982, Davis & Jones 1986), pear—*Pyrus* spp. (Prokopy & Bush 1972), plum—*Prunus* spp. (Herrick 1920, Davis & Jones 1986), pyracantha—*Pyracantha coccinea* Roemer (Bush 1966, Davis & Jones 1986), quince—*Cydonia oblonga* Miller (Fisher 1981), rose—*Rosa rugosa* Thunberg (Prokopy & Berlocher 1980), snowberry—*Symphoricarpos* spp. (J. F. Brunner, unpublished data), sour (tart) cherries—*Prunus cerasus* L. (Shervis et al. 1970, Jorgensen et al. 1986, Davis & Jones 1986), and sweet cherries—*Prunus avium* L. (Jorgensen et al. 1986, Davis & Jones 1986).

AM was first collected in Utah from a Malaise trap located about 8 km from the nearest domestic fruit trees in Box Elder County in 1967 (Jorgensen et al. 1986). It was not collected again until 1983 when it was found in Pherocon® AM traps in Utah County during a western cherry fruit fly (*Rhagoletis indifferens* Curran) survey (Edward J. Bianco, personal communication). Since 1983, AM have been collected from many hosts in Utah, especially river hawthorn *Crataegus douglasii* Lindley (Jorgensen 1986, Davis & Jones 1986).

It is thought that the AM was recently introduced into Utah, although it is not clear if it originated from the eastern United States or the Pacific Northwest (McPheron 1990a). McPheron et al. (1988) and McPheron (1990b) have speculated that early populations experienced a "founders effect" in which individuals from tart cherries went through a genetic bottleneck resulting in less genetic

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variation compared to AM from hawthorn (*Crataegus mollis* Scheele) in Illinois and the eastern United States, or from hawthorn (*C. douglasii*) or apple from the Pacific Northwest (McPheron 1990a, McPheron 1990b). McPheron (1990a) found relatively high interpopulation heterogeneity in four Utah AM populations. He suggested that this pattern may be the result of a single introduction of AM into Utah, followed by secondary introductions into other areas of the state. He also reported allele frequency differences at 2 genes in AM populations infesting *C. douglasii* and *P. cerasus* which are similar to allele frequency differences between sympatric apple and hawthorn infesting flies in Washington and genes that mark interhost differentiation in the eastern United States.

AM could cause significant losses to Utah's fruit industry (Bond et al. 1984, Dowell 1990). This research was conducted to gain the information needed to help reduce these losses. Our objectives were to: (1) determine AM hosts that serve as reservoirs for flies infesting commercial fruit, (2) describe adult AM emergence patterns to help time pesticide applications, and (3) determine AM geographic distribution within Utah.

Materials and Methods

AM adults were trapped using Pherocon® AM traps hung within the canopies of suspected host plants, largely Rosaceae. Fruit samples were collected where adults had been trapped and then dissected to detect larvae. Additional fruits were held over trays of moistened vermiculite to collect the larvae as they descended from fruit to pupate. The vermiculite was screened periodically to recover pupae, which were then placed in moistened vermiculite and retained at 4° C for 3–6 months. The pupae were then incubated at 24° C and 16:8 (L:D) until adults emerged. Adults were identified by morphological characteristics (Westcott 1982). Unless stated otherwise, in this paper a host is defined as a field collected fruit in which an AM had oviposited and the resulting larva completed development to the adult.

Trottier et al. (1975), Laing & Heraty (1984), and Jones et al. (1990) have demonstrated that trap catch is a good predictor of AM emergence. Adult emergence (50%) associated with several spatially isolated host plants was determined using Pherocon® AM traps. Captured adults were assumed to have originated from the hosts in which they were trapped as either no other potential hosts were within 0.8 km or all potential hosts in a particular area were monitored. Numbers trapped were recorded 2–3 times per week and traps replaced weekly. We used 1 Mar as a starting date and a lower threshold of 8° C to calculate AM degree-days. Emergence patterns for 1985 were determined from river hawthorn in Provo, and from apricot, cherry (both sweet and tart), chokecherry (*Prunus virginiana* L.), crabapple, mahaleb (*Prunus mahaleb* L.), and ornamental hawthorn (*Crataegus monogyna* Jacquin) in Mapleton. Emergence patterns for 1986 were determined using trapping data from river hawthorn in Provo; cherry (both sweet and tart) and plum (purple and yellow varieties from volunteer rootstock) in Spanish Fork; apricot, chokecherry, crabapple, mahaleb, ornamental hawthorn, and pyracantha in Mapleton. Temperature and moisture data were monitored daily using Omnidata electronic data loggers (Omnidata International, Logan, Utah 84321).

AM geographic distribution throughout the state was determined using Pher-

Table 1. Number of fruit collected, number of pupae, and number of apple maggot adults reared in Utah during 1985.

Host	Location	Date collected	Approx. no. fruit	No. of apple maggot	
				Pupae	Adults
River hawthorn	Mapleton	Jul 31	15,000	2500	522
River hawthorn	Provo	Aug 8	2500	550	331
Crabapple	Mapleton	Aug 14	2500	121	28
Ornamental hawthorn	Provo	Sep 5	2500	56	14
Ornamental hawthorn	Mapleton	Oct 9	3000	51	9
Apricot	Mapleton	Aug 8	750	15	6
Pyracantha	Mapleton	Oct 16	5000	6	3
Mahaleb	Mapleton	Jul 29	2000	27	2
Chokecherry	Mapleton	Aug 14	15,000	1	1
Chokecherry	Spanish Fork	Aug 14	5000	0	0
Plum	Provo	Aug 15	4000	0	0
Plum	Spanish Fork	Aug 15	600	0	0
Apple	Mapleton	Sep 12	300	0	0
Apple	Mapleton	Sep 21	500	0	0
Apple	Mapleton	Oct 9	200	0	0
Apple	Provo	Sep 5	300	0	0
Apple	Provo	Sep 11	500	0	0
Peach	Mapleton	Aug 14	500	0	0

ocon® AM traps to capture adults within the canopies of suspected host plants, especially river hawthorn.

Results and Discussion

Hosts.—Adult AM were trapped in the canopies of 20 potential host species in Utah from 1985 to 1987—apple (*Malus* spp.), apricot (*P. armeniaca*), ash (*Sorbus scopulina* Greene), chokecherry (*P. virginiana*), crabapple (*Malus* spp.), currant (*Ribes* spp.), mahaleb (*P. mahaleb*), ornamental hawthorn (*C. mollis* and *C. monogyna*), peach (*Prunus persica* L.), pear (*Pyrus* spp.), plum (*Prunus americana* Marshall, *P. cerasifera* Ehrhart, and *P. domestica* L.), pyracantha (*P. coccinea*), river hawthorn (*C. douglasii*), rose (*R. rugosa*), serviceberry (*Amelanchier* spp.), sweet cherry (*P. avium*), and tart cherry (*P. cerasus*). They were detected in 97%, 91%, and 92% of the river hawthorn trapping sites monitored by the Utah Department of Agriculture in 1985, 1986, and 1987 respectively (Allred 1988), and adults were reared from >90% of river hawthorn sites from which fruit was collected. In comparison, during 1986, 16%, 16%, and 8% of the trap sites caught AM in apple, sweet cherry, and tart cherry, respectively (Spangler 1986). During 1987, 6%, 13%, and 8% of the trap sites detected apple maggot adults in these same three hosts (Allred 1988). Adults were reared from <20% of cherry (both sweet and tart) sites sampled from 1985–1986. AM were reared from <50% of the crabapple and ornamental hawthorn (*C. monogyna* and *C. mollis*) trees sampled from 1985–1986.

Adult AM were reared from chokecherry and mahaleb which had not been shown to be hosts previously. However, chokecherry may be a rare or incidental host; one adult was reared from approximately 20,000 fruits collected in 1985 (Table 1). Additional verification could not be obtained in 1986 (Table 2) because

Table 2. Number of fruit collected, number of pupae, and number of apple maggot adults reared in Utah during 1986.

Hosts[a]	Location	Date collected	Approx. no. fruit	No. of apple maggot	
				Pupae	Adults
River hawthorn	Alpine	Sep 5	12,500	397	—[a]
Plum (red)	Spanish Fork	Aug 19	1360	34	22
Ornamental hawthorn	Mapleton	Oct 21	7500	65	10
Pyracantha	Mapleton	Oct 14	15,000	7	6
Plum (purple)	Provo	Aug 11	1800	4	3
Mahaleb	Mapleton	Jul 24	7200	22	4
Crabapple	Mapleton	Sep 26	1680	1	1
River hawthorn	Milburn	Oct 10	1500	3	0
River hawthorn	Fairview	Oct 10	1500	3	0
Plum (purple)	Mapleton	Aug 19	300	0	0
Plum (yellow)	Mapleton	Aug 19	1000	0	0
Serviceberry	Mapleton	Jul 16	3600	0	0
Ash	Mapleton	Sep 4	13,700	0	0
Ash	Springville	Sep 20	13,600	0	0
Rose hips	Mapleton	Oct 21	5000	0	0
Rose hips	Mapleton	Oct 23	5000	0	0
Rose hips	Mapleton	Oct 30	5000	0	0
Pear	Mapleton	Aug 21	100	0	0
Pear	Mapleton	Sep 4	80	0	0
Pear	Mapleton	Sep 20	90	0	0
Pear	Mapleton	Oct 3	130	0	0
Pear	Mapleton	Oct 4	100	0	0
Pear	Mapleton	Oct 21	150	0	0
Apple	Spanish Fork	Aug 21	150	0	0
Apple	Mapleton	Sep 20	150	0	0
Apple	Mapleton	Sep 30	150	0	0
Apple	Provo	Sep 30	500	0	0
Currant	Mapleton	Aug 11	2500	0	0

[a] These were retained for future use, but not reared.

most chokecherry lacked fruit. Glasgow (1933) reported mahaleb as a host of two fruit flies closely related to the AM, the black cherry fruit fly (*Rhagoletis fausta* (Östen Sacken)) and the eastern cherry fruit fly (*Rhagoletis cingulata* Loew). He also reported chokecherry as host of the black cherry fruit fly.

AM pupae were not recovered from wild apple or peach; however, apple and peach had been reported earlier as larval hosts (Walsh 1867, Porter 1928). Previous research (Davis & Jones 1986) and inspections by the Utah Department of Agriculture (Spangler 1986, Allred 1988) have not found AM in commercial apples in Utah. However, V. P. Jones (personal communication) reared AM adults that had been collected from non-commercial apples growing near river hawthorn in Wellsville, Utah in 1987.

Varieties of red or purple plum growing from volunteer rootstock (*P. americana*) and ornamental cherry plum (*P. cerasifera*) are hosts of AM in Utah, but yellow plum from volunteer rootstock (*P. americana*) and commercial plum (*P. domestica*) are not (Table 2). AM adults were reared from crabapple, mahaleb, ornamental hawthorn, and pyracantha in 1985 and 1986 (Tables 1 and 2). Pupae were not recovered from serviceberry, ash (*S. scopulina*), pear, or apple (Tables 1 and

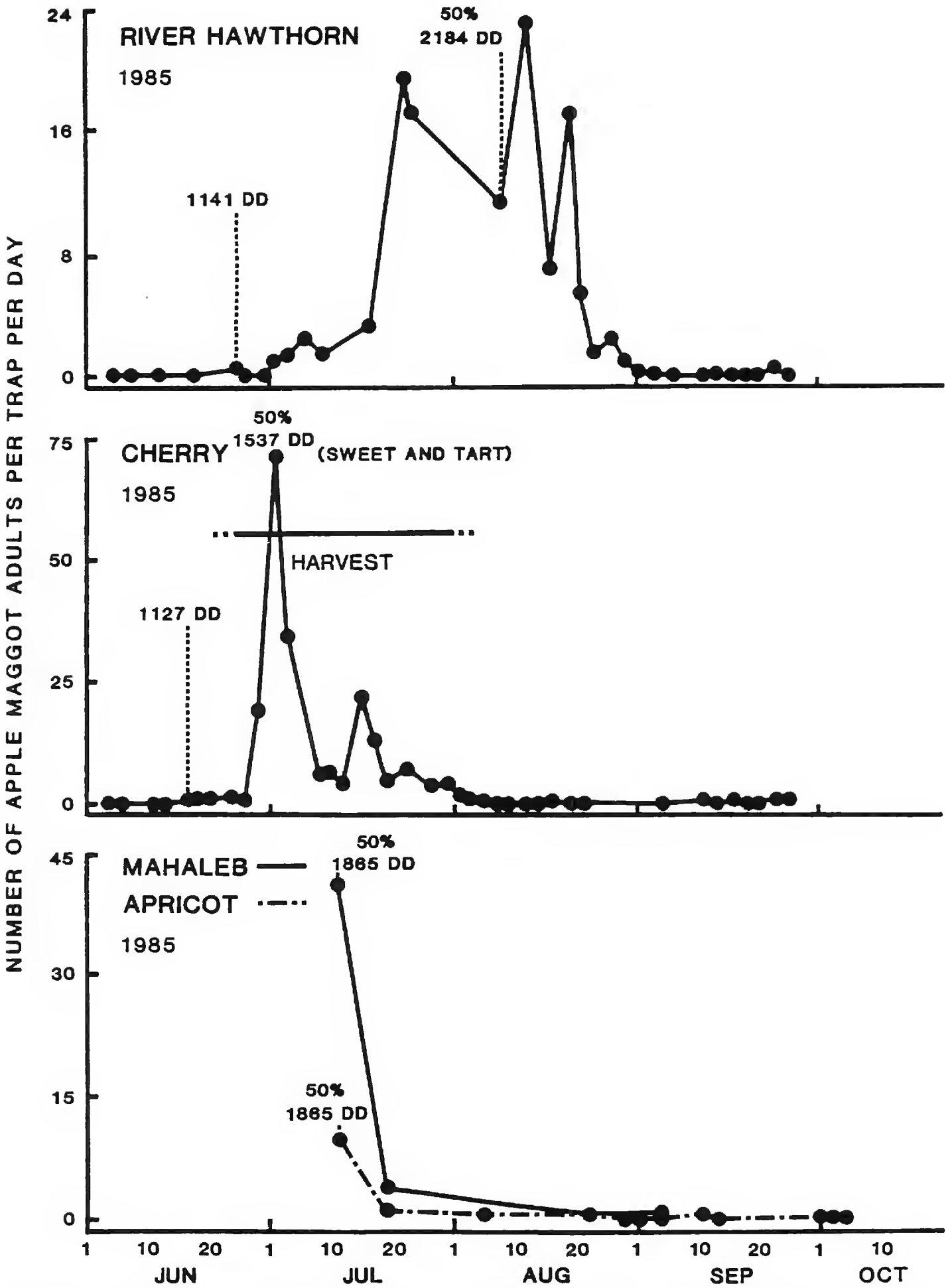

Figure 1. Emergence patterns for apple maggot in Utah from river hawthorn, sweet and tart cherry, mahaleb, and apricot, 1985: first and 50% emergence indicated using degree-days.

2). AM were not reared from rose hips or currant (*Ribes* spp.), although *Rhagoletis ribicola* Doane was reared from currant and *Rhagoletis basiola* (Östen Sacken) from rose hips.

Documented hosts of the AM in Utah now include: apple, apricot, chokecherry,

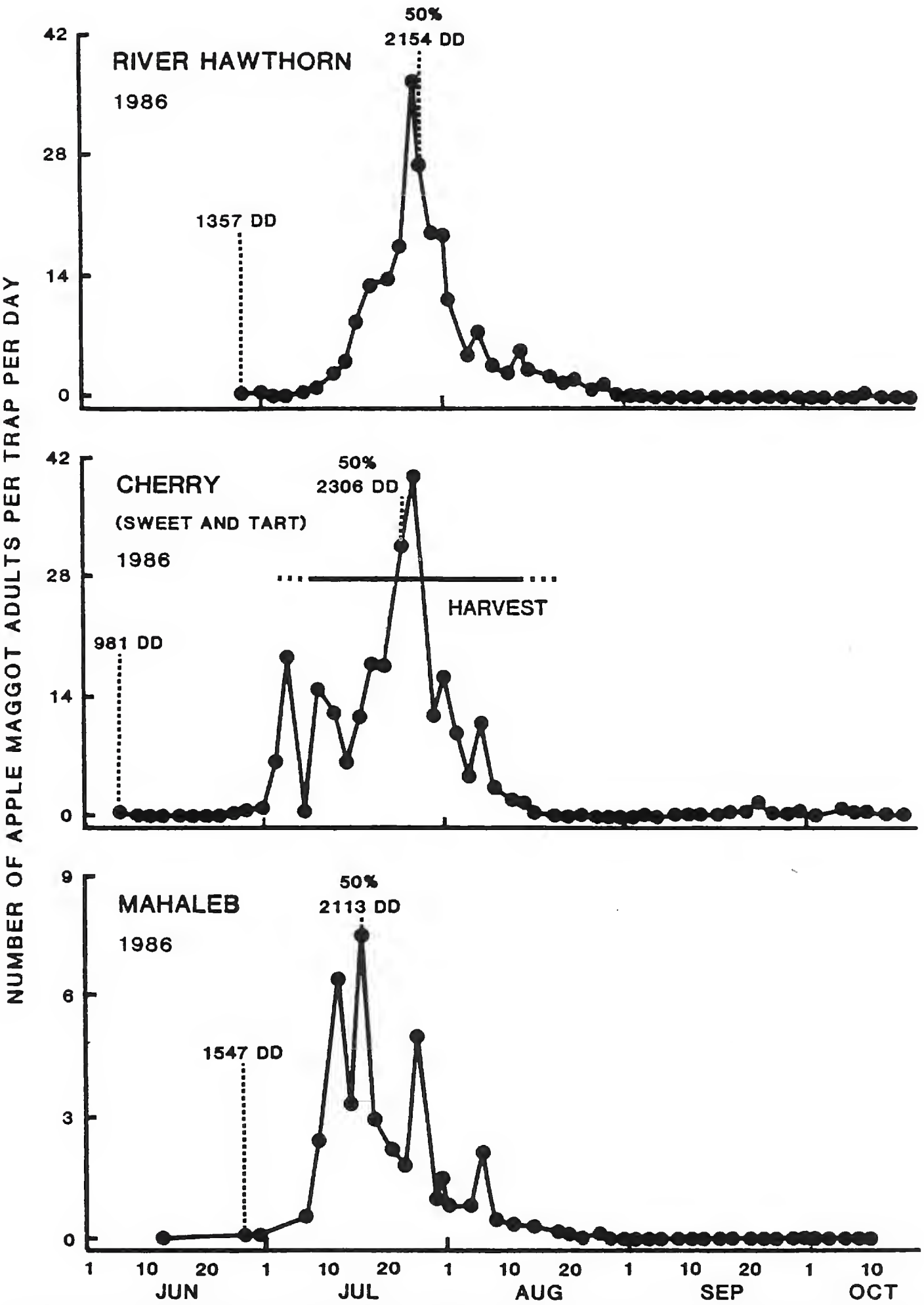

Figure 2. Emergence patterns for apple maggot adults in Utah from river hawthorn, sweet and tart cherry, and mahaleb, 1986: first and 50% emergence indicated using degree-days.

crabapple, mahaleb, ornamental and river hawthorn, plum, pyracantha, and sweet and tart cherry.

Emergence Patterns.—Adult AM emergence is governed by temperature and moisture (Jones et al. 1990, Davis & Jones 1986, Joos et al. 1984). Requirements

for chilling and moisture are usually attained during the winter. Survival of fruit infesting *Rhagoletis* species requires synchrony of adult emergence with fruit maturation (Bush 1974). Asynchrony is not unusual when a species is first introduced into a new area. However, to survive, the species must adapt to new hosts or alter its emergence times, as the AM apparently has in Utah.

Data for AM in 1984 (Jorgensen et al. 1986) and 1985 (Fig. 1) indicated that emergence may be synchronized with maturation of fruit varieties from which adults were trapped and 50% emergence times (ET50) of 1537 DD in cherry and 2184 DD in river hawthorn showed that distinct populations may have developed (Fig. 1). Although McPheron et al. (1988) reported that AM may have gone through a genetic bottleneck after their introduction into Utah, their adaptation to a variety of hosts is evident from the data in Tables 1 and 2. The latest ET50s in 1985 were for chokecherry (25 Jul), crabapple (5 Aug), and ornamental hawthorn (1 Oct) (emergence curves not shown). Values ranged from 1537 DD in cherries to 3718 DD in ornamental hawthorn—a difference of 2181 DD in 1985.

Although the emergence patterns in 1986 (Fig. 2) followed much the same trends as observed in 1985 (Fig. 1), the ET50s associated with cherry and hawthorn were not as broad. These reduced ranges were apparently due to the later emergence of adults from early fruits (cherries) in 1986, coupled with earlier emergence of adults trapped from river hawthorn. ET50s ranged from 2113 DD on mahaleb to 3773 DD for pyracantha—a difference of 1660 DD in 1986 (Fig. 2, 3).

Bush (1974), Reissig & Smith (1978), Prokopy et al. (1982), and Diehl (1983) suggested that allochronic isolation, such as that observed between 1985 populations on cherry (both sweet and tart) and river hawthorn (Fig. 1), was important in the evolution of sympatric host races of AM using apple and hawthorn (*Crataegus* spp.) in eastern North America. It is unclear whether the Utah AM populations will follow a similar trend.

The earliest emergence of adult AM detected during 1985 and 1986 in Utah was 6 Jun 1986 (981 DD) in cherry (both sweet and tart) at Spanish Fork (Fig. 2). Early emergence allows infestation of and complete development in both sweet and tart cherries (Jorgensen et al. 1986).

The latest adult trapped during 1985 or 1986 was on 4 Nov 1985, when four inches of snow was on the ground. These late flights were well past the ripening of commercial apple. It is unlikely that larvae, present in the fruit at this late date, could successfully complete development. Dissections of collected adult females, conducted by Utah State University researchers, found immature ovaries. This suggests these flies were either part of a second generation or late emergents from a single generation.

It is not known why AM have not been found in apples from the major fruit growing areas in Utah, particularly since apples and river hawthorn fruits mature at almost the same time. They are less likely to complete development in late maturing hard varieties of apples ('Golden Delicious', 'Red Delicious', 'Rome Beauty'), which are predominantly grown commercially in Utah, than in the early, softer varieties usually grown commercially in the eastern United States ('Yellow Transparent', 'Gravenstein', 'Wealthy', 'McIntosh') (Neilsen 1971, Reissig 1979, Joos et al. 1984, Jorgensen et al. 1986). Jorgensen et al. (1986) reported that the AM in Utah is more likely to oviposit in fruits that mature before the native host (river hawthorn) than after. Accordingly, adaptation to the hard apple varieties

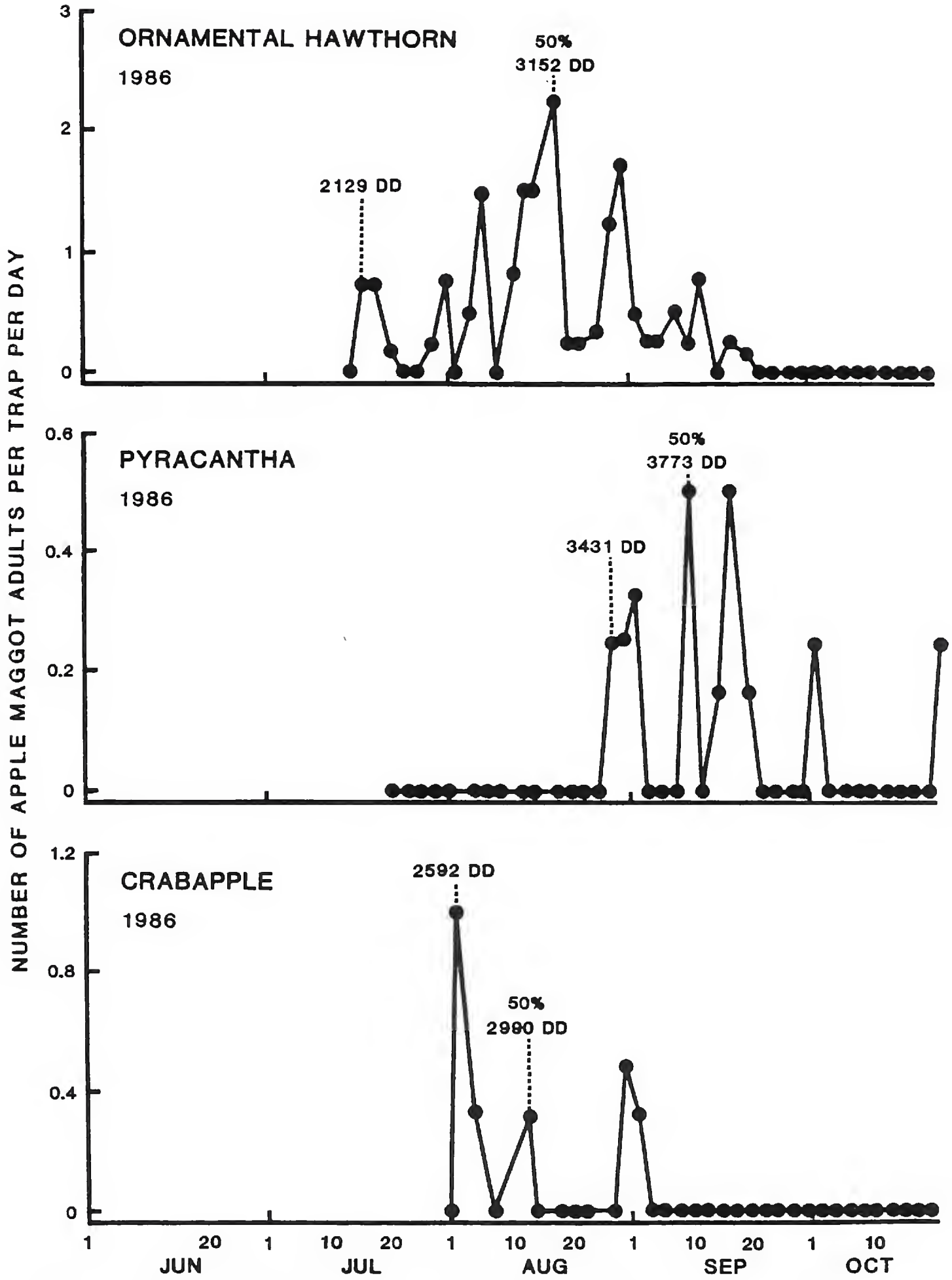

Figure 3. Emergence patterns for apple maggot adults in Utah from ornamental hawthorn, pyracantha, and crabapple, 1986: first and 50% emergence indicated using degree-days.

that mature slightly later than river hawthorn is less likely than adaptation to early-maturing apples and cherries (Jorgensen et al. 1986). Since the AM has apparently adapted phenologically to develop in early rather than late apple varieties, and since the early emergence of Utah AM females is synchronized with

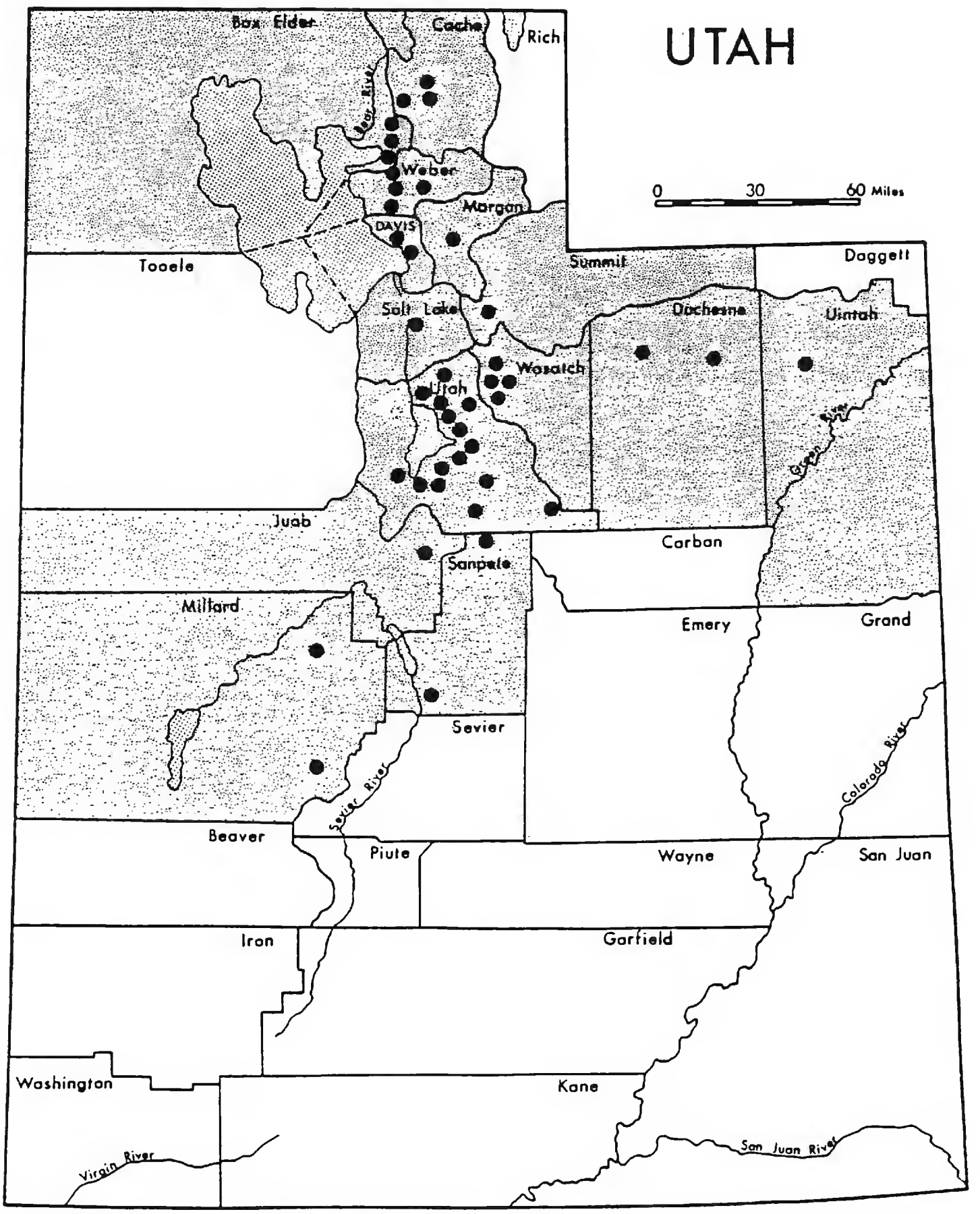

Figure 4. Distribution of the apple maggot in Utah, by county.

cherries, it may take many generations before this insect becomes a general pest of the apple varieties grown commercially in Utah.

Distribution.—Our apple maggot surveys and those by the Utah Department of Agriculture (Spangler 1986, Allred 1988), and Wilford Hansen, Utah State University, found AM in Box Elder, Cache, Davis, Duchesne, Juab, Millard, Morgan, Salt Lake, Sanpete, Summit, Uintah, Utah, Wasatch, and Weber Counties (Fig. 4).

Other counties suspected of having AM, because of the presence of river hawthorn (Welsh et al. 1987), are: Beaver, Daggett, Piute, San Juan, Sevier, Tooele,

and Washington. Surveys are needed in these counties in areas where river hawthorn is present near commercial fruit orchards. All major commercial fruit growing areas in Box Elder, Cache, Davis, Salt Lake, Utah, and Weber Counties are threatened with Utah AM eventually adapting to apple.

We conclude that because the AM has been found in apple in California (Joos et al. 1984), Oregon (AliNiazee & Penrose 1981), Utah (V. P. Jones, personal communication), Washington (J. F. Brunner, unpublished data), and in the eastern United States (Pickett 1937, Reissig 1979) and because the AM is found in the majority of the commercial apple growing areas in Utah, it seems probable that this insect will eventually infest unsprayed and commercial apple orchards throughout Utah.

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A NEW SPECIES OF *CIXIUS* FROM THE UNITED STATES (HOMOPTERA: FULGOROIDEA: CIXIIDAE)

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Abstract.—Twenty-seven species of *Cixius* are recognized as occurring in the United States; of these, eight have been known from California. A ninth cixiid species for California, *Cixius yufengi* NEW SPECIES, is described and illustrated here.

Key Words.—Insecta, Cixiidae, *Cixius yufengi* NEW SPECIES

Thirteen genera and 174 species of Cixiidae have been reported from North America, all of which occur in the United States. Recently, an undescribed species of *Cixius* from California, collected by Yu-Feng Hsu, was found and is described in this paper. This brings the total of United States species of *Cixius* to 27, nine of which occur in California. All the scale units used here are in mm.

GENUS *CIXIUS* LATREILLE, 1804

Type Species.—*Cicada nervosa* L. (Subsequent designation by Curtis).

Cixius yufengi Tsaur, NEW SPECIES
(Fig. 1)

Type.—Holotype: male; data: USA. CALIFORNIA. *MONTEREY Co.:* 13 Apr 1990, Y. F. Hsu; deposited: Institute of Zoology, Academia Sinica, Taipei, Taiwan, Republic of China.

Male.—Body length: 7.0 mm; length of tegmen: 5.9 mm. General coloration black. Body covered with powdery wax. Lateral carinae of vertex each with round yellow macula on basal one-third. Median carina of face dull brown. Lateral carinae of face and transverse carina between face and vertex brown. Ocelli tawny. Legs black-yellow on coxae, trochanters and femora, yellow on tibiae and tarsi. Tegmina translucent, with prominent black pustules, 1 faint oblique grey stripe originating from fork of Sc+R to ramification of A. Vertex 1.3× as wide (at level of basal emargination) as length along middle line. Rostrum attaining hind coxae. Tegmen with 11–12 apical cells, finely curving outward on costal margin. Chaetotaxy of hind tarsi 7/6–7. Second tarsomere with double row of spines with second row membraneous. Genitalia: in ventral view, pygofer roundly U-shaped; in lateral view dorsolateral angle with small production curving mesad, in ventral view medioventral process large, triangular, in lateral view blade-like. Anal segment slightly widening toward anal opening, in lateral view apical projection gently curving ventrad, apical margin concave medially, anal style slender. In lateral view genital styles symmetrical, in ventral view slightly curving dorsad toward apex, distal lobe flap-like, and parallel-sided on basal two-thirds. Aedeagus slender, basoventral surface not indented, with total of 3 spinose processes, 2 visible in left-side orientation, 1 in right side aspect: shortest implanted on lateroapical angle near base of flagellum, acuminate, gently curving outward, directed dorsad at tip; intermediate originating from ventral surface near apex, stout for most portion, curving laterad and tapering to apex at apical one-fourth; longest located opposite shortest, awl-shaped, smoothly curving dorsad, directed cephalad at tip.

Female.—Unknown.

Diagnosis.—*Cixius yufengi* NEW SPECIES is similar to *C. prominens* Tsaur, and these two species can be easily distinguished from other species in the genus

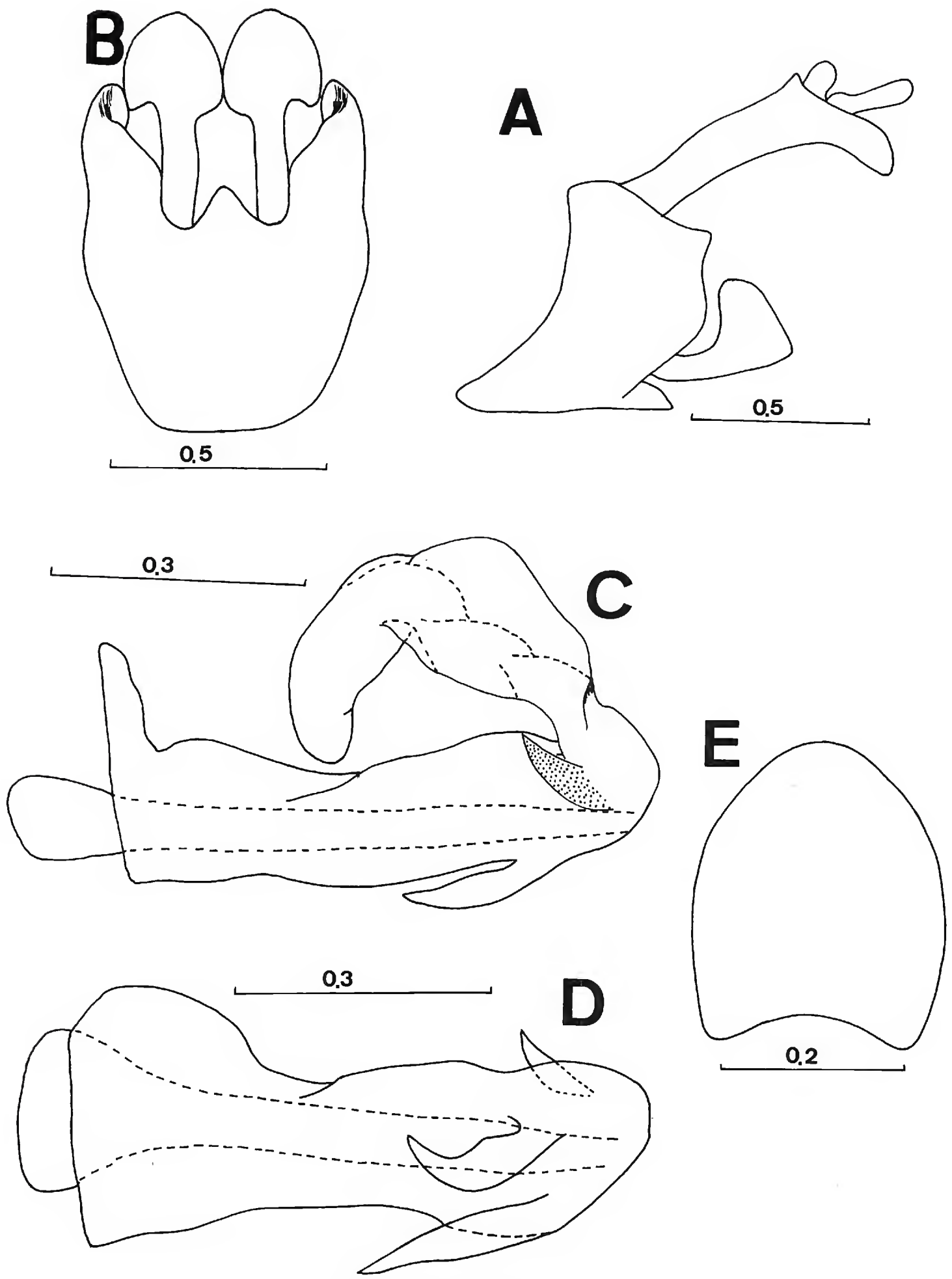

Figure 1. Male genitalia of *Cixius yufengi* NEW SPECIES. A, Left lateral view of pygofer, anal segment and anal style; B, ventral view of pygofer and genital styles; C–D, aedeagus; C, left lateral view; D, ventral view; E, anal segment, caudal view.

in that each bears a prominent production in lateral view. These 2 species may be separated by aedeagal pattern, which, for *C. yufengi,* is shown in Fig. 1: C, D.

Distribution.—United States (California).

Etymology.—This new species is named after the collector of the holotype, Yu-Feng Hsu.

Material Examined.—See type.

Acknowledgment

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APHIDS (HEMIPTERA: APHIDIDAE) AND ASSOCIATED BIOTA FROM THE KINGDOM OF TONGA, WITH RESPECT TO BIOLOGICAL CONTROL

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Abstract.—Surveys of the aphid and associated insect fauna of The Kingdom of Tonga were conducted as part of a biological control program against the banana aphid, *Pentalonia nigronervosa* Coquerel, using the polyphagous aphidiine parasite, *Aphidius colemani* Viereck. Ten aphid species were collected, plus three species of primary parasites (Hymenoptera: Aphelinidae and Braconidae: Aphidiinae); one species of hyperparasite (Hymenoptera: Charipidae); coccinellid, hemerobiid, and syrphid predators (Coleoptera: Coccinellidae; Neuroptera: Hemerobiidae; and Diptera: Syrphidae); parasites of syrphids (Hymenoptera: Ichneumonidae and Encyrtidae); and eleven species of aphid-attendant ants. The aphids *Brachycaudus helichrysi* (Kaltenbach), *Hyperomyzus carduellinus* (Theobald), *Hysteroneura setariae* (Thomas), *Myzus persicae* (Sulzer), and *Toxoptera citricidus* (Kirkaldy) are new records for Tonga. *Aphis craccivora* Koch, *A. gossypii* Glover, *Brachycaudus helichrysi, Myzus persicae, P. nigronervosa, Rhopalosiphum maidis* (Fitch), *Toxoptera aurantii* (Boyer de Fonscolombe) and *T. citricidus* are all known to be suitable hosts for *A. colemani*. Compiled distributional data of aphids on South Pacific islands show that these species are present throughout the region, which suggests that *A. colemani* could be a useful addition to the insect fauna of the region. *Aphidius colemani* was recovered in 1992 from *Aphis gossypii*. The hyperparasite *Alloxysta darci* (Girault) is unlikely to parasitize *A. colemani* or any other Aphidiinae.

Key Words.—Insecta, *Aphidius colemani,* biological control, Aphididae, Tonga, *Pentalonia nigronervosa,* distribution of aphids, natural enemies of aphids

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The banana aphid, *Pentalonia nigronervosa* Coquerel, is an important pest of banana in the Pacific and South-East Asian region and can cause major crop losses either through direct damage or as a transmitter of banana bunchy top virus disease. In the Pacific region, the aphid is locally important in the Cook Islands, Fiji, French Polynesia, Kiribati, Marianas, New Caledonia, Niue, Papua New Guinea, American and Western Samoa, Tonga, Tuvalu and the Wallis Islands (Waterhouse & Norris 1987b). In areas with bunchy top, the favored method of control is the destruction (roguing) of infected plants and aphid infestations. However, successful implementation of these control practices has proved difficult, especially when aphid populations are epidemic.

Biological control of *P. nigronervosa* may be a more suitable control strategy, particularly if it can be integrated with cultural control practices and the use of virus-free planting material. To date, two biological control programs have been attempted: in Western Samoa, using two species of coccinellid predators (Waterhouse & Norris 1987b), and, in Tonga, using two species of aphidiine parasites (Stechmann & Völkl 1988). These programs have produced no evidence for establishment of any of the introduced agents.

In April 1990, CSIRO Division of Entomology (PJH & PWW) took laboratory

stock of the aphidiine parasite *Aphidius colemani* Viereck from Canberra, A.C.T., Australia to Tongatapu Island, Tonga. In Tonga, the first generation was reared and screened in quarantine, and then mass-reared for field release. Concurrently, surveys were conducted to 1) determine the range of aphid infestation levels in banana plantations around the island, 2) seek evidence for establishment of agents released in the earlier biological control program in Tonga and 3) ascertain what other aphid species and associated biota are present in Tonga. This paper focuses on the third objective and documents the aphids, natural enemies and associated ants collected principally during short surveys made during 1990–1992. As *A. colemani* is a polyphagous species, the results provide information about the potential host range in Tonga of this biological control agent. These data are important as successful biological control may depend on the presence of alternative hosts at times of scarcity of the target pest and on the absence of hosts that are acceptable for oviposition but unsuitable for successful development of progeny (Carver 1984). In addition, we provide an overview of the known distribution of aphids throughout the South Pacific region.

Methods and Materials

Surveys were done at a number of locations on Tongatapu Island (21° 09′S 175°14′ W) over a four-week period in April and May 1990 and a two-week period in April 1991. Collections were also made on Tongatapu in November and December 1991, and in July and August 1992; and at one location on Vava'u in April 1991 and on 'Eua in March 1992. Some specimens were located on weeds growing in the understory and surrounds of banana plantations; others were found by inspecting plants in screenhouse areas or in the grounds of the Ministry of Agriculture, Forests and Fisheries (MAFF) Research Station, Vaini. A Moericke-type, yellow pan/water trap was used on one occasion. The collectors were P. J. Hart, V. Kami, W. Liebregts, D. Morneau and P. W. Wellings. Plant species were identified on site or later in the laboratory and predatory larvae were reared to adulthood. The aphids and associated insects, except mummies (dead, mummified aphids containing developing hymenopterous parasites), were preserved in 80% ethanol or in gelatine according to the method described by Milne (1984). Mummies were carefully removed from the plant material, placed individually into gelatine capsules (size 00) and adult parasites allowed to emerge. The collected and reared insect specimens were transferred post mortem to Canberra for identification. All are presently lodged in the Australian National Insect Collection, CSIRO, Canberra. The aphid species recorded from other, mostly intertropical, oceanic Pacific Islands were tabulated. Abbreviations used: apt. = apterae viviparae; al. = alatae viviparae; * = new aphid records for Tonga.

Results and Discussion

Ten aphid species were collected during the study, plus three species of primary parasites (Hymenoptera: Aphelinidae and Braconidae: Aphidiinae); one species of hyperparasite (Hymenoptera: Charipidae); coccinellid, hemerobiid, and syrphid predators (Coleoptera: Coccinellidae; Neuroptera: Hemerobiidae; and Diptera: Syrphidae); parasites of syrphids (Hymenoptera: Ichneumonidae and Encyrtidae) and eleven species of aphid-attendant ants (Hymenoptera: Formicidae):

Aphis craccivora Koch, cowpea aphid
Persea americana (avocado) (Lauraceae), Vaini Research Station, 30 Apr 1990, apt., al.
Phaseolus sp. (bean) (Fabaceae), Lapaha, 26 Apr 1990, apt., al.
Synedrella nodiflora (Asteraceae), Vaini Res. Stn, 30 Apr 1990, apt.

Aphis gossypii Glover, cotton/melon aphid
Cassia occidentalis (Caesalpiniaceae), Kolonga, 23 Apr 1991, apt., al.;
Ants: *Pheidole megacephala* (Fabr.) (Myrmicinae).
Colocasia esculenta (tarotonga) (Araceae), Utulau, 24 Apr 1990, 1 May 1990, apt., al.;
Parasites: *Aphelinus gossypii* Timberlake (Aphelinidae);
Hyperparasites: *Alloxysta darci* (Girault) (Charipidae);
Predators: *Micromus timidus* (Fabr.) (Hemerobiidae), larvae.
Colocasia esculenta, Kolomatua, 24 Apr 1991, apt.;
Parasites: *Aphelinus gossypii*;
Hyperparasites: *Alloxysta darci.*
Colocasia esculenta, Ngeleia, Nuku'alofa, 17–19 Aug 1992, apt.;
Parasites: *Aphelinus gossypii*; *Aphidius colemani* (Aphidiinae);
Hyperparasites (via *Aphelinus gossypii*): *Alloxysta darci*;
Predators: *Harmonia octomaculata* (Fabr.) (Coccinellidae), adult.
Colocasia esculenta, Pa'hu, 25 Aug 1992, apt.;
Parasites: *Aphelinus gossypii*; *Aphidius colemani*;
Hyperparasites (via *Aphelinus gossypii*): *Alloxysta darci.*
Commelina sp. (Commelinaceae), Utulau, 21 Aug 1992, apt., al.
Hibiscus sp. (Malvaceae), Fatai, 1 May 1990, apt.;
Ants: *Pheidole megacephala.*
Persea americana (avocado) (Lauraceae), Vaini Res. Stn, 30 Apr 1990, al.
Salvia coccinea (Lamiaceae), Vaini Res. Stn, 22 Apr 1991, al.
undetermined host, Lapaha, 26 Apr 1990, apt.
ex yellow pan trap, Vaini Res. Stn, 16 Jul 1992, al.

Brachycaudus helichrysi (Kaltenbach), leafcurl plum aphid *
Ageratum sp. (Asteraceae), Fungafonua, 'Eua, 5 Mar 1992, apt.
ex yellow pan trap, Vaini Res. Stn, 16 Jul 1992, al.

Hyperomyzus carduellinus (Theobald) *
Sonchus sp. (Asteraceae), Tatakamotonga, 26 Aug 1992, apt., al.

Hysteroneura setariae (Thomas), rusty plum aphid *
Sorghum halepense (Johnson grass) (Poaceae), Lapaha, 16 Apr 1991, apt., al.

Myzus persicae (Sulzer), green peach aphid *
Brassica oleracea Capitata gp (cabbage) (Brassicaceae), Vaini Res. Stn, 16 Jul 1992, apt., al.
ex yellow pan trap, Vaini Res. Stn, 16 Jul 1992, al., male.

Pentalonia nigronervosa Coquerel, banana aphid
Musa × *paradisiaca* (banana) (Musaceae), eastern Tongatapu, 26 Apr 1990, apt.;
Ants: *Pheidole megacephala, P. umbonata* Mayr, *Solenopsis geminata* (Fabr.),

Monomorium floricola (Jerdon) (Myrmicinae); *Paratrechina longicornis* (Latreille) (Formicinae).

Musa × *paradisiaca,* Vaini Res. Stn, 19 Apr 1991, apt.;
Ants: *Pheidole megacephala.*

Musa × *paradisiaca,* Ha'asini, 23 Apr 1991, apt.;
Predators: *Micromus timidus,* larvae;
Ants: *Pheidole megacephala*; *Technomyrmex albipes* (Smith) (Dolichoderinae).

Musa × *paradisiaca,* Fatai, 24–27 Nov 1991, 11 Dec 1991, apt.;
Predators: *Ischiodon scutellaris* (Fabr.) (Syrphidae);
Parasites of *I. scutellaris*: *Diplazon laetatorius* (Fabr.) (Ichneumonidae); *Ooencyrtus guamensis* Fullaway (Encyrtidae);
Ants: *Pheidole umbonata, Solenopsis geminata, Tetramorium simillimum* (Smith) (Myrmicinae); *Paratrechina vaga* (Forel) (Formicinae); *Tapinoma melanocephalum* (Fabr.) (Dolichoderinae).

Musa × paradisiaca, Te'ekiu, 18 Aug 1992, apt.;
Ants: *Monomorium floricola*; *Technomyrmex albipes*; *Tetramorium bicarinatum* (Nylander) (Myrmicinae).

Musa × *paradisiaca,* Tatakamotonga, 26 Aug 1992, apt.;
Ants: *Anoplolepis longipes* (Jerdon) (Formicinae).

Zingiber officinale (white ginger) (Zingiberaceae), on flowers, Nuku'alofa, 22 Apr 1991, apt.

ex yellow pan trap, Vaini Res. Stn, 16 Jul 1992, al.

Rhopalosiphum maidis (Fitch), maize aphid

Sorghum halepense, Lapaha, 26 Apr 1990, apt., al.

Zea mays (corn) (Poaceae), Te'ekiu, 18 Aug 1992, apt., al.

Toxoptera aurantii (Boyer de Fonscolombe)

Synedrella nodiflora, Vaini Res. Stn, 30 Apr 1990, al.

undetermined host, Vaini Res. Stn, 30 Apr 1990, 22 Apr 1991, apt., 27 Aug 1992, apt., al.;
Ants: *Pheidole megacephala.*

Toxoptera citricidus (Kirkaldy), black citrus aphid *

Citrus aurantifolia (Tahitian lime) (Rutaceae), MAFF Expt Stn, Vava'u, 4 Apr 1991, apt.

Citrus sp., Vaini Res. Stn, 30 Apr 1990, apt., al.

Without host data
Parasite: *Lipolexis scutellaris* Mackauer (Aphidiinae), Vaini Res. Stn, 17 May 1990; one live adult female on banana sucker in banana plantation.

Twelve species of Aphididae are now recorded from Tonga (Table 1): *Brachycaudus helichrysi, Hyperomyzus carduellinus, Hysteroneura setariae, Myzus persicae,* and *Toxoptera citricidus* are new records; *Tetraneura nigriabdominalis* and *Astegopteryx nipae,* which have been previously recorded, were not collected during the present study. Ours was not an intensive survey; more aphid species are undoubtedly to be found in Tonga, especially those known from elsewhere in the region (Table 1), and from Hawaii, which has a larger and more diverse aphid

Table 1. Aphididae of some south Pacific islands.

References	Caroline Is.	Cook Is.	Easter I.	Fiji	Johnston I.	Kiribati	Mariana Is.	Marquesas	Marshall Is.	New Britain	New Caledonia	Niue	Phoenix Is.	Pitcairn Is.	Samoa/West Samoa	Society Is.	Solomon Is.	Tokelau	Tonga	Tuvalu	Vanuatu	Wake I.	Wallis Is.	Aphid Species
	Islands																							Aphidinae
3–6, 8, 11, 13, 16	●	●	●	●	●	●	●		●	●					●	●	●		●	●		●		*Aphis craccivora* Koch
2–16, 18–21	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●		●	*Aphis gossypii* Glover
17								●																*Aphis mumfordi* Takahashi
2, 5–6, 8–9, 11	●			●			●				●				●	●	●				●			*Aphis nerii* Boyer de Fonscolombe
4						●																		*Aulacorthum circumflexum* (Buckton)
4–5, 16				●																				*Aulacorthum solani* (Kaltenbach)
16		●																	●					*Brachycaudus helichrysi* (Kaltenbach)
2, 4, 8, 16		●		●			●				●													*Brevicoryne brassicae* (L.)
2											●													*Capitophorus elaeagni* (del Guercio)
6, 18	●						●																	*Hyalopterus pruni* (Geoffroy)
5				●															●					*Hyperomyzus carduellinus* (Theobald)
12											●													*Hyperomyzus lactucae* (Kaltenbach)
3–4, 11, 16			●	●		●										●	●		●					*Hysteroneura setariae* (Thomas)
11																●								*Ipuka dispersum* (van der Goot)
4–6, 8, 16				●			●			●							●							*Lipaphis erysimi* (Kaltenbach) [= *pseudobrassicae* (Davis)]
2											●													*Macrosiphum rosae* (L.)
7																	●							*Micromyzus katoi* (Takahashi)
2–6, 8, 11, 16		●	●	●		●	●			●	●					●	●		●					*Myzus persicae* (Sulzer)
4–6, 8, 10, 11, 13–16, 18, 22	●	●		●		●	●		●			●			●	●	●	●	●	●	●		●	*Pentalonia nigronervosa* Coquerel
1				●											●									*Rhodobium porosum* (Sanderson)
2–6, 8, 10, 11, 15–16, 18–19, 21	●	●	●	●			●			●	●					●	●		●				●	*Rhopalosiphum maidis* (Fitch)

Table 1. Continued.

References	Caroline Is.	Cook Is.	Easter I.	Fiji	Johnston I.	Kiribati	Mariana Is.	Marquesas	Marshall Is.	New Britain	New Caledonia	Niue	Phoenix Is.	Pitcairn Is.	Samoa/West Samoa	Society Is.	Solomon Is.	Tokelau	Tonga	Tuvalu	Vanuatu	Wake I.	Wallis Is.	Aphid Species
																								Islands
5, 8, 16				●																				*Rhopalosiphum nymphaeae* (L.)
3, 12		●	●								●	●												*Rhopalosiphum padi* (L.)
4–5, 8, 16				●			●																	*Rhopalosiphum rufiabdominalis* (Sasaki)
8				●																				*Schizaphis rotundiventris* (Signoret) [= *cyperi* (van der Goot)]
1				●																				*Sitobion lambersi* David
1, 11				●											●									*Sitobion luteum* (Buckton)
1, 5, 11		●		●											●									*Sitobion miscanthi* (Takahashi)
2, 4–6, 8–9, 15–16, 18–21	●	●		●			●	●		●	●				●		●		●			●		*Toxoptera aurantii* (Boyer de Fonscolombe)
4–5, 8–9, 16, 20		●		●											●				●					*Toxoptera citricidus* (Kirkaldy) [= *Aphis tavaresi* del Guercio]
																								Pemphiginae
1																	●							*Geoica lucifuga* (Zehntner)
1																	●							*Patchiella reaumuri* (Kaltenbach)
6							●																	*Tetraneura akinire* Sasaki
1, 8, 16, 19				●															●					*Tetraneura nigriabdominalis* (Sasaki)

Table 1. Continued.

References	Caroline Is.	Cook Is.	Easter I.	Fiji	Johnston I.	Kiribati	Mariana Is.	Marquesas	Marshall Is.	New Britain	New Caledonia	Niue	Phoenix Is.	Pitcairn Is.	Samoa/West Samoa	Society Is.	Solomon Is.	Tokelau	Tonga	Tuvalu	Vanuatu	Wake I.	Wallis Is.	Aphid Species
	Islands																							
																								Hormaphidinae
1, 2, 6, 8, 18	●			●							●													*Astegopteryx bambusae* (Buckton)
6	●																							*Astegopteryx esakii* (Takahashi)
1				●													●		●		●			*Astegopteryx nipae* (van der Goot)
1																	●							*Astegopteryx rappardi* (Hille Ris Lambers)
1, 6, 8	●																●							*Astegopteryx rhapidis* (van der Goot)
2, 6, 16, 18				●			●				●													*Cerataphis lataniae* (Boisduval)
5, 8, 11				●												●	●							*Cerataphis orchidearum* (Westwood)
5, 8, 16				●													●				●			*Cerataphis variabilis* Hille Ris Lambers
1				●													●							*Ceratovacuna lanigera* Zehntner
1, 6		●		●																				*Pseudoregma bambusicola* (Takahashi)
																								Doubtful records
9, 18		●		●			●									●	●							*Aphis cytisorum* Hartig [= *laburni* Kaltenbach][a]
8, 16, 18			●	●				●									●							*Sitobion avenae* (F.)[b]

[a] Probably refers to *Aphis craccivora.*

[b] Probably refers to *Sitobion miscanthi.*

Key to literature cited: 1. Blackman & Eastop 1985; 2. Brun & Chazeau 1986; 3. Campos & Peña 1973; 4. Distribution Maps; 5. Eastop 1966; 6. Essig 1956; 7. Heie 1968; 8. Hinckley 1966; 9. Laing 1927; 10. O'Connor 1949; 11. Remaudière 1977; 12. Sallée & Chazeau 1985; 13. Stechmann & Semisi 1984; 14. Stechmann & Völkl 1988; 15. Stechmann & Völkl 1990; 16. Stout 1982; 17. Takahashi 1934; 18. Takahashi 1936, 1939; 19 Völkl et al. 1990; 20. Walker & Deitz 1979; 21. Waterhouse & Norris 1987a; 22. Waterhouse & Norris 1987b.

fauna (Beardsley 1979), a probable reflection of its greater commercial and political association with the Northern Hemisphere.

Aphidius colemani was recovered in 1992 from *Aphis gossypii* on tarotonga at two sites. An account of its establishment will be provided at a later date.

Aphelinus gossypii has previously been recorded from Tonga (Stechmann & Völkl 1988, 1990). We reared it in abundance from *Aphis gossypii* on *Colocasia esculenta* (tarotonga) at four sites. *Aphelinus gossypii* was described from Hawaii and is also recorded from Australia and New Zealand, and probably elsewhere under other names.

At each of the sites where collected, *Aphelinus gossypii* was parasitized by the cynipoid *Alloxysta darci,* to the extent of 30% at Kolomatua, and at least 60% at Ngeleia. *Alloxysta darci* was described from Australia, where it parasitizes *Aphelinus* spp., but not species of Aphidiinae, within diverse aphid hosts (Carver 1992). In the absence of other distribution records, it is not possible to say whether *A. darci* is naturally occurring in Tonga and Australia or has been accidentally introduced to these countries. True aphid hyperparasites such as Alloxystinae can be expected to be normally host-specific to either *Aphelinus* or Aphidiinae because of the vast disparity in morphology, ontogeny, behavior etc., between the two groups of parasites. One can, therefore, confidently predict that *A. darci* will not normally parasitize *Aphidius colemani* or any other Aphidiinae in Tonga. *Alloxysta darci* is very closely related to *A. brevis* (Thomson), a Palaearctic species parasitic in Aphidiinae. Stechmann & Völkl (1990) have recorded what is evidently the same species heavily parasitizing the same host species in Tonga under the name *A. brevis.*

Lipolexis scutellaris is an Oriental species previously known from China and India (Raychaudhuri 1990). The records indicate a wide host range and a preference for *Aphis* species.

The syrphid *Ischiodon scutellaris* is widespread in the Pacific region, its range extending to Australia, Japan and India (Thompson & Vockeroth 1989).

Diplazon laetatorius is an obligate, solitary, primary parasite of Syrphidae. Presumed to be of Nearctic origin, it is now almost cosmopolitan in distribution. Oviposition takes place in the egg or early instar of the host, and the adult emerges from the host puparium. Males are unknown outside the Nearctic region; all specimens collected in Tonga were female.

Most *Ooencyrtus* spp. parasitize eggs of Lepidoptera, Heteroptera and spiders, but a number are parasites of insect larvae and pupae. *Ooencyrtus guamensis* is also known from Guam and sub-Saharan Africa as a primary parasite of puparia of Syrphidae (Noyes & Hayat 1984, Prinsloo 1987 and personal communication). Several adults emerged per host puparium in the present study.

The coccinellid *Harmonia octomaculata* [= *Coccinella arcuata* Fabr.] is widespread in tropical and subtropical areas of Asia, Australia and the South Pacific (Pope 1988).

The hemerobiid *Micromus timidus* [= *Archaemicromus navigatorum* (Brauer)] is a common predator of aphids in Tonga (Stechmann & Völkl 1990) and is widespread throughout the region (New 1988).

The ants are exotic 'tramp' species, most of which are already known from Tonga and are widespread in the region (Wilson & Taylor 1967). The high incidence of attendance on *P. nigronervosa* is noteworthy. Eleven ant species were

collected in association with *P. nigronervosa,* most colonies of which were attended in abundance. *Aphis gossypii, P. nigronervosa* and *T. aurantii* are also ant-attended in other areas of their distribution; so, also, are *A. craccivora, H. setariae* and *T. citricidus.*

The prognosis for the effective establishment of *A. colemani* in Tonga, especially as a generalist, is very good, although this could be impeded by ant attendance. No evidence was found indicating that populations of either *A. colemani* or *Lysiphlebus testaceipes* (Cresson), released in earlier biological control studies, were established on Tongatapu Island (Stechmann & Völkl 1988, Völkl et al. 1990). *Aphidius colemani* is believed to be a parasite of east Mediterranean–Indian origin, which is now widely distributed in warmer parts of the world (Starý 1975). In Australia, it is a common, widespread parasite of members of the subfamily Aphidinae, successfully parasitizing many species of Aphidini, Rhopalosiphini and Myzini (known exceptions: *Aphis spiraecola* Patch and *Hysteroneura setariae*) but not those of Macrosiphini. Its host spectrum elsewhere is similar. In Tonga, *Aphis craccivora, A. gossypii, Brachycaudus helichrysi, Myzus persicae, Pentalonia nigronervosa, Rhopalosiphum maidis, Toxoptera aurantii*, and *T. citricidus* are available as potential hosts. On the other islands in the region, the recorded species of *Aphis, Brachycaudus, Lipaphis, Myzus, Pentalonia, Rhopalosiphum* and *Toxoptera* are known hosts of *Aphidius colemani.* Aphidophagous parasites are poorly represented in the fauna of the Pacific Islands and the records of aphids presented in Table 1 indicate that there is a strong case to make systematic introductions of *A. colemani* and other selected parasites throughout the region. Most, if not all, of the recorded Aphidinae in the region are exotic and many of these are well known pests. The further introduction of Aphidiinae, which are obligate parasites of aphids, could assist in their control and would not pose a threat to the native or the beneficial fauna.

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ARTHROPODS OCCURRING ON SWEET WHITE LUPIN AND NATIVE LUPINS IN SOUTHEASTERN WASHINGTON

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Abstract.—The major pests of white lupin, *Lupinus albus* L., in eastern Washington were *Lygus* spp., *Delia* spp., *Spodoptera praefica* (Grote), and *Mamestra configurata* Walker. On native lupins (*L. leucophyllus* Douglas, *L. polyphyllus* Lindl. and *L. sulfureus* Douglas), the most destructive insects were *Tychius lineelus* LeConte and *Glaucopsyche lygdamus* (Doubleday). *Pima albocostalialis* (Hulst) was a primary pest of both native and white lupin as it bored into pods and fed on seeds. Native lupins develop, on average, earlier in the year than white lupin. Pests associated with these native lupins are often univoltine and closely synchronized with their host plant. Consequently, these pests are separated temporarily from the development of white lupin. In contrast, pests associated with white lupin are typically multivoltine and are more generalized with regard to their food source requirement. Because of these factors, pests of native lupin species, with the exception of *P. albocostalialis,* do not contribute greatly to the pest complex of white lupins.

Key Words.—Insecta, white lupin, *Lupinus albus,* Washington

A survey of arthropods collected from native and commercially grown lupins in the Pacific Northwest has not been previously reported. Accounts of insect visitors to low alkaloid, commercially grown lupins have often been general (Frey 1983; Gladstones 1970; Myhre 1988; Nelson et al. 1983a, b); dealt with one or a few species (Cohen & Mackauer 1986, 1987; Guthrie 1954; Knowlton 1945; Nel 1961); or have related to a specific aspect of the plant's biology such as pollination (Bohart 1960, Forbes et al. 1971, Leuck et al. 1968, Williams 1987). Studies of arthropods associated with native *Lupinus* spp. (Breedlove & Ehrlich 1968, Knowlton 1945, Rockwood 1951) are either general or specific to one lupin or arthropod species. This paucity of information may, in part, be due to the uniqueness of lupins as a crop plant and to the rarity of cases where their associated insects have reached damaging levels.

Cereal farmers in the Palouse region of eastern Washington have, in recent years, experimentally grown white lupin, *Lupinus albus* L., as a rotational crop to replace traditional rotations of peas and lentils (Goldstein 1986). However, damaging arthropods and an arthropod borne bacterial disease were apparent in Washington almost from the outset and after three seasons accounted for almost total seed crop loss (Tanigoshi & Babcock 1989). In order to successfully integrate *L. albus* into a dryland cropping program in the Palouse, knowledge about potential pest complexes, reservoirs of those populations, and timing of their occurrence on the host plants is needed.

We report here the arthropods encountered on *L. albus* and on native *Lupinus* spp. that may serve as reservoirs of pest species.

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Materials and Methods

Experimental plots of *L. albus,* variety 'Ultra', were established in 1985 at the Washington State University Spillman Agronomy Farm, Pullman, Whitman Co.; in 1986 near Waitsburg, Walla Walla Co.; 21 km N of Davenport, Lincoln Co. and the Spillman site; in 1987 and 1988 at the Beulah Wilson Wilke Research and Extension Farm, Davenport, Lincoln Co., and at the Waitsburg site. Native lupins from near Pullman and Sprague, Whitman Co., Waitsburg, Walla Walla Co., and Central Ferry, Garfield Co., were surveyed for arthropods on a regular basis during 1986, 1987, and 1988. A survey visit was made to the Hanford Arid Lands Ecology Reserve, Benton Co. in 1988. Samples of native lupin species were identified by personnel at the Ownby Herbarium at Washington State University.

Records of arthropod species present, their damage, and relative abundance on lupin were made throughout the growing season (Table 1). Voucher specimens are deposited in the James Entomological Collection at Washington State University. Observations on the phenology of native and white lupin species were made to correlate arthropod presence with food resources (i.e., pods, stems, flowers). Figure 1 shows the phenological separation between perennial native lupins and annual, spring cultivated white lupin.

White lupin plots were primarily sampled with a standard 38 cm diameter sweep net. Aerial nets, Malaise traps and whole plant samples were also used to sample for arthropods. In native lupin plots both aerial and sweep nets were used. However, to assure that only insects actually on lupins were collected, many arthropod species were aspirated directly from the plants. Whole plants were collected throughout the season and arthropods extracted in the laboratory. When immature forms were collected, an attempt was made to rear representatives to adulthood.

Results and Discussion

Very few non-insect arthropods were collected from either *L. albus* or the native lupins. However, low populations of the twospotted spider mite, *Tetranychus urticae* Koch, developed on the leaves of *L. albus* in mid to late July. At this time, leaf abscission is occurring through the normal maturation of the crop and the twospotted spider mite does not achieve pest status. This phytophagous mite was never observed on native lupin species. Occasionally, predaceous prostigmatid mites were observed at very low densities on native lupins. Spiders of the family Thomisidae and Salticidae were common on native lupins and were occasionally collected from *L. albus.*

The western flower thrips, *Frankliniella occidentalis* (Pergande) was common in all commercial plots and native lupin plots during flowering. Less frequently encountered was *Odontothrips loti* (Haliday). Population numbers peaked around 15 Jun–1 Jul and corresponded with peak *L. albus* bloom. The anthocorid, *Orius tristicolor* White, which is a predator of thrips became abundant during this same time period. Following bloom, both thrips species declined rapidly. No damage was attributed to feeding by *F. occidentalis.* Forbes et al. (1971) showed that *Frankliniella* spp. could cause male sterility by destroying pollen. The destruction of male gametes within a flower might reduce yield since *L. albus* is primarily self-fertilized. Henson & Stephens (1958) showed that *Frankliniella tritici* (Fitch)

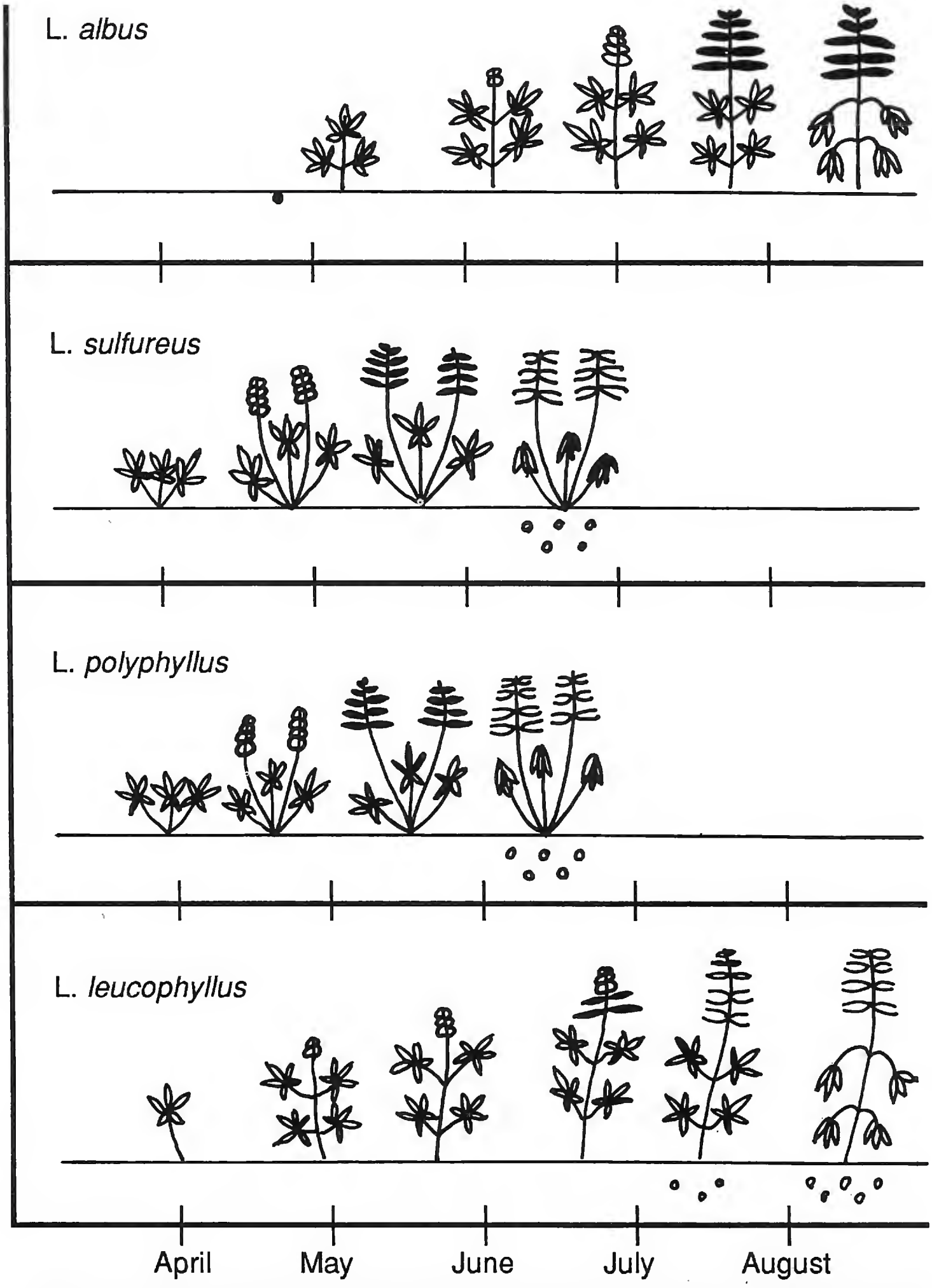

Figure 1. Seasonal phenology of *Lupinus albus* and native lupin species near Waitsburg, Washington, 1988.

and *Dendrothrips bispinosa* Bagnall were responsible for stunting, poor bloom and leaf drop of *Lupinus angustifolius*. L.

Homoptera were represented in our plots by cicadellids, membracids, cercopids, and aphids. Of these groups, the cicadellids were occasionally common on *L.*

Table 1. Arthropods associated with *L. albus* and native lupin species.

	Native lupins	White lupin
Acari		
Tetranychidae		
Tetranychus urticae Koch	N[a]	U
Araneae		
Thomisidae		
Misumena vatia (Clerck)	U	C
Xysticus sp.	U	U
Misumenops sp.	U	U
Insecta		
Orthoptera		
Gryllidae		
Oecanthus quadripunctatus (Beutenmuller)	N	U
Acrididae		
Melanoplus bivivittatus (Say)	N	R
Dissosteira carolina (L.)	N	R
Thysanoptera		
Thripidae		
Frankliniella occidentalis (Pergande)	C	C
Odonotothrips loti (Haliday)	U	U
Hemiptera		
Anthocoridae		
Orius tristicolor White	C	C
Miridae		
Chlammydatus sp.	A	C
Plagiognathus sp.	C	U
Labops hesperius Uhler	C	N
Leptopterna dolabrata (L.)	C	N
Lygus hesperus Knight	R	A
L. desertinus Knight	R	U
L. elysis Van Duzee	R	C
L. lineolaris de Beauvois	R	A
Nabidae		
Nabis alternatus Parshly	C	A
Lygaeidae		
Lygaeus kalmii Stål	R	R
Geocorus bullatus Say	C	A
Berytidae		
Neides muticus Say	R	R
Alydidae		
Alydus calaratus (L.)	U	U
Megalotomus quinquespinosus (Say)	R	N
Tollius curtulus (Stål)	N	U
Pentatomidae		
Chlorochroa uhleri (Stål)	R	A
C. granulosa (Uhler)	R	C
Thynata pallidovirens setosa Ruckes	R	U

Table 1. Continued.

	Native lupins	White lupin
Codophila remota Hovarth	R	R
Euschistus variolaris (de Beauvois)	N	R
Holcostethus limbolarius (Stål)	N	R
Homoptera		
Membracidae		
Tortristilus inermis Fabricus	U	U
Aphididae		
Acyrthosiphon pisum (Harris)	N	R
Macrosiphum albifrons Essig	N	U
Aphis lupini (Gillette & Palmer)	U	N
Neuroptera		
Raphididae		
Agulla sp.	R	R
Hemerobiidae	R	U
Chrysopidae		
Chrysopa plorabunda Fitch	R	U
C. oculata Say	R	U
Coleoptera		
Scarabaeidae		
Euphora inda L.	R	R
Elateridae		
Ctenicera glauca (Germar)	U	R
C. lobata (Eschscholtz)	R	R
Limonius infuscata Motschulsky	N	R
Aeolus dorsalis Say	N	R
Cardiophorus montanus Bland	R	R
Dermestidae		
Cryptorhopalum uteanum Casey	N	R
Melyridae		
Collops versatilis Fall	R	R
C. hirtellus LeConte	U	C
Amecocerus glabratus Hatch	U	N
Coccinellidae		
Hippodamia apicolis Casey	N	R
H. caseyi John	N	R
H. sinulata Mulsant	N	R
H. tredecimpuctata L.	N	R
H. convergens Guerin-Meneville	U	A
Coccinella transversagutatta Brown	U	C
C. novemnotata Herbst	N	R
C. trifaciata L.	R	U
Scymnus marginicollis Mannerheim	N	R
Hyperaspis dissoluta Crotch	N	R
Meloidae		
Epicauta puncticollis (Mannerheim)	U	U

Table 1. Continued.

	Native lupins	White lupin
E. normalis Werner	R	R
Lytta cyanipennis LeConte	U	N
Cerambycidae		
Xestopleura crassipes LeConte	R	R
Stenocorus vestitus Haldeman	R	R
Bruchidae		
Acanthoscelides submuticus (Sharp)	R	N
Chrysomelidae		
Psylliodes punctulata Melsneimer	N	R
Leptinotarsus decimlineatus (Say)	N	R
Phyllotreta lewsii (Crotch)	N	R
Monoxia angularis (LeConte)	R	U
Curculionidae		
Sitona lineatus L.	U	C
Tychius lineelus LeConte	A	N
Otiorhynchus ovatus (L.)	R	N
Ceutorhynchus rapae Gryllenhal	N	R
Lepidoptera		
Pyralidae		
Pima albocostalialis (Hulst)	C	C
Etiella zinckenella (Trietsche)	U	U
Psychidae		
Apterona helicus (Siebold)	R	N
Gelechiidae		
Filatima sp.	C	N
Arctiidae		
Estigmene acrea (Drury)	N	R
Noctuidae		
Spodoptera praefica (Grote)	R	C
Mamestra configurata Walker	R	C
Schinia sveta (Grote)	R	U
Lycaenidae		
Strymon melinus Heubner	R	U
Glaucopsyche lygdamus (Doubleday)	A	N
Nymphalidae		
Autographa californica Speyer	N	U
Diptera		
Cecidomyiidae		
Dasyneura sp.	U	N
Chloropidae		
Chloropsica glabra (Meigen)	U	C
Anthomyiidae		
Delia platura Meigen	C	C
D. lupini Coquillett	C	C
Adia cincerella (Fallen)	N	R

Table 1. Continued.

	Native lupins	White lupin
Agromyzidae	C	C
Sarcophagidae		
Wohlfahrtia vigil (Walker)	N	U
Hymenoptera		
Braconidae		
Crassomicrodus sp.	R	N
Bracon prob. *tychii* (Muesbeck)	R	N
Pteromalidae		
Habrocytus sp.	U	N
Perilampidae		
Perilampus sp.	U	U
Chrysolampus schwarzi Crawford	U	N
Eurytomidae		
Eurytoma sp.	U	N
Chalcididae		
Brachymeria sp.	N	U
Spilochalcis sp.	N	U
Vespidae		
Polistes fuscatus aurifer Sassure	N	R
Apidae		
Bombus sp.	U	U
Colletidae		
Hylaeus sp.	N	R
Halictidae		
Halictus spp.	N	R
Dialictus spp.	N	R
Andrenidae		
Andrena spp.	N	R
Megachilidae		
Synhalonia sp.	U	U

Key to insect abundance: a = Abundant at all locations for a large part of the season; C = Common at all locations but for a brief period of time; U = Uncommon. May be sporadically common but usually not collected at all locations on the same date; R = Rare. Found at very low densities throughout the season and may be found only at one location. N = Not encountered at any location.

albus early in the season prior to flowering. No damage was attributable to leafhoppers although they were often abundant.

The aphid *Macrosiphum albifrons* Essig was found on *L. albus* in highly clumped aggregations. These founder clumps did not disseminate into the remainder of the field but remained localized within several square meters of the initial infestation. This behavior was similar to that reported by Cohen & Mackauer (1986) for *M. albifrons*. Although *M. albifrons* was never found during this study on any of the native lupin species, *Aphis lupini* Gillette & Palmer was encountered on *Lupinus sulphureus* Douglas and *L. leucophyllus* Douglas at several locations but

never on *L. albus.* Rockwood (1951) and Knowlton (1945) reported *M. albifrons* commonly infesting *L. polyphyllus* Lindl. *Macrosiphum albifrons* also infested *L. polyphyllus* and *L. leucophyllus* in the greenhouse. *Aphis lupini* was transferred to *L. albus* in the laboratory and was able to survive for several weeks, however, the population did not increase. *Aphis lupini* was first observed on native lupin species around middle to late May and alate forms were typically not common until mid June when native lupins are senescing.

Hemipterans are well represented on both white lupin and native lupin species, however, the assemblage of species found on *L. albus* and native lupins was substantially different. The lygus bug complex of *Lygus hesperus* Knight, *L. desertinus* Knight, *L. elysis* Van Duzee, and *L. lineolaris* Palisot de Beauvois was found in abundance on *L. albus,* but these bugs were infrequently found on native lupins. Although lists of *Lygus* spp. hosts (Domek & Scott 1985, Fye 1980) have no lupins listed, Horning & Barr (1970) collected *L. hesperus* from *Lupinus* spp. in southern Idaho. *Lygus* spp. first appeared on *L. albus* around 1 Jun, but did not become common until the first week of July. At this time there was an influx of *Lygus* from maturing and senescing weed hosts. Simultaneously, peak flowering and first pod set in white lupin makes it susceptible to *Lygus* feeding injury. This abundance, of prime food resource, affects a dramatic population increase that by 15 Jul reached over 150 adult *Lygus* and 400 nymphs per five, 180 degree sweeps. At levels considerably below these peaks, severe damage to young pods and flowers is produced and leads to significant yield reduction (Tanigoshi & Babcock 1989). As plants mature, *Lygus* numbers will decrease, but remain at low densities until harvest.

Native lupins are fed on by an abundance of bugs other than species of *Lygus. Lupinus polyphyllus* and *L. sulphureus* are not utilized to a great extent because they mature before hemipterans become abundant. Later maturing *L. leucophyllus* are hosts for the mirids *Labops hesperius* Uhler, *Plagiognathus* sp., *Chlammydatus* sp. and *Leptopterna dolabrata* (L.). These mirids were common on *L. leucophyllus* as adults at the end of May and remained until the plants dry out. Little damage was apparent from their feeding activity. Of the mirids occurring on native lupins, only *Chlamydatus* sp. was collected from *L. albus* with any regularity. *Nabis alternatus* Parshly and *Geocorus bullatus* Say were often found feeding on small arthropods such as hemipteran nymphs on *L. albus* and native lupins.

The alydid, *Alydus calaratus* (L.), was often found on *L. leucophyllus* where it was observed feeding on pods. This bug was occasionally found on white lupin along with another alydid *Tollius curtulus* (Stål).

Pentatomids were abundant on *L. albus* but uncommon on native lupins. The most common of these were the *Chlorochroa* spp. which appeared in the field around mid to late July when pods were maturing. Like *Lygus* spp. these pentatomids migrated into lupins from drying cereal crops and weeds. The pentatomids fed on pods but did not cause extensive damage because their densities remained low and they fed on mature, less easily damaged pods.

Chrysopid and hemerobiid adults were common on *L. albus* but immatures were rarely seen. The raphidiid *Agulla* sp. was often found pupating in dead stems of *L. leucophyllus.*

The most common plant feeding beetle was the weevil *Tychius lineelus* LeConte which was collected from *L. leucophyllus, L. sulphureus* and *L. polyphyllus.* This

univoltine weevil feeds on seeds inside the pod and mature larvae drop to the ground to pupate and overwinter. Clarke (1971) reared the weevil from *Lupinus* spp. in Utah and described its biology. In some areas, up to 75% of the pods hosted weevil larvae. *Tychius lineelus* was not collected from white lupin due to its temporal synchrony with earlier developing native lupin hosts.

Several species of immature wireworms were collected from the roots of young *L. albus* seedlings. Adult wireworms were common on flowers of *L. albus* and native lupins, with neither life stage attaining economic levels.

The melyrid, *Collops hirtellus* LeConte, was common on *L. albus* through June and July with populations peaking around the middle of June. These beetles moved into white lupin from maturing wheat. Average control densities of up to 10 *C. hirtellus* per five, 180 degree sweeps occurred at the Waitsburg site. These beetles were rarely collected on native lupins because these plants had typically senesced by this time. Another melyrid, *Amecocerus glabratus* Hatch, was common on native lupins at the Hanford ALE reserve on 9 May 1988. This species is probably a flower feeder, as no feeding damage was apparent.

Adult coccinellid beetles were common on native lupins in May and early June, and peaked around the third week of July on *L. albus*. The ladybird beetles, found on native lupins, were overwintering adults while those on *L. albus* had typically migrated from drying cereal crops where they had developed on cereal aphids. The majority of ladybird beetles were *Hippodamia convergens* Guerin-Meneville with *Coccinella transversogutatta* Brown second in abundance. Other ladybird species, together, comprised a small fraction of the total. On white lupins the coccinellid fauna attained densities of up to 90 adults per five sweeps.

Blister beetles, *Epicauta* spp., were common feeders on lupin flowers. Some damage was attributable to this feeding; these beetles rarely became abundant enough to reduce pod set. *Lytta cyanipennis* LeConte occurred toward the end of May and fed on flowers of the native lupins.

The pea leaf weevil, *Sitona lineatus* L., was present on *L. albus* throughout the season and may scallop leaves. However, this damage seemed to cause little reduction in plant vigor. Farrar & Anderson (1953) described the feeding damage of *S. explita* Say larvae on *L. angustifolius* root nodules in South Carolina. Rockwood (1951) also described similar feeding behavior of larval *S. californicus* Fahr. Neither of these weevils were recovered from lupins in this survey.

Lepidopterans are responsible for a large amount of pod and plant damage. Many of the species involved appear to be host specific to native lupins. An exception to this is *Pima albocostalialis* Hulst, a pyralid whose larvae bore into pods and feed on developing seeds. This species appears to be univoltine and is synchronized closely with the phenology of native lupins. Because of its mobility, *P. albocostalialis* will infest *L. albus* and remain at low population levels. Also occurring on both white and native lupins were *Spodoptera praefica* (Grote) and *Mamestra configurata* Walker. These noctuids feed on racemes and young pods of white lupins and can produce large open wounds in more mature pods. *Schinia sveta* (Grote), another noctuid, was an occasional visitor to white and native lupins where their larvae fed on flowers and young pods.

The lycaenid, *Strymon melinus* Heubner, was occasionally found on *L. albus* and its larvae fed on the developing pods and seeds. This species was also observed ovipositing on *L. leucophyllus,* however, larvae were not reared from any native

lupins. *Glaucopsyche lygdamus* (Doubleday) was common on *L. leucophyllus.* Larvae remain on the exterior of the pods and feed on seeds by means of a telescoping prothoracic segment. In some areas the larvae caused considerable damage to developing pods similar to that described by Breedlove & Ehrlich (1968) for *G. lygdamus* feeding on *Lupinus amplus* Greene. Larvae of *G. lygdamus* developed successfully on *L. albus* pods in the laboratory, but they were never found in field plots. This was probably due to the phenological separation of *L. albus* and the univoltine *G. lygdamus.*

Delia lupini Coquillett and *D. platura* Meigen, seedcorn maggots, were common on *L. albus* from the middle of May to the end of June. These anthomyiid flies occasionally oviposited into mature racemes which became stunted and often died as a result of larval feeding. *Delia lupini* was also reared from racemes and stems of *L. polyphyllus.* This maggot was described by Coquillett (1901) from *L. albus* in California and as a pest of blue lupin by Henson & Stephens (1958).

An agromyzid fly was common in May before bloom of *L. albus* where it created small mines in the parenchyma of the leaves. These leafminers were not present at densities high enough to cause visible plant stress. Mines were also common on *L. polyphyllus.*

Wild bees including *Bombus* sp. and *Synhalonia* sp. were commonly observed visiting flowers of both white and native lupins. Leuck et al. (1968) recorded numerous species of bees pollinating *L. angustifolius,* including *Bombus* sp., *Andrena* sp. and *Dialictus* sp. They described the mechanism of pollination for *L. angustifolius* as being similar to that described for peanut flowers (Leuck & Hammons 1965). For exposure of the stigma to occur a pollinator of sufficient mass must alight on the wing petals. Larger bees such as *Bombus* sp. and *Synhalonia* sp. have sufficient mass to expose the stigma. Bohart (1960) listed megachilids as a predominant pollinator of lupins. This agrees with our observations of *Synhalonia* sp. pollinating lupins. Other taxa encountered were *Halictus* spp. and *Diodontus* sp.

In summary, many insect problems may develop on *L. albus.* The pests most frequently encountered (e.g., *Lygus* spp., *S. praefica, M. configurata*) are not prevalent on native lupins or they do not reach damaging levels. Conversely major pests of native lupins (e.g., *T. lineelus* and *G. lygdamus*) do not occur or are not as damaging to white lupin. The pyralid, *P. albocostalialis,* occurs more commonly on native lupins but may reach pest status on *L. albus.* The separation of pest complexes is related to the phenological separation of the two crops and the inherent synchrony of pests attacking native lupins. Often the pests of native lupins can develop on *L. albus* but their life cycles are not synchronized with the appropriate stage of *L. albus.* The pests common on *L. albus* are typically multivoltine and are more generalized with regard to their food resource requirements. These pests utilize *L. albus* at a time when many alternate food sources are drying up.

Acknowledgment

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Scientific Note

THE FIRST FIELD RECORD FOR THE ANT *TETRAMORIUM BICARINATUM* NYLANDER (HYMENOPTERA: FORMICIDAE) IN CALIFORNIA

On 19 Apr 1990, I discovered foraging columns of small, unfamiliar, pale red ants in a residential area of Long Beach. The ants were nesting in the soil at the edge of walks along the curb at the base of trees and in the bark of trees. The colonies occur as numerous scattered nests spread out over a large area. The workers are small, 3–4 mm long with pale red to bright orange brown head and thorax and much darker black brown gaster with two nodes on the abdominal pedicel. The queens are the same color as the workers but larger, 4.5–5 mm long. The winged males have a brown head and thorax with a dark brown gaster and are 3–4 mm long.

I was certain that the ants were a species of *Tetramorium.* Roy Snelling (Los Angeles County Natural History Museum) sent me keys to the species of this genus and I identified the ants as *Tetramorium bicarinatum* (Nylander) (= *Tetramorium guineense* (Fabr.)); later Snelling and E. O. Wilson (Harvard University) confirmed my identification. This is the first field record of this species being established in California, although it has been intercepted in quarantine situations including greenhouses and warehouses several times in California (M. S. Wasbauer, personal communication).

The ant is native to Africa and has been spread throughout the tropics via commerce. It is found in the southern United States (South Carolina and Florida to Texas). It nests in moderate to large colonies that spread by budding. There may be several dealated queens per colony. My observations indicate that *T. bicarinatum* competes successfully with another introduced species, the Argentine ant, *Iridomyrmex humilis* (Mayr), and is spreading at the expense of the latter. It seems to have less conflict with the southern fire ant, *Solenopsis xyloni* (McCook), although I observed skirmishes between the two species during the summer and fall of 1992 with *T. bicarinatum* often being the aggressor. I call this species the "false fire ant" because of its close resemblance to *S. xylonis'* color and size. *Tetramorium bicarinatum* has 12 segments on the antenna, with no distinct club, instead of the 10 antennal segments and 2-segmented club found in the true fire ants. My observations support previous reports that this ant is a predator, scavenger and seed eater, and probably of little or no economic importance (Taylor, R. W. & E. O. Wilson. 1961. Psyche, 68: 138; Brown, W. L. 1964. Entomol. News, 75: 14–15). This find is the second of a new ant in about a year (Martinez, M. J. 1992. Pan-Pac. Entomol. 68: 153–154).

Material Examined.—*Tetramorium bicarinatum*: CALIFORNIA. *LOS ANGELES Co.*: Long Beach (area bounded by Junction of Pacific Coast Highway and Maine Avenue on the west, Eucalyptus Avenue to the east and Hill Street to the north), 19 Apr 1990, M. J. Martinez.

Acknowledgment.—I thank Roy Snelling and E. O. Wilson for confirming my identification of this ant to species; my wife Charlean for her support; Susan

Mondragon of the Long Beach Parks, Recreation and Marine Department for typing the manuscript; and Nick Nisson, Orange County Entomologist for looking at these ants and my previous ant find.

Michael J. Martinez, *City of Long Beach Department of Parks, Recreation and Marine, Long Beach, California, 90815-1697.*

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Scientific Note

THE TYPE LOCALITY OF *BOLORIA FREIJA NABOKOVI* STALLINGS & TURNER (LEPIDOPTERA: NYMPHALIDAE)

The type locality restriction of *Boloria freija nabokovi* Stallings & Turner, 1946 by Troubridge & Wood (Troubridge, J. T. & D. M. Wood. 1990. J. Lepid. Soc., 44: 180–187) is incorrect. In describing the type locality of *B. f. nabokovi* as "102 miles north of Summit 2," they left out a comma that occurs in both the original description and on the labels of the type specimens. They also misplaced and misspelled words describing the locality. The locality was given as "Mile 102, North of Summit 2" in the original description. The full information, given in the original description (Stallings, D. B. & J. R. Turner. 1946. Canad. Entomol., 78: 134–137), follows: "Alaska Military Highway, July 23, 1943, Mile 102, North of Summit 2, Ravine, Elevation 6000 ft., Collector: D. S. Correll." This is an exact repeat of the labels attached to the type specimens as examined by Shepard in 1980.

This locality information has confused many investigators attempting to relocate *B. f. nabokovi.* There is no point near mile 102 (km 164.1) on the present Alaska Highway that is near an elevation of 6000 feet (1815 m). The only points where the Alaska Highway approaches 6000 feet in British Columbia are at Summit Lake and at the Sentinel Range, where Troubridge & Wood attempted to restrict the type locality. In the last 50 years, there have also been several reroutings of the original Alaska Highway that have obscured references to early mileage markers.

In 1989, Shepard examined the archives of the Yukon Territory, Whitehorse, and the Pacific Northwest Collection at the University of Washington, Seattle. Kondla examined locally available documents and interviewed long-time residents. During the construction of the Alaska Highway, in 1942, and its first year of service, in 1943, the highway utilized a mileage system different than that used after 1943.

The highway was first marked with mile posts in several sections. Section D of the road went from Fort Nelson to Watson Lake (Cohen, S. 1979. The Trail of '42. Pictorial Histories Publ. Co., Missoula, Montana). At each construction base

camp, the mileage markers were begun again at mile zero (Lanks, H. C. 1944. Highway to Alaska. D. Appleton-Century Co., New York). From the southern end of the highway, the first work camp was at the present mile zero. The second work camp was near Fort Nelson. The 1952 Milepost (Anonymous 1952. Milepost. [new revised 1952 edition]) was published before any rerouting and change of miles on the Alaska Highway but after the present mile zero was established. The 1952 Milepost shows that in 1952 Summit Lake was listed at mile 392.1; at mile 395.2 there was a sign identifying "One-O-Five Creek," and at mile 396.7 there was a sign identifying "One-O-Seven Creek." This means that One-O-Five Creek was 105 miles from Fort Nelson work camp and, thus, Summit Lake was 3 miles less distant from Fort Nelson work camp at mile 102. The "Summit 2" at "mile 102," referred to in the original description of *B. freija nabokovi,* must be at this locality. From the 1943 mile zero of Fort Nelson, Steamboat Mountain is Summit 1 and Summit Lake is Summit 2. Specimens collected by Crabo & Pelham on 4 Jun 1989, and by Troubridge on 19–25 Jun 1989, near Summit Lake further justify this deduction.

Based on the above, we restrict the type locality of *B. freija nabokovi* Stallings & Turner, 1946 to "a ravine north of Summit Lake, mile 392 [now km. 621.7] Alaska Highway, British Columbia, Canada." No specimens of *B. f. nabokovi* have been collected near the attempted type locality restriction of Troubridge & Wood (1990). A British Columbia topological map (MacDonald Creek, 1:50,000, 94 k/10 East Half) shows an unnamed creek near the east end of Summit Lake coming from a ravine that reaches 2188 m (6000 ft) at its upper end. This is likely the exact spot where the type specimens were collected. It is also the Mt. St. Paul locality of Troubridge, and he undoubtedly recollected the type locality.

Acknowledgment.—We greatly appreciate the assistance of Fay Tangemann, Yukon Archives, Whitehorse, Yukon Territory and Carla Rickerson, Head, Pacific Northwest Collection, University of Washington Libraries, Seattle, Washington.

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Scientific Note

INTRODUCTION OF A NEW ORB-WEAVING SPIDER, *NEOSCONA CRUCIFERA* (LUCAS) (ARANEAE: ARANEIDAE), INTO CALIFORNIA

On 7 Oct 1983, I collected specimens of an unfamiliar orb-weaving spider at Santiago Oaks Regional Park in the city of Orange, California. I sent the specimens to Herbert W. Levi, at Harvard University, who referred to them as *Neoscona hentzii* (Keyserling), a species found in the eastern U.S. I recently sent him more

specimens of this spider from Long Beach, California. He responded that these and my original specimens sent him from Orange were *Neoscona hentzii,* which, in 1984, was found to be an introduced African species, *Neoscona crucifera* (Lucas). He also stated that my records are the first from California.

Identification.—*Neoscona crucifera* is a large spider; females are 14.5–20 mm and vary in color from dull brown to gray. The abdomen is angular in shape, rather than round, as in the more common native *Neoscona oaxacensis* (Keyserling); however, it is not humped, as in the humped orb-weaver spiders, *Araneus.* The central ventral markings are the same as in *Neoscona oaxacensis,* black with four white spots. *Neoscona crucifera* has a cross pattern on the dorsal surface of abdomen, but it is absent in some individuals.

Biology.—*Neoscona crucifera* matures from mid-August through October. The webs may be over 0.6 m (2 ft) across and from 1.5 m (5 ft) from the ground to as high as 12.2 m (40 ft). They usually are found around buildings or in thick shrubbery bushes, vines, and trees. In this habitat, it may be found also with *Araneus gemma* (McCook) and *N. oaxacensis,* but the latter is also found in more open areas (e.g., fields, parks, gardens). *Neoscona crucifera* appears to be displacing *N. oaxacensis* is southern California, where it is established in many areas.

Material Examined.—CALIFORNIA. *LOS ANGELES Co.*: Long Beach, Rancho Los Cerritos Historical Museum, 14 Oct 1991; El Dorado Park Nature Center, 1 Nov 1991. *ORANGE Co.*: Orange Santiago Oaks Regional Park, 7 Oct 1983. *SAN BERNARDINO Co.*: Prado Regional Park, 5 Sep 1992.

Acknowledgment.—I thank Herbert W. Levi, Harvard University, for the identification of this spider; my wife, Charlean, for her support; Nick Nisson, Orange County Entomologist, for examining the spider; and Susan Mondragon, Department of Parks, Recreation and Marine, for typing the manuscript.

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PAN-PACIFIC ENTOMOLOGIST
Information for Contributors

See volume 66 (1): 1–8, January 1990, for detailed general format information and the issues thereafter for examples; see below for discussion of this journal's specific formats for taxonomic manuscripts and locality data for specimens. Manuscripts must be in English, but foreign language summaries are permitted. Manuscripts not meeting the format guidelines may be returned. Please maintain a copy of the article on a word-processor because revisions are usually necessary before acceptance, pending review and copy-editing.

Format. — Type manuscripts in a legible serif font IN DOUBLE OR TRIPLE SPACE with 1.5 in margins on one side of 8.5 × 11 in, nonerasable, high quality paper. THREE (3) COPIES of each manuscript must be submitted, EACH INCLUDING REDUCTIONS OF ANY FIGURES TO THE 8.5 × 11 IN PAGE. Number pages as: title page (page 1), abstract and key words page (page 2), text pages (pages 3+), acknowledgment page, literature cited pages, footnote page, tables, figure caption page; place original figures last. List the corresponding author's name, address including ZIP code, and phone number on the title page in the upper right corner. The title must include the taxon's designation, where appropriate, as: (Order: Family). The ABSTRACT must not exceed 250 words; use five to seven words or concise phrases as KEY WORDS. Number FOOTNOTES sequentially and list on a separate page.

Text. — Demarcate MAJOR HEADINGS as centered headings and MINOR HEADINGS as left indented paragraphs with lead phrases underlined and followed by a period and two hypens. CITATION FORMATS are: Coswell (1986), (Asher 1987a, Franks & Ebbet 1988, Dorly et al. 1989), (Burton in press) and (R. F. Tray, personal communication). For multiple papers by the same author use: (Weber 1932, 1936, 1941; Sebb 1950, 1952). For more detailed reference use: (Smith 1983: 149–153, Price 1985: fig. 7a, Nothwith 1987: table 3).

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Literature Cited. — Format examples are:

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Blackman, R. L., P. A. Brown & V. F. Eastop. 1987. Problems in pest aphid taxonomy: can chromosomes plus morphometrics provide some answers? pp. 233–238. *In* Holman, J., J. Pelikan, A. G. F. Dixon & L. Weismann (eds.). Population structure, genetics and taxonomy of aphids and Thysanoptera. Proc. international symposium held at Smolenice Czechoslovakia, Sept. 9–14, 1985. SPB Academic Publishing, The Hague, The Netherlands.

Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in *Aedes albopictus*. Evolution, 42: 895–899.

Sorensen, J. T. (in press). Three new species of *Essigella* (Homoptera: Aphididae). Pan-Pacif. Entomol.

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STUDIES ON THE CHRYSOMELIDAE (COLEOPTERA) OF THE BAJA CALIFORNIA PENINSULA: A NEW SPECIES OF *ORTHALTICA* (ALTICINAE), WITH NOTES ON THE GENUS IN BAJA CALIFORNIA

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Abstract.—*Orthaltica capensis* NEW SPECIES is described from the Cape Region of Baja California Sur, Mexico. Notes on the hosts and distribution for *Orthaltica* Crotch species in Baja California are presented.

Key Words.—*Orthaltica, capensis,* Baja California Peninsula, Mexico, Coleoptera, Chrysomelidae

Species of *Orthaltica* Crotch have been described from the United States, Africa and Asia (Seeno & Wilcox 1982). The four species known from North America were reviewed by Scherer (1974). Among the Alticinae the genus *Orthaltica* is unique in lacking an extensor apodeme (Maulik Organ, "spring mechanism") in the metafemora. All host records for the four North American species are from species of *Rhus* (Anacardiaceae).

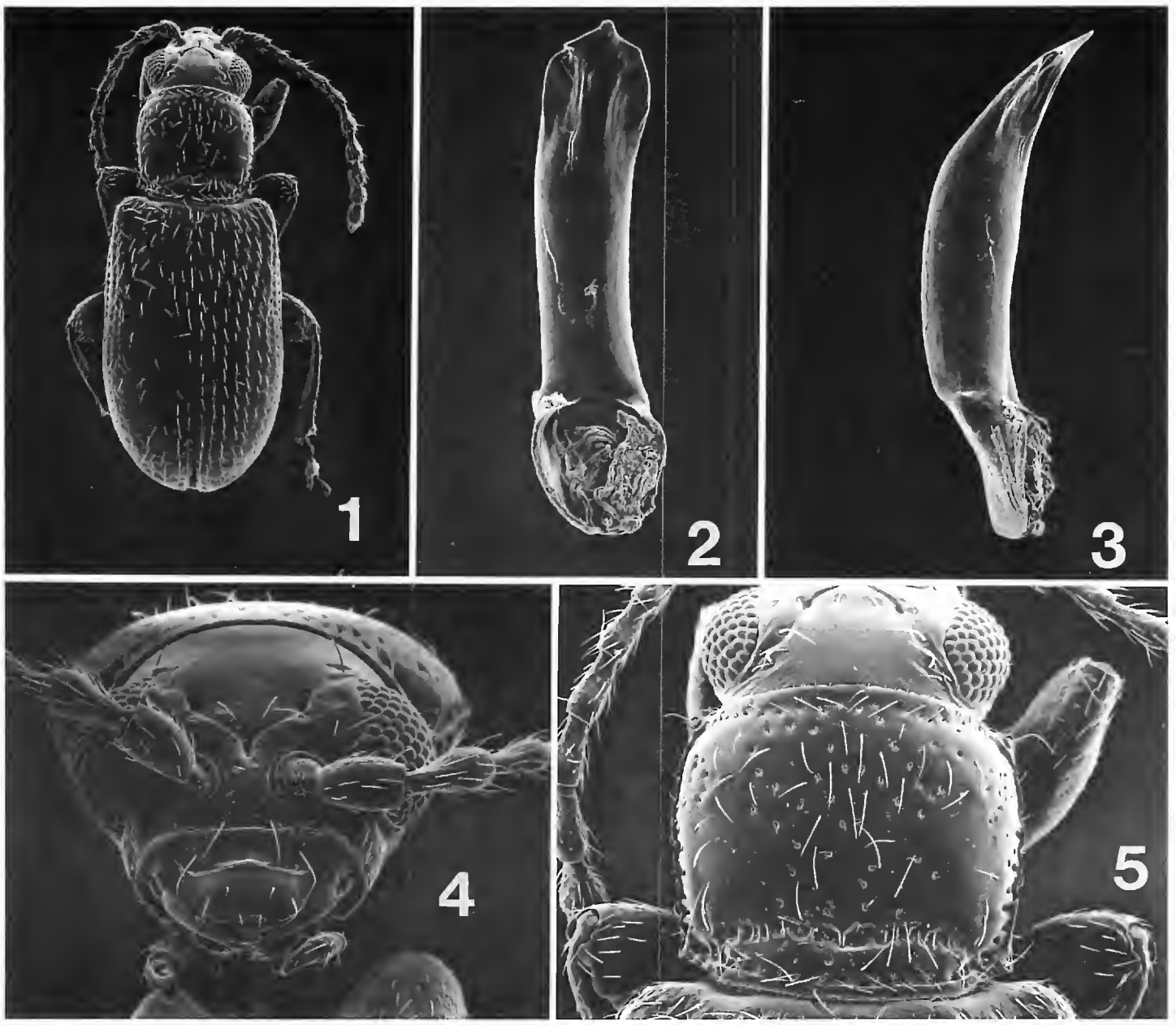
On a recent trip to Baja California, we collected *Orthaltica recticollis* (LeConte) in the northern half of the Baja California peninsula, a species previously known only from the United States. We also discovered an undescribed *Orthaltica* in the southern end of the peninsula.

Specimen Depositories.—The following abbreviations refer to: AJGC—Arthur J. Gilbert collection, CAS—California Academy of Sciences, CDFA—California Dept. of Food & Agriculture, TAMU—Texas A&M University, UCRC—University of California, Riverside.

ORTHALTICA CAPENSIS ANDREWS & GILBERT, NEW SPECIES

Types. HOLOTYPE (male) (CAS #16835) AND ALLOTYPE (female): MEXICO. *BAJA CALIFORNIA SUR*: 20.3 km (12.2 mi) SE of San Pedrito near Rancho Saucito, 8 Oct 1981, F. Andrews & D. Faulkner. Type and Allotype deposited in the California Academy of Sciences. PARATYPES (46)—Same data as holotype (17) [CDFA]; 23.2 km (14 mi) N of Cabo San Lucas, 9 Sep 1988, A. J. Gilbert (1) [AJGC]; 2.3 km (1.4 mi) W of El Aguaje, 17 Sep 1988, on *Cryptocarpus edulis* (Brandergee) Stanley, E. G. Riley (12) [TAMU]; 7.1 km (4.3 mi) W of hwy 1 on Ramal a El Rosario, 6–7 Sep 1988, E. G. Riley (6) [TAMU]; 11.9 km (7.2 mi) W on Ramal Naranjos Road, 15 sep 1988, A. J. Gilbert, on *Cryptocarpus edulis* (3) [AJGC]; Ramal Naranjos Road, 0.6 km (0.1 mi) W highway 1, 198 m (650 ft), 1 Sep 1990, F. Andrews, T. Eichlin & A. Gilbert (2) [CDFA]; 15.2 km (9.2

[2] 2889 N. Larkin #106, Fresno, California 93727.



Figures 1–5. *Orthaltica capensis* Andrews & Gilbert. Figure 1. Dorsal habitus. Figure 2. Male aedeagus, ventral view. Figure 3. Male aedeagus, lateral view. Figure 4. Head, anterior view. Figure 5. Pronotum, male, dorsal view.

mi) W of San Ignacio, 23 Sep 1981, D. Faulkner & F. Andrews (2) [CDFA]; San Felipe, 15.8 km (9.5 mi) NW of San Jose del Cabo, 9 Sep 1988, E. G. Riley (1) [TAMU].

Description.—Male (holotype). Length 1.68 mm; width 0.68 mm. Testaceous, elytra (except suture), legs slightly lighter than other body parts. Head smooth, shining, several setose punctures dorsal to eyes; frontal tubercles smooth, shining; frontal suture distinct, "V" shaped, deep between frontal tubercles, terminating toward vertex in pit on each side at about center of eyes (Fig. 4); distinct transverse groove bearing 2 large setae separates frons from clypeus; clypeus distinct; labrum elongate, anteriorly biemarginate; antennae separated by distance subequal to width of antennal socket; antennae extending beyond humerus. Segments 7–11 enlarged; eyes entire; interocular width approximately 3.0× width of eye (on a line drawn through center of eyes when viewed head on). Pronotum transverse, 1.17× wider than long (width measured at the widest portion—apical one-third); anterior angles produced, bearing coarse seta; pubescent; coarse, deep irregular punctation with 2 large, glabrous, semicircular areas at each side anterior to transverse suture; transverse suture broad, irregularly defined; lateral margins shallowly crenulate (not serrate) (Fig. 5). Scutellum small with few setiferous punctures. Elytra with 9 regular rows of deep punctures (not including scutellar, lateral rows); humeri prominent; pubescence erect, in regular rows (Fig. 1). Venter with scattered setiferous punctures; procoxal cavity closed; mesocoxae, metacoxae widely separated; last abdominal sternum biemarginate, forming distinct, inwardly appressed, rectangular lobe. Legs all of approximate equal size, shape; femora medially expanded; metafemora without extensor apodeme; tarsal claws appendiculate. Genitalia Figs. 2 and 3.

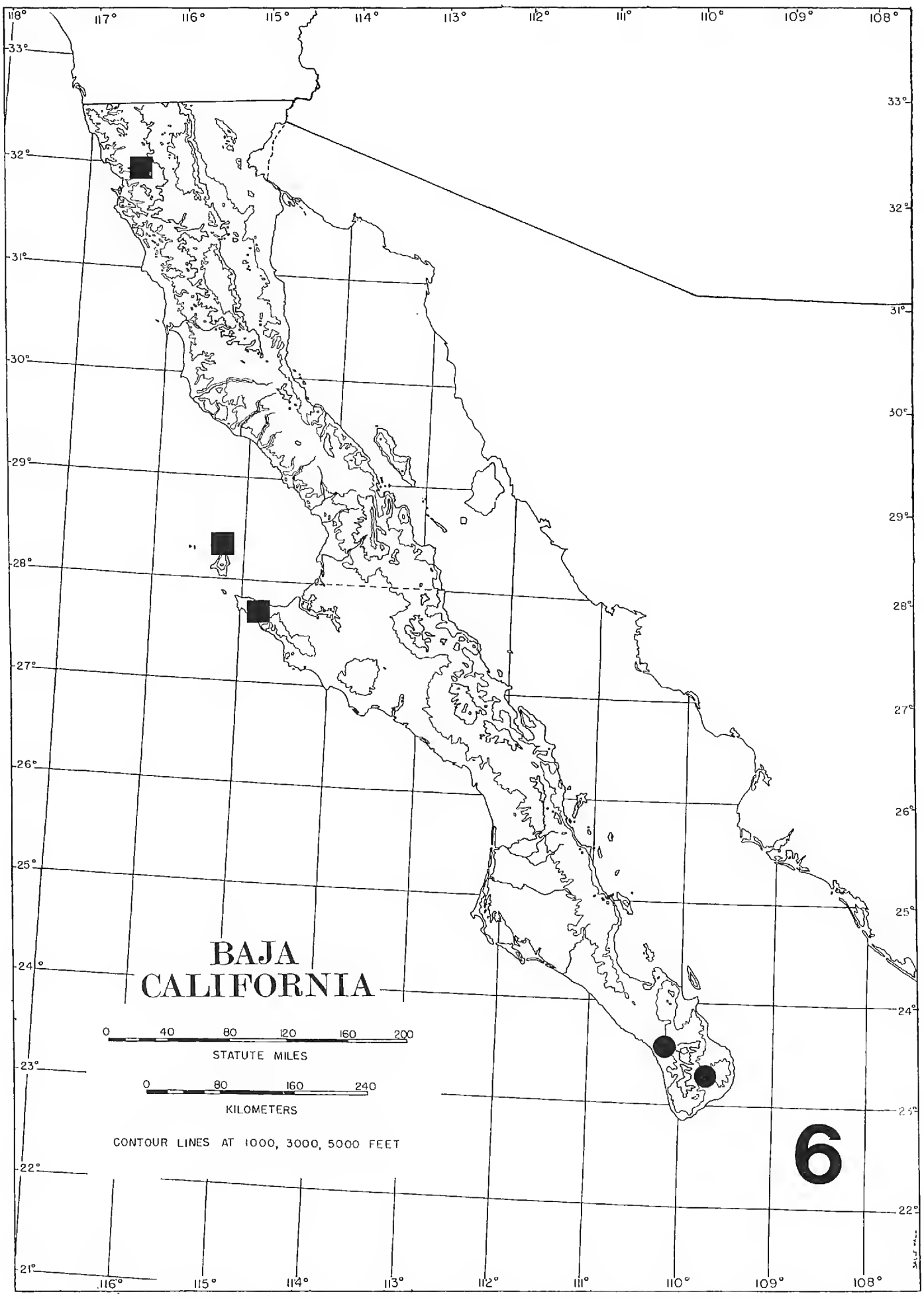


Figure 6. Known geographical distribution *Orthaltica recticollis* (■) and *O. capensis* (●) in the Baja California peninsula.

Female (allotype).—Similar to holotype, differing in the following characters: size slightly larger (length 1.88 mm; width 0.76 mm; antennae slightly shorter; last abdominal sternum entire.

Variation.—Male: length 1.52–1.76 mm; width at elytral humeri 0.60–0.72 mm. Female: length 1.68–2.00 mm; width 0.64–0.80 mm.

Diagnosis.—*Orthaltica capensis* NEW SPECIES can be distinguished from all other described Neartic species of *Orthaltica* by the erect elytral setation, the smooth asetose areas on the pronotum, the form of the frontal suture, the unique shape of the male aedeagus, and geographical isolation in the southern end (Cape Region) of Baja California (Fig. 6). From *O. recticollis* (LeConte), the only other species known from the Baja California peninsula, *O. capensis* can be differentiated by the above characters and by the absence of an enlarged pronotum in the male, and by its smaller size and lighter color. The aedeagus in North American *Orthaltica* is distinctly asymmetrical, but in *O. capensis* it is asymmetrical only in having a slight notch on the left side near the apex (Fig. 2, dorsal view).

Host.—The host association with *Cryptocarpus edulus* (Brandergee) is consistent with the known *Rhus* association of the other Neartic species, in that *Cryptocarpus* is in the same family (Anacardiaceae) and is listed as its closest relative by Wiggins (1980).

Etymology.—Named for the cape region of Baja California Sur, to which it appears to be confined.

Material Examined.—See types.

Orthaltica recticollis (LeConte)

This species is known from many locations in California and Oregon. We report it from Baja California for the first time. Specimens in the California Department of Food and Agriculture Collection indicate a host association with *Rhus laurina* (Nutt.), *R. ovata* Wats. and *R. diversiloba* T. & G. This species has been collected in northern and central Baja California (Fig. 6) and from an additional species of *Rhus*.

Material Examined.—MEXICO. *BAJA CALIFORNIA (Norte)*: 20.1 km (12.1 mi) NE of Ensenada, 25 Mar 1966, 360 m, M. E. Irwin [UCRC]; Isla Cedros, North Point, 20-21 Mar 1981, F. Andrews & D. Faulkner [CDFA]. *BAJA CALIFORNIA SUR*: 18.6 km (11.2 mi) SSE of Bahia Tortugas, 18 Apr 1987, on *Rhus integrifolia* (Nutt.), F. Andrews & A. Gilbert [CDFA].

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The following individuals and institutions made specimens available for study: Ed Riley, Texas A & M University, Saul Frommer, University of California Riverside.

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NEW GENERA AND NEW SPECIES OF MICROPTEROUS COLPURINI FROM BURU ISLANDS AND NEW GUINEA (HETEROPTERA: COREIDAE)

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Abstract.—Three new genera and three new species, collected in Buru Islands and New Guinea are described in the tribe Colpurini (Coreidae). Dorsal habitus illustrations and drawings of the male genital capsule are provided.

Key Words.—Insecta, Hemiptera, Heteroptera, Coreidae, Colpurini, Buru Islands, New Guinea

This is the third contribution in a series of papers aimed at resolving taxonomic problems within the Indo-Pacific Colpurini fauna published concurrently with a series of more comprehensive revisions (Brailovsky 1990, 1992; Dolling 1987).

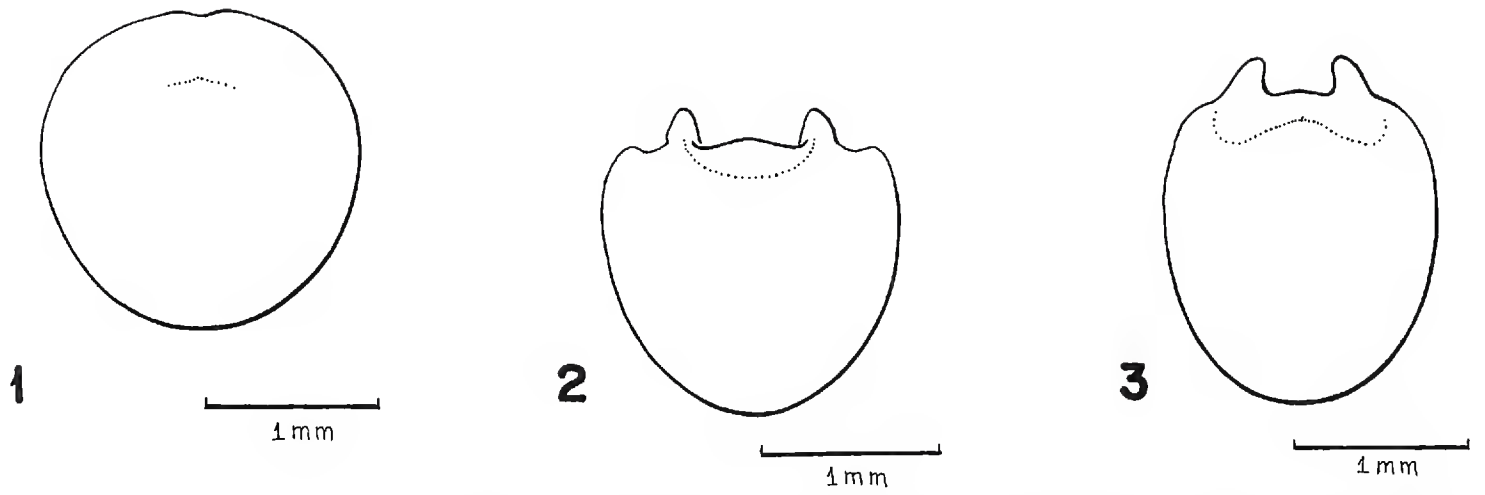
One of the striking features of the tribe Colpurini is the large number of undescribed species that exhibit wing polymorphism. The reduction of wings is a well known phenomenon and occurs frequently in many, if not most, other families of Heteroptera (Slater 1975). The three new genera and three new species proposed here from Buru Islands and New Guinea are micropterous; their wings are widely to scarcely separated from each other, reaching anterior or posterior one-third of abdominal segment I or II, with clavus and corium fused and the membrane always represented by a small flap.

Depository Abbreviations.—The institutions where types are deposited, and from which the specimens were loaned are: Bernice P. Bishop Museum, Honolulu, Hawaii (BPBM); Colección Entomológica del Instituto de Biología, Universidad Nacional Autonóma de México (IBUNAM); Zoologisches Museum, Universiteit van Amsterdam, Netherlands (ZMUA).

BURUHYGIA BRAILOVSKY, NEW GENUS

Type species.—*Buruhygia parva* Brailovsky, NEW SPECIES.

Description.—Head pentagonal, wider than long and dorsally slightly convex; tylus basally globose, unarmed, apically truncate, extending anterior to jugae and seen laterally extending above them; antenniferous tubercles unarmed, with truncated apex; jugae unarmed; sides of head in front of eyes unarmed, straight and shorter than total length of eyes; antennal segment I shortest, robust, thickest, slightly curved outwards and shorter than head; segments II and III cylindrical and slender; segment IV fusiform and longer than III; antennal segment II longest; ocelli absent; posterior pit between eyes deep and diagonally excavated; eyes spherical; postocular tubercles protuberant; bucculae rounded, short, not projecting beyond anterior one-third of antenniferous tubercles, with sharp mesial projection; rostrum long, reaching anterior one-third of abdominal sternite VI. Thorax. Pronotum: Trapeziform, wider than long; collar wide; frontal angles obliqually straight to slightly bilobated; humeral angles rounded, not exposed; posterolateral and posterior edge straight; pronotal disc laterally with small depression. Anterior lobe of metathoracic scent gland globose, posterior lobe sharp, small. Legs: Femora armed with 2 subdistal short spines and few more scattered along ventral surface; tibiae cylindrical, sulcated and much more slender than femora. Scutellum: Hemispheric, wider than long, with apex



Figures 1–3. Frontal view of the male genital capsule. Figure 1. *Buruhygia parva* Brailovsky NEW SPECIES. Figure 2. *Heisshygia novoguinensis* Brailovsky NEW SPECIES. Figure 3. *Missimhygia tytthos* Brailovsky NEW SPECIES.

rounded; disc slightly convex. Hemelytra: Micropterous, reaching anterior one-third of abdominal segment I; clavus and corium fused into coriaceous pad, wings widely separated from each other leaving abdomen exposed mesally; membrane represented by small flaps. Abdomen: Abdominal segments convexly elevated; posterior angle of connexival entire, not extended into short spine; abdominal sternites with medial sternal furrow projecting to anterior border of sternite VI. Integument: Body surface rather dull. Thorax and exposed parts of genital segments of both sexes punctate. Head, pronotum, scutellum, hemelytra, legs and abdomen with long to short decumbent to suberect bristle-like hairs.

Male Genitalia.—Genital capsule. Simple, globose; posteroventral edge enterely, with small mesial concavity (Fig. 1).

Female Genitalia.—Abdominal sternite VII without plica or fissure; gonocoxae I square and larger; paratergite VIII short, square, with spiracle visible; paratergite IX nearly square, larger than paratergite VIII.

Diagnosis.—*Buruhygia* NEW GENUS, like its closely related genus *Sciophyrus* Stål, has the tylus apically globose or truncate, the antenniferous tubercles unarmed, the bucculae rounded with a sharp mesial projection and the abdominal sternite VII of female without a plica or fissure. *Buruhygia* can be recognized by its micropterous condition, absent ocelli and a hemispheric scutellum that is apically rounded and wider than long. *Sciophyrus* is always macropterous or submacropterous; it has conspicuously developed ocelli, and a triangular scutellum that is longer than wide, with its apex acute or truncated.

Distribution.—Only known from Buru Islands.

Etymology.—Named for its occurrence in Buru Islands.

Material Examined.—*Buruhygia parva.*

Buruhygia parva, Brailovsky NEW SPECIES
(Figs. 1, 4)

Types.—Holotype; male; data; BURU ISLANDS. Station 9, 1–28 Jun 1921, L. J. Toxopeus. Deposited in Zoologisches Museum, Universiteit van Amsterdam, Netherlands. Paratype: 1 female; data: BURU ISLANDS. Station 8, Feb 1922, L. J. Toxopeus. Deposited in the "Colección Entomologica del Instituto de Biología, UNAM, México."

Description.—*Male* (holotype). Coloration: Head brown-red with following areas yellow to orange-yellow: a short longitudinal band running close to eyes, external face of postocular tubercle and rostral

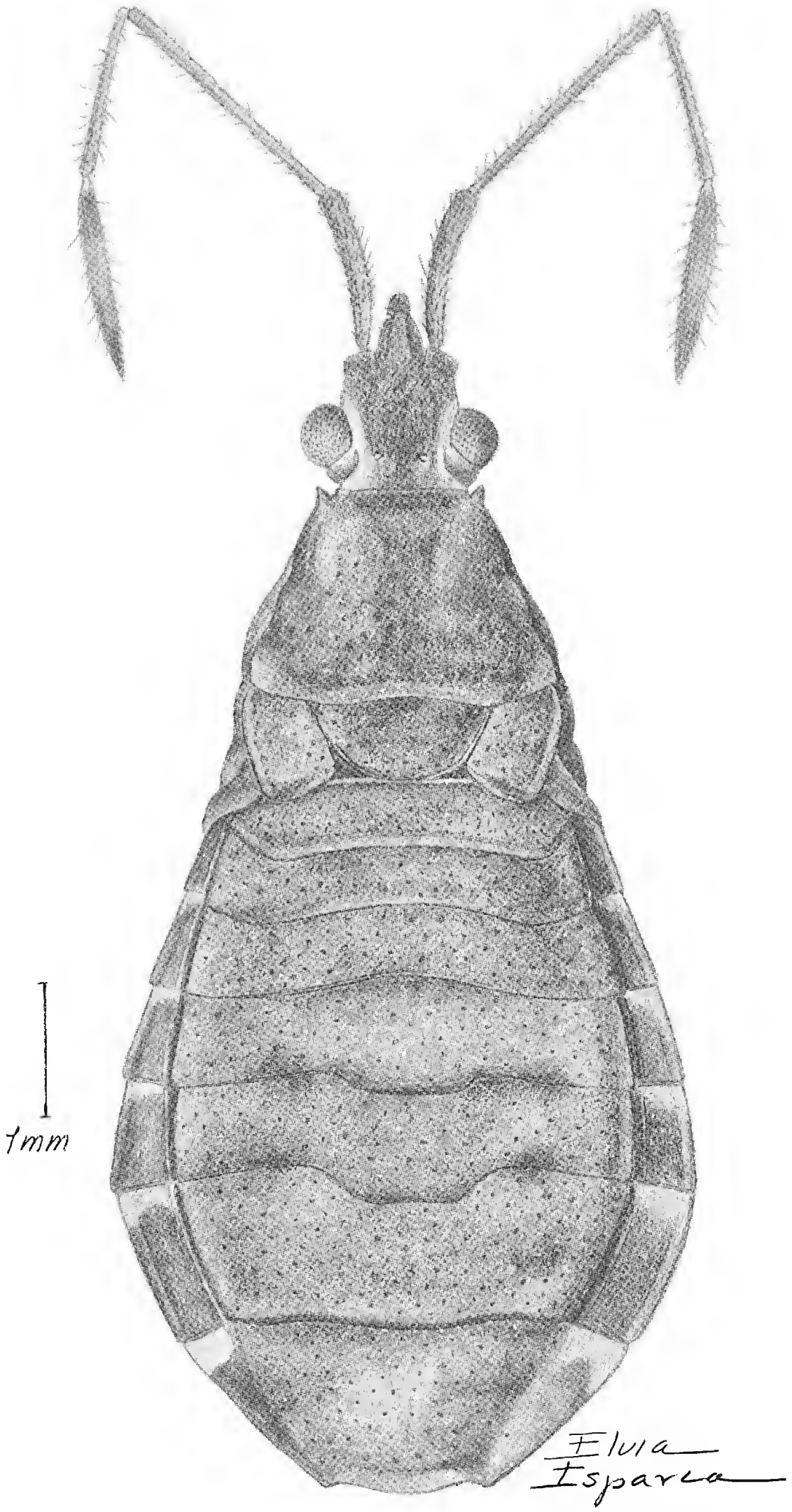


Figure 4. Dorsal view of *Buruhygia parva* Brailovsky NEW SPECIES.

segments I to IV; antennal segment I dark orange-hazel and segments II to IV pale orange-hazel; pronotum, scutellum, hemelytra, thorax and abdomen pale orange with following areas pale yellow: irregular spots scattered over body, costal margin of hemelytra, anterior margin of connexival segments II to VII, anterior angle of pleural sternites III to VII and anterior lobe of metathoracic scent gland; coxae brown-red with pale orange reflections; trochanters orange-hazel with bright yellow reflections; anterior and middle femora yellow, with apical one-third, 1 or 2 incomplete rings and few scattered spots dull orange; posterior femora brown-red with following areas yellow: basal one-third and 2 incomplete rings near central axis; anterior tibiae alternating 2 yellow rings with 3 dark orange rings; middle and posterior tibiae dull orange with 1 yellow ring near the middle line; tarsi dark orange with yellow reflections. Measurements: Head length: 1.40 mm; width across eyes: 1.64 mm; interocular space: 0.84 mm; preocular distance: 1.00 mm. Length of antennal segments: I, 1.28 mm; II, 1.96 mm; III, 1.36 mm; IV, 1.50 mm. Pronotal length: 1.52 mm; width across frontal angles: 1.44 mm; width across humeral angles: 2.44 mm. Scutellar length: 0.60 mm; width: 1.20 mm. Total body length: 8.94 mm.

Female (paratype).—Coloration: Brown-red with following areas yellow to orange-yellow: tylus, a short longitudinal band running close to eyes, external face of postocular tubercle, rostral segments, few irregular spots scattered through the body, costal margin of hemelytra, anterior margin of connexival segments III to VII, anterior angle of pleural sternites III to VII and anterior lobe of metathoracic scent gland; antennal segments and legs similar to holotype. Measurements: Head length: 1.54 mm; width across eyes: 1.72 mm; interocular space: 0.90 mm; preocular distance: 1.03 mm; length of antennal segments: I, 1.40 mm; II, 2.16 mm; III, 1.44 mm; IV, 1.48 mm. Pronotal length: 1.60 mm; width across frontal angles: 1.56 mm; width across humeral angles: 2.54 mm. Scutellar length: 0.68 mm; width: 1.28 mm. Total body length: 9.85 mm.

Diagnosis.—*Buruhygia parva* is the only species in the genus.

Etymology.—Named for its small size; from the Latin "parva," meaning rather small.

Material Examined.—See types.

Heisshygia Brailovsky, NEW GENUS

Type Species.—*Heisshygia novoguinensis* Brailovsky, NEW SPECIES.

Description.—Head: Pentagonal, longer than wide, and dorsally slightly convex; tylus projecting anteriad of jugae, upturned to form sharp long horn; jugae unarmed, thick and shorter than tylus; antenniferous tubercles armed, lobes raised, diverging anteriorly and apically rounded; sides of head anteriad of eyes unarmed and straight; antennal segment I robust, thickest, slightly curved outwards and slightly shorter than head; segments II and III cylindrical and slender; segment IV shortest and fusiform; segment II longest; segments I and III subequal; ocelli absent; posterior pit between eyes deep and diagonally excavated; eyes spherical; postocular tubercles protuberant; bucculae rounded, short, not projecting beyond anterior one-third of antenniferous tubercles, with sharp mesial projection; rostrum long, reaching anterior one-third of abdominal sternite V. Thorax. Pronotum: Trapeziform, wider than long; collar wide; frontal angles produced forward as round small lobe; anterolateral edges almost straight; humeral angles rounded, not exposed and noticeably elevated above disc; posterior edge straight; pronotal disc flat, posteriorly with median depression. Anterior lobe of metathoracic scent gland globose, posterior lobe sharp, small. Legs: Femora armed with 2 rows of spines along ventral surface; tibiae cylindrical, sulcated and much more slender than femora. Scutellum: Triangular, wider than long with apex rounded; disc almost flat. Hemelytra: Micropterous, reaching posterior one-third of abdominal segment II; clavus and corium fused into coriaceous pad and wings widely separated from each other, leaving abdomen exposed mesally; membrane represented by small flap. Abdomen: Connexival segments higher than body; posterior angle of connexival extended into short wide projection; abdominal sternites with medial furrow projecting to anterior border of sternite VI. Integument: Body surface rather dull. Head, pronotum, scutellum, clavus, corium, thorax, abdominal sterna and exposed parts of genital segments of both sexes punctate. Head, pronotum, scutellum, hemelytra, thorax and abdominal sterna with long to short decumbent to suberect bristle-like hairs.

Male Genitalia.—Genital capsule. Simple and semiglobose; posteroventral edge with 2 short lateral projections, surrounding a broad middle plate (Fig. 2).

Female Genitalia.—Abdominal sternite VII with plica and fissure; plica triangular, reaching medial one-third of sternite VII; gonocoxae I square-shaped and larger; paratergite VIII short, square, with spiracle visible; paratergite IX nearly square, larger than paratergite VIII.

Diagnosis.—*Acanthotyla* Stål, *Agathyrna* Stål, *Brachylybas* Stål and *Heisshygia* NEW GENUS, show the apex of tylus projected as a short or large spine. *Heisshygia* can be distinguished by its absent ocelli and the abdominal sternite VII of the female bearing a plica and fissure. On the other three genera, the ocelli are always present and the abdominal sternite VII of their females are without a plica or fissure. In *Lygaeopharus* Stål, the ocelli are reduced or absent, but the apex of tylus is globose and truncate, the bucculae is rounded without teeth or spines and the femora are unarmed; *Heisshygia* differs in having a spiny projection on the bucculae and all femora armed.

Distribution.—Only known from New Guinea.

Etymology.—This genus is named for Eng. Ernest Heiss, distinguished Austrian hemipterist.

Material Examined.—*Heisshygia novoguinensis.*

Heisshygia novoguinensis, Brailovsky NEW SPECIES
(Figs. 2, 5)

Types.—Holotype: male; data: NEW GUINEA (NE). 30 km S of Garaina, 2000 m, 9 Jan 1968, J. and M. Sedlacek. Deposited in Bernice P. Bishop Museum, Honolulu, Hawaii. Paratypes: 2 females; data: NEW GUINEA (NE). Wau, 1150–1250 m, 22–23 Feb 1966, J. Sedlacek. One paratype deposited in Bernice P. Bishop Museum, Honolulu, Hawaii, the other in the "Coleccion Entomologica del Instituto de Biología, UNAM, México."

Description.—*Male* (holotype). Dorsal coloration: Dull brown-red with orange reflections; apex of scutellum light yellow; antennal segments I to III dark brown-red and IV dark orange-hazel. Ventral coloration: Bright orange-hazel; head somewhat redder; anterior lobe of metathoracic scent gland creamy-yellow; coxae, trochanter, prosternum, mesosternum and metasternum light orange-hazel. Measurements: Head length: 1.89 mm; width across eyes: 1.76 mm; interocular space: 1.08 mm; preocular distance: 1.32 mm. Length antennal segments: I, 1.80 mm; II, 2.52 mm; III, 1.80 mm; IV, 1.44 mm. Pronotal length: 1.96 mm; width across frontal angles: 1.60 mm; width across humeral angles: 3.68 mm. Scutellar length: 1.20 mm; width: 1.40 mm. Total body length: 10.80 mm.

Female.—Color: Similar to male. Measurements: Head length: 2.07 mm; width across eyes: 1.88 mm; interocular space: 1.16 mm; preocular distance: 1.38 mm. Length antennal segments: I, 1.80 mm; II, 2.56 mm; III, 1.80 mm; IV, 1.48 mm. Pronotal length: 2.20 mm; width across frontal angles: 1.76 mm; width across humeral angles: 3.76 mm. Scutellar length: 1.36 mm; width: 1.60 mm. Total body length: 12.50 mm.

Diagnosis.—*Heisshygia novoguinensis* is the only species in its genus.

Etymology.—Named for its occurrence in New Guinea.

Material Examined.—See types.

Missimhygia Brailovsky, NEW GENUS

Type species.—*Missimhygia tytthos* Brailovsky, NEW SPECIES.

Description.—Head: Pentagonal, wider than long, dorsally flat; tylus projecting in front of jugae, apically upturned to form blunt median horn, basally globose and seen laterally higher than them; jugae unarmed, thick and shorter than tylus; antenniferous tubercles armed with wide lobes, diverging

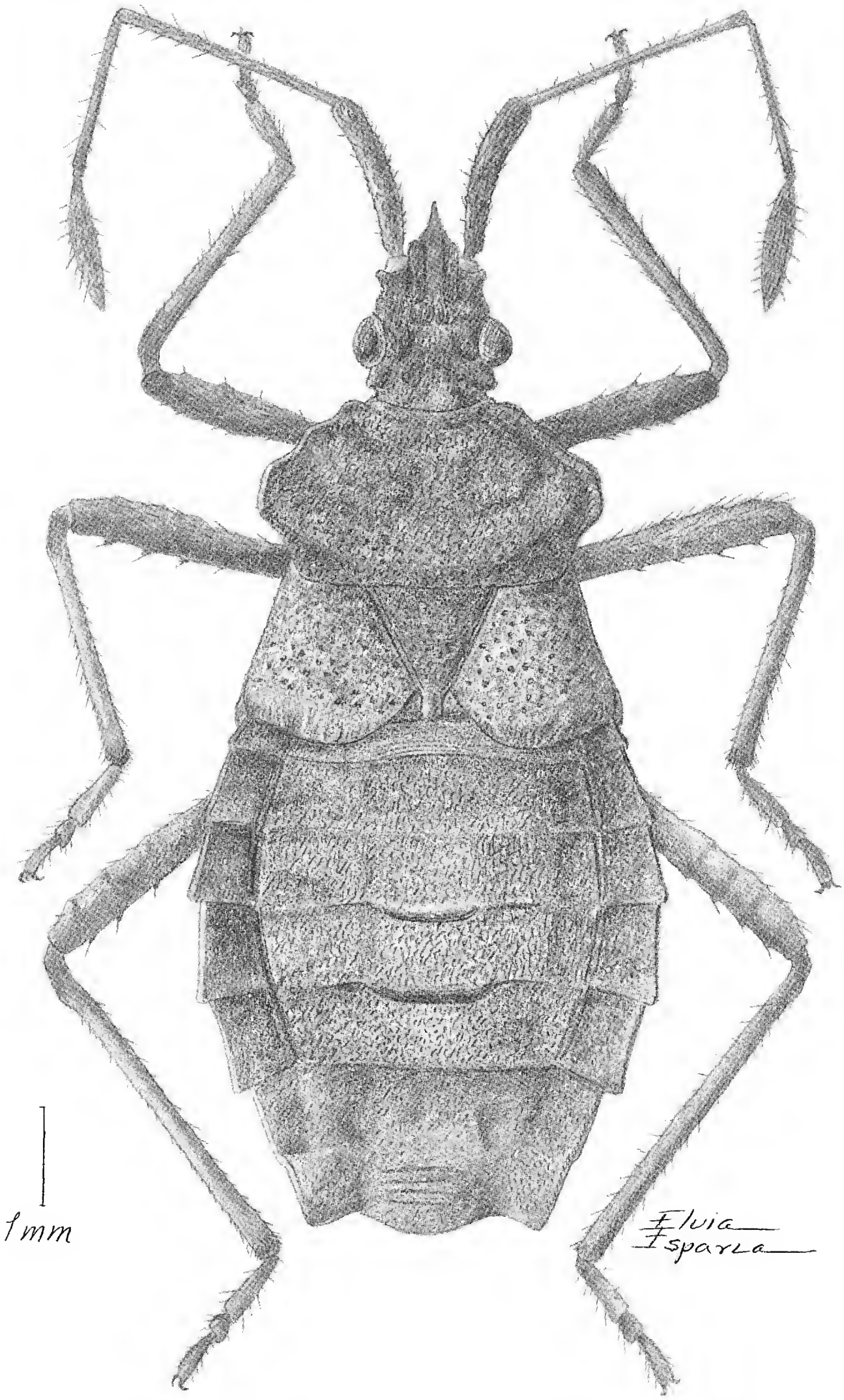


Figure 5. Dorsal view of *Heisshygia novoguinensis* Brailovsky NEW SPECIES.

anteriorly and apically rounded; sides of head anteriad of eyes unarmed, straight and shorter than total length of eyes; antennal segment I robust, thickest, slightly curved outwards and shorter than head; segments II and III cylindrical and slender; segment IV fusiform and shorter than I; segment II longest and III shortest; ocelli and posterior pit between eyes absent; eyes globose, exposed; postocular tubercles conspicuously protuberant; bucculae rounded, elevated, not projecting beyond antenniferous tubercles, external edge without teeth and buccular disc with short conical tubercle; rostrum long, reaching posterior one-third of abdominal sternite V. Thorax. Pronotum: Wider than long, rectangular and clearly bilobate; anterior lobe shorter than posterior lobe, with lateral margin moderately elevated, exposed and resembling short truncated wing; posterior lobe laterally almost straight to subbilobate; anterior collar wide; frontal angles rounded; humeral angles rounded, not exposed; posterolateral and posterior border straight; posterior lobe with deep elongated depression, located on middle point. Anterior lobe of metathoracic scent gland reniform, posterior lobe sharp, small. Legs: Femora tuberculated along ventral and dorsal surface; tibiae cylindrical, sulcated and much more slender than femora. Scutellum: Triangular, wider than long, with apex acute; disc flat to concave. Hemelytra: Micropterous, reaching posterior one-third of abdominal segment II; clavus and corium indistinguishably fused into coriaceous pad, wings scarcely separated from each other; costal margin convexly exposed; membrane represented by small flap. Abdomen: Connexival segments higher than body; posterior angle of connexival enterely, not extended as short spine; abdominal sternites with medial sternal furrow projecting to anterior border of sternite V. Integument: Body surface bright, not dull. Thorax, hemelytra, abdominal sterna and genital capsule punctate. Head, pronotum, scutellum, hemelytra, legs and abdomen with long to short decumbent to suberect bristle-like hairs.

Male Genitalia.—Genital capsule simple, semiglobose; posteroventral edge with 2 robust lateral arms surrounding a broad middle plate (Fig. 3).

Female.—Unknown.

Diagnosis.—Like *Acanthotyla* Stål, *Agathyrna* Stål, *Brachylybas* Stål, and *Heisshygia* Brailovsky, this shows the apex of tylus upturned on a short or large spine. *Heisshygia* and *Missimhygia* NEW GENUS have the ocelli absent, whereas in the three other genera the ocelli are always present. *Missimhygia* can be recognized by a bilobate pronotum, a head wider than long, an entire external edge of the bucculae, an acute apex of the scutellum, a convexly exposed costal margin of the hemelytra, and a femora that is tuberculated dorsally and ventrally. The closely related genus *Heisshygia* has the pronotum trapeziform and not bilobate, the head longer than wide, the bucculae with a sharp mesial projection, the apex of scutellum rounded, the costal margin of hemelytra straight and not exposed, and the femora smooth dorsally, with two rows of spines along the ventral surface.

Distribution.—Only known from New Guinea.

Etymology.—Named for its occurrence in Mt. Missim, New Guinea.

Material Examined.—*Missimhygia tytthos.*

Missimhygia tytthos Brailovsky, NEW SPECIES
(Figs. 3, 6)

Type.—Holotype: male; data: NEW GUINEA (NE). Mt Missim, 2400–2800 m, 22–30 Apr 1968, J. L. Gressitt, R. C. A. Rice and J. Sedlacek. Deposited in Bernice P. Bishop Museum, Honolulu, Hawaii.

Description.—Male (holotype). Coloration: Dorsally bright hazel-brown with orange reflections and ventrally paler; antennal segments I to III hazel-orange and IV paler; rostral segments pale orange; anterior lobe of metathoracic scent gland dirty creamy-yellow. Measurements: Head length: 1.40 mm; width across eyes: 1.70 mm; interocular space: 1.04 mm; preocular distance: 1.00 mm. Length of antennal segments: I, 1.20 mm; II, 1.40 mm; III, 1.08 mm; IV, 1.16 mm. Pronotal length of anterior lobe: 0.56 mm; pronotal length of posterior lobe: 1.00 mm; width across anterior lobe: 2.36 mm;

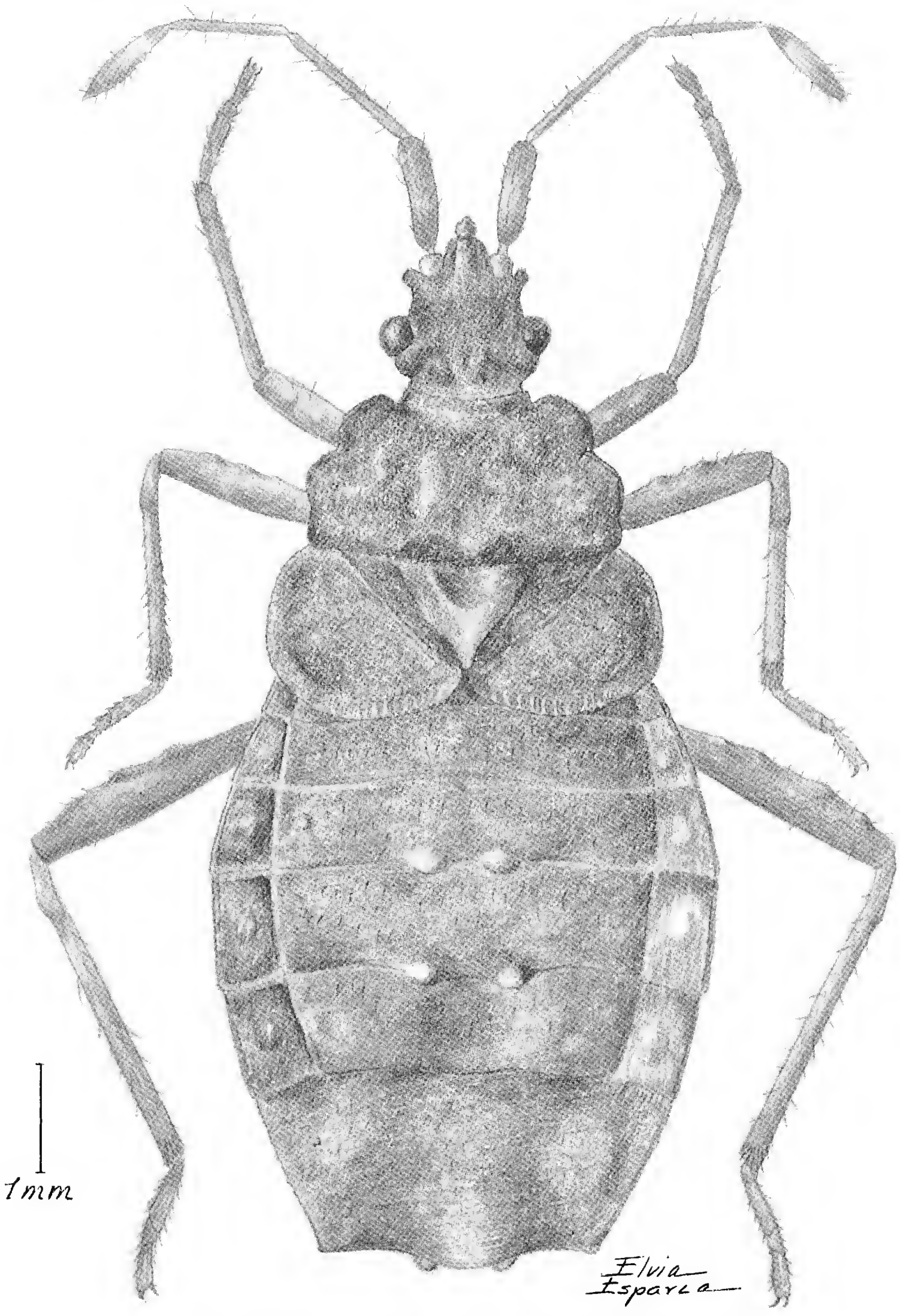


Figure 6. Dorsal view of *Missimhygia tytthos* Brailovsky NEW SPECIES.

width across posterior lobe: 2.76 mm. Scutellar length: 0.88 mm; width: 1.08 mm. Total body length: 9.45 mm.

Diagnosis.—*Missimhygia tytthos* is the only species in the genus.

Etymology.—Named for its small size; from the Greek "tytthos," meaning small.

Material Examined.—See types.

Acknowledgment

I am indebted to the following individuals and institutions for the loan of specimens and other assistance relevant to this study: Gordon M. Nishida (Bernice P. Bishop Museum, Honolulu); and W. Hogenes (Zoologisches Museum, Universiteit Van Amsterdam, Netherlands). Special thanks for Biol. Ernesto Barrera, Biol. Albino Luna and Mrs. Elvia Esparza for the preparation of illustrations (each one of the Instituto de Biología, Universidad Nacional Autonóma de México).

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TWO NEW SPECIES OF ONCIDERINI (COLEOPTERA: CERAMBYCIDAE) FROM THE STATE OF JALISCO, MEXICO

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Abstract.—Two new species of the tribe Onciderini are described from the Pacific Coast of Mexico, *Taricanus zaragozai,* NEW SPECIES and *Lochmaeocles grisescens,* NEW SPECIES. Information on some biological aspects of *Taricanus zaragozai* is included.

Resumen.—Dos nuevas especies de la tribu Onciderini son descritas de la costa del pacífico en México, *Lochmaeocles grisescens* y *Taricanus zaragozai.* Se incluye información sobre algunos aspectos de la biología de *Taricanus zaragozai.*

Key Words.—Insecta, Cerambycidae, Onciderini, Taxonomy, New Species, Bionomics

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As a result of intensive collecting of Cerambycidae during the last seven years in the Chamela region of Jalisco, Mexico, numerous new species have been described (Chemsak & Giesbert 1986, Giesbert 1986, Hovore 1987, Chemsak & Linsley 1988). In this paper, two new species, *Lochmaeocles grisescens,* NEW SPECIES and *Taricanus zaragozai,* NEW SPECIES are described. The Chamela region is situated on the Pacific coast of the state of Jalisco; the floral community is tropical deciduous forest (Bullock 1988).

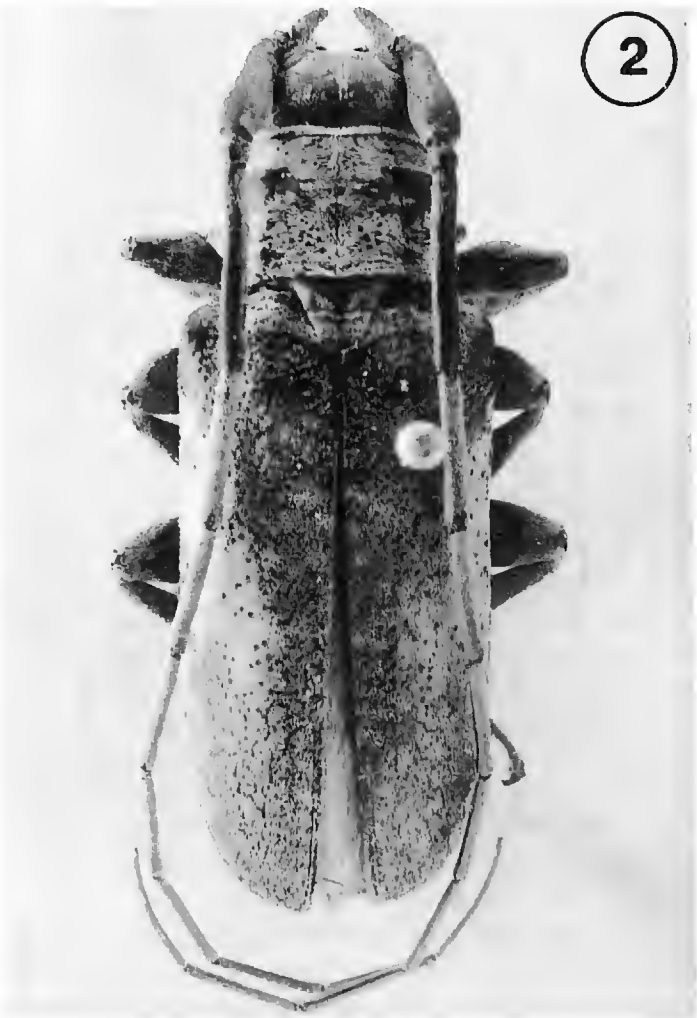
The genus *Lochmaeocles* is predominantly neotropical with only six species previously known from Mexico (Chemsak et al., 1992). *Taricanus* is a Mexican genus and was previously monotypic, containing only *T. truquii* Thomson (Dillon & Dillon 1946).

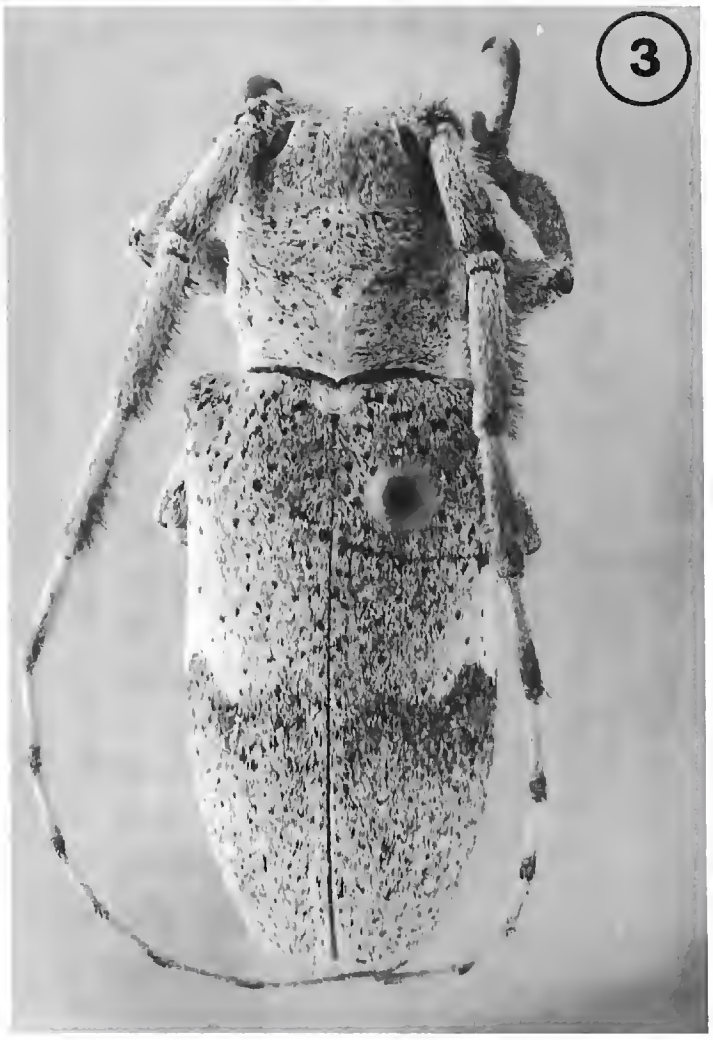
Depository Abbreviations.—Instituto de Biología, Universidad Nacional Autónoma de México (UNAM); Estación de Biología Chamela, UNAM, (EBCH); Essig Museum of Entomology, University of California, Berkeley (EMEC); Frank T. Hovore (FHEC) and R. Turnbow (RTEC).

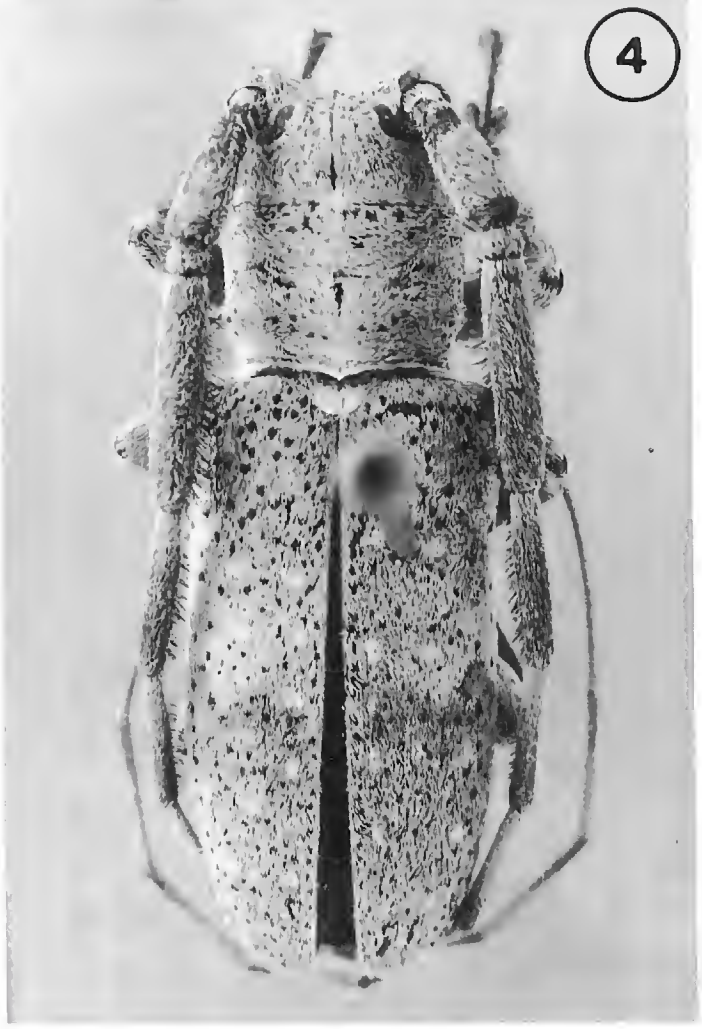
LOCHMAEOCLES GRISESCENS NOGUERA & CHEMSAK, NEW SPECIES

Types.—HOLOTYPE Female: MEXICO: *JALISCO:* 21 km N of Melaque, 15 Jun 1990, A luz, F. A. Noguera; deposited in the Instituto de Biología, Universidad Nacional Autónoma de México. ALLOTYPE. MEXICO. *JALISCO:* 7.6 km N of Chamela, at light, 16 Jul 1987, R. Turnbow. PARATYPES: same locality but with the following data: 2 females, Fiesta Americana sign, 15 Jul 1987, Chemsak, EG & JM Linsley, at light (deposited EMEC); 17-22 July 1987, F. T. Hovore, at billboard lights (deposited FHEC); 1 male, 21 km N of Melaque, 21 Jul 1992, at light, Noguera (deposited EBCH).

[1] Estación de Biología Chamela, Apartado Postal 21, San Patricio, Jalisco, 48980, México.







Figures 1–4. Figure 1. *Lochmaeocles grisescens* Noguera & Chemsak, female. Figure 2. *Lochmaeocles grisescens* Noguera & Chemsak, male. Figure 3. *Taricanus zaragozai* Noguera & Chemsak, female. Figure 4. *Taricanus zaragozai* Noguera & Chemsak, male.

Female (holotype).—Length: 20.3 mm. Width: 7.5 mm. Form elongate, subcylindrical, robust; integument dark red-brown to black. Head with front uneven; area at base of labrum transversely rugose; frontal suture impressed, with small triangular depression at apex; pubescence sparse, white and orange, lateral margins orange; vertex with white pubescence sparse, variegated with orange; lower eye lobes ovate, broad and longer than genae, margins with short orange and white pubescence; genae with deeper and broader punctures, with sparse orange and white pubescence; antennal tubercles prominent; antennae 1.1× longer than body; scape more or less strongly dilated at apex; third segment slightly curved at middle, 1.3× longer than scape; eleventh segment shorter than tenth; first and second segments with sparse white and orange pubescence, remaining segments densely white pubescent at basal two-thirds, apical one-third sparsely pubescent; all segments fringed with a line of black setae. Pronotum 1.5× wider than long; lateral tubercles moderately prominent and blunt; apex with broad shallow depression; base with narrow, deep depression, which extends to lateral tubercles; disk with 3 prominent calluses; sides of middle callus with transverse rugosities and small granules; sides with strong transverse rugosities; pubescence sparse, white and orange; anterior margin with white and orange pubescence. Elytra 1.7× longer than broad; humeri angular, with apices rounded and projecting feebly forward; basal punctures deep, denser obliquely from humeri to middle, becoming finer and sparser toward apex; white pubescence sparse on basal area over dense punctures, denser at middle forming a white fascia interrupted before suture and apical one-third with areas of sparse white pubescence. Prosternum narrow, angled transversely, with white pubescence moderately dense; meso- and metasternum moderately densely white pubescent; mesepisternum, mesepimeron and metepisternum variegated with orange. Abdomen white pubescent, segments margined with pale yellow; last segment emarginate, with triangular depression extending from apex to middle and continuing as deep groove.

Male.—Length: 22.3 mm. Width: 8.1 mm. Similar to female, body more elongate. Head with lower eye lobe 1.6× longer than genae; interantennal region with depression that extends to middle of front; antennal tubercles prominent, projecting outward and directed inward; antennae 1.7× longer than body; scape with strong transverse rugosities beneath, becoming feebler toward apex; third segment 1.4× longer than scape. Pronotum 1.7× wider than long; anterior margin slightly emarginate. Elytra twice as long as wide. Prosternum with prominent transverse tubercle at middle. Legs with procoxae more prominent, tumid, with obtuse tubercle and strong irregular rugosities on internal side; profemora with transverse rugosities at apex of posterior face. Abdomen with last sternite uniformly convex.

Diagnosis.—This species may be easily separated from all other known *Lochmaeocles* by the sparse pubescence and by the lack of a distinct pubescent pattern on the elytra. The dark integument and the sparse white pubescence give this species an overall gray cast to its appearance. This coloration is not known for other species in the genus.

Material Examined.—See types.

Taricanus zaragozai Noguera and Chemsak, NEW SPECIES

Types.—HOLOTYPE female: MEXICO. *JALISCO:* Chamela, 19 Dec 1989, F. A. Noguera, on *Prosopis juliflora*; deposited in the Instituto de Biología, Universidad Nacional Autónoma de México. PARATYPES (all deposited in EBCH, except as indicated): MEXICO. *JALISCO:* Chamela, 19 Jan 1984, S. H. Bullock (1 female); Dec 1986, F. A. Noguera (1 female); 22 Oct 1987, F. A. Noguera (1 male); 28 Oct 1987, F. A. Noguera, on *Caesalpinia eryostachis* (1 female & 1 male); 29 Oct 1987, F. A. Noguera, on *Delonix regia* (1 female); 29 Oct 1987, F. A. Noguera (1 female); 30 Oct 1987, F. A. Noguera, on *Caesalpinia eryostachis* (1 female); 16 Nov 1987, F. A. Noguera (1 male); 22 Nov 1987, F. A. Noguera, on *Enterolobium cyclocarpum* (2 females); 23 Nov 1987, F. A. Noguera, on *Caesalpinia eryostachis* (2 females); 28 Nov 1987, F. A. Noguera, on *Caesalpinia eryostachis* (1 female); 1 Dec 1987, F. A. Noguera, on *Delonix regia* (1 male, 1 female); 9 Dec 1987, F. A. Noguera, on *Caesalpinia* sp.; 9 Dec 1987, F. A. Noguera,

on *Leucaena* sp. (1 female); 1 Dec 1988, F. A. Noguera, on *Delonix regia* (1 female); 19 Dec 1989, F. A. Noguera, on *Prosopis juliflora* (3 females); 20 Dec 1989, F. A. Noguera, on *Caesalpinia eryostachis* (1 male, 2 females); Puerto Marquez, 23 Dec 1971, D. Kistner; Chamela, 6–12 Oct 1988, F. T. Hovore, R. L. Penrose (4 males, 2 females); Playa Careyes, 6, 11 Oct 1988, on *Acacia,* R. L. Penrose (6 males, 3 females); Chamela, 15–21 Oct 1987, E. F. Giesbert (1 male); 7 km N of Melaque, 4 Oct 1991, F. A. Noguera, A. Rodriguez (4 males, 5 females).

Female (holotype).—Length: 16.8 mm. Width: 5.9 mm. Form elongate, subcylindrical, moderately robust; integument dark red-brown to black. Head with front and vertex deeply punctate, pubescence fulvous, variegated with white cast; lower eye lobes ovate and broad, internal margins with white pubescence, external margins fulvous pubescent; genae twice as long as lower eye lobes, pubescence white, variegated with fulvous; antennal tubercles moderately prominent; antennae 1.5× longer than body; scape moderately dilated toward apex, depressed dorsoventrally; third segment straight, 1.3× longer than scape; eleventh segment 1.4× longer than tenth; first 4 segments clothed with white pubescence variegated with brown, remaining segments white pubescent, apices brown; first to fourth segments densely fimbriate beneath with long, black, white and fulvous hairs, fifth segment with black hairs only. Pronotum 1.3× longer than broad; sides with small tubercle at each side; sides almost straight, slightly impressed behind tubercles; apex and disk with several transverse rugosities that extend to sides; base with shallow depression at middle; pubescence white, variegated with fulvous, apical and basal one-third with fulvous line. Scutellum trapezoidal, with median depression, pubescence white and fulvous at middle. Elytra twice as long as broad; sides almost straight, slightly wider behind middle; punctures sparse, deep, becoming shallower toward apex; basal punctures with small granules that become denser toward humeri; humeri angular, apices rounded with several contiguous granules; pubescence white with sparse irregular fulvous maculae, white pubescence denser at middle, forming incomplete pale fascia; irregular brown stripe present behind fascia; humeri with brown pubescence. Prosternum moderately wide, convex, with longitudinal median depression, pubescence white at base and fulvous at apex; meso- and metasternum with white pubescence, sides fulvous; mesepisterna and mesepimera with brown and fulvous pubescence; metepisterna white pubescent, variegated with fulvous. Legs with pubescence white and fulvous; femora with anterior margin straight, posterior margin curved, more or less strongly dilated toward apex; profemora with internal side rugose; protibiae curved, meso- and metatibiae straight. Abdomen with white pubescence variegated with fulvous at sides; last sternite emarginate at apex, median depression triangular.

Male.—Length: 14.3 mm. Width: 4.9 mm. Form similar, less robust. Head with interantennal region more concave; antennal tubercles more prominent; antennae twice as long as body, base of scape with a small longitudinal groove and 2 transverse grooves on lower margin; third segment 1.5× longer than scape; third and fourth segments dilated. Pronotum 1.4× wider than long, apex slightly impressed. Prosternum impressed longitudinally. Procoxae more prominent with subacute tubercle; profemora parallel-sided and more rugose. Abdomen with last sternite slightly impressed at apex.

Diagnosis.—This species may be separated from *T. truquii* Thomson by the following combination of characters: front, vertex and elytra with sparse punctures; elytra with the granules less evident and sparse; pubescence white; elytra with an incomplete white fascia and an irregular band of brown pubescence behind the middle fascia; maculae fulvous with white centers.

Bionomics.—The activity of the adults begins at the end of the rainy season and only leguminosae are utilized as host plants. The host species recorded to date are: *Caesalpinia eryostachis, C. caladenia, C. sclerocarpa, Acacia angustissima, A. cochliacantha, Alvizia* sp., *Enterolobium cyclocarpum, Lonchocarpus eriocarinalis, Leucaena* sp., *Enterolobium cyclocarpum, Lonchocarpus eriocarinalis, Leucaena* sp., *Mimosa arenosa, Delonix regia* (introduced species), and *Prosopis juliflora.* All of these records are from reared material.

Etymology.—We dedicate this species to Santiago Zaragoza C., of the Instituto de Biología, UNAM.

Material Examined.—See types.

Acknowledgment

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THREE NEW SPECIES OF *LORELUS* FROM PUERTO RICO (COLEOPTERA: TENEBRIONIDAE)

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Abstract.—Three new species of *Lorelus* are described from Puerto Rico: *L. wolcotti* NEW SPECIES, *L. bicolor* NEW SPECIES, and *L. glabratus* NEW SPECIES.

Key Words.—Insecta, Coleoptera, Tenebrionidae, Lorelus, Puerto Rico

Lorelus Sharp is a small genus of lagriine Tenebrionidae distributed in the Neotropical region (especially the Caribbean area) and in the Papuan-Pacific region, including Australia and New Zealand (Kaszab 1982). Doyen et al. (1989) placed *Lorelus* and related genera from the Australian region in the Lupropini, and that classification is followed here. *Lorelus* and its relatives probably form a monophyletic lineage, which might be recognized as a subtribe, Lorelina. Biological information for *Lorelus* species is scanty. Several of those described by Kaszab (1982) were beaten from dead branches. I collected *L. crassicornis* Broun from the moist, rotten stems of tree ferns on the North Island of New Zealand, and *L. curticollis* Champion from the same situation in Veracruz, Mexico. The three species described herein were taken from the pithy, moist interior of rachi of the palm, *Prestoea montana* (R. Graham) Nichols. This plant occurs on many other islands in the Antilles, suggesting that the beetles or related species might also be more widespread. In this regard, it is significant that one of the included species here, *L. wolcotti* NEW SPECIES, is indistinguishable from a Dominican amber fossil (J. T. Doyen & G. Poinar, in press); moreover *L. bicolor* NEW SPECIES is rather similar to another Dominican fossil.

Neotropical *Lorelus* are practically unstudied excepting the cursory treatments of Champion (1896, 1913). In the former paper, he described the genus *Lorelopsis* for *L. pilosus* Champion from the Island of St. Vincent. The more strongly lamellate penultimate tarsomere, projecting beneath the ultimate, supposedly differentiated *Lorelopsis* from *Lorelus*. My observations suggest that this character is variable and that *Lorelopsis* is probably not distinct from *Lorelus*. Accordingly, both species described here are placed in the latter genus, even though Wolcott (1936) mentioned one as a member of *Lorelopsis*. This paper makes available the names of the extant species in order to facilitate the comparative study of the fossils.

LORELUS WOLCOTTI, NEW SPECIES

Lorelopsis sp., Wolcott, 1936: 236.

Types.—Holotype male and 18 paratypes (sex not determined), from PUERTO RICO. Sierra Luquillo, Caribbean National Forest, Road 191, 550 m, 22 Dec 1986, J. Doyen and J. Santiago-Blay; 8 paratypes: Sierra Luquillo, Caribbean National Forest, Road 191, 12 km S of Palmer, 750 m, 22 Dec 1986, J. Doyen

and J. Santiago-Blay; 4 paratypes: Cordillera Central, SW of Lago Matrullas, Rd 564, 900 m, 23 Dec 1986, J. Doyen and J. Santiago-Blay. Holotype deposited in California Academy of Sciences, San Francisco.

Description.—Elongate, red-brown to piceous beetles with subparallel sides and densely setose dorsum. Head with uniform punctures about as large as eye facets, separated by less than puncture diameter, each bearing slender, yellow seta about as long as fourth antennal segment. Epistoma darkened and slightly depressed laterally anterad of antennal sockets, briefly produced as small rounded elevations just above sockets; eyes almost round, front margin very slightly flattened. Antenna with second segment 0.75× length of third, fourth through eighth slightly more than 0.5× length of third, about as long as wide; ninth and tenth about 2.0× as wide and long as eighth; eleventh about 1.5× length of tenth, apically rounded, slightly asymmetrical. Pronotum as wide as long, broadest two-thirds toward anterior edge; disk densely, almost reticulately punctate, punctures slightly larger than on head and slightly larger laterally; anterior border almost straight, faintly and narrowly margined; anterior angles rounded, slightly obtuse; lateral borders gently arcuate anteriorly, becoming almost straight in posterior one-third; carina complete, finely crenulate, slightly wider posteriorly; hind angles nearly 90° or sometimes narrowly and briefly exserted, acute; posterior border arcuate, narrowly margined; foveae lacking; discal setae as on head, declined slightly anterad. Elytra at base about 1.5× as wide as pronotal base; widest slightly behind middle; confusedly, evenly punctate, punctures slightly larger than on pronotum; setae declined slightly posterad; epipleuron narrowing from humerus to first abdominal sternite, then with subparallel margins almost to elytral apex. Venter laterally more coarsely, sparsely punctate than dorsum; metasternum impunctate medially; setae much more strongly declined; hypomeron with deep, broad transverse groove just before posterior border; posternal process horizontal, expanded laterally behind coxae, apex broadly rounded; intercoxal process deltoid, acute. Tarsi with long, fine, dense, silky pubescence ventrally; penultimate segment bilobed, extending beneath ultimate segment about 0.3× its length. Greatest pronotal width, 0.6–0.7 mm; median pronotal length, 0.6–0.7 mm; greatest elytral width, 0.8–1.1 mm; median elytral length, 1.7—2.3 mm.

Diagnosis.—*Lorelus wolcotti* NEW SPECIES is most similar to *L. trapeziderus* Champion, from Guatemala. The latter is larger (3.75 to 4.0 mm versus 2.7 to 3.3 mm for *L. wolcotti*) and has the second and third antennal segments subequal (third much longer than second in *L. wolcotti*). In *L. wolcotti,* the anterior margin of the pronotum is slightly convex when viewed normally; in *L. trapeziderus* the margin is slightly concave.

Discussion.—All the specimens of *L. wolcotti* were taken from the rotten pith of the rachi of dead fronds of *Prestoea montana* (R. Graham) Nichols (palma de sierra) (Palmae), where they are associated with *Lorelus bicolor* NEW SPECIES and *L. glabratus* NEW SPECIES, described below. Other associates included Curculionidae, Staphylinidae and *Monoedus* (Colydiidae).

Material Examined.—See types.

Lorelus bicolor, NEW SPECIES

Types.—Holotype female and 84 paratypes (sex undetermined), from PUERTO RICO. Sierra Luquillo, Caribbean National Forest, Road 191, 7 km S of Palmer, 750 m, 22 Dec 1986, J. Doyen and J. Santiago-Blay. Holotype deposited in California Academy of Sciences, San Francisco.

Description.—Very slender, elongate, parallel sided beetles with red-brown body and head, much paler, yellow brown elytra and legs; integument covered with short, declined pubescence, especially dorsally. Vertex with punctures about 2.0× diameter of eye facets, separated by one puncture diameter or less; punctures becoming smaller and sparser anteriorly, especially on epistoma; each puncture with pale, inclined seta about as long as fourth antennal segment; epistomal sutures darkened, faintly visible in lateral quarters; genae briefly produced as small, rounded swellings just above antennal sockets, then transversely, shallowly depressed just before epistoma; lateral epistomal margins weakly concave.

Eyes prominent, rounded, without trace of anterior emargination; bordered posteriorly by several erect, bristling setae. Third segment about 1.12 (one and one-eighth)× length of second and stouter; segments 4 through 8 slightly more than 0.5× length of third, submoniliform; 9 and 10 about 1.5× as long and wide; 11 globular, slightly longer than broad. Pronotal width and length subequal, disk widest just behind anterior angles, slightly narrower across posterior angles, with punctures about 3.0× eye facets in diameter, separated by one puncture diameter or less; anterior border almost straight, not margined; anterior angles exserted laterally, tuberculiform; lateral borders very slightly arcuate and converging to hind angles; carina complete, very narrow, finely crenulate; hind angles slightly obtuse, sometimes very weakly exserted; posterior border evenly arcuate, not margined; discal setae as on head, declined slightly anterad or mesad. Elytra at base about 1.17 (one and one-sixth)× wide as pronotal base, sides almost parallel to third abdominal segment; confusedly punctate, punctures 3.0–4.0× eye facet diameter, finest near suture; setae declined posterad or posterolaterad; epipleuron narrowing to hind coxa, then with subparallel margins almost to elytral apex. Venter more sparsely, finely punctate than dorsum, epimeron almost impunctate; hypomeron posteriorly with broad, transverse groove almost to hind angle; prosternal process horizontal, gradually expanded behind coxae, subtruncate posteriorly. Tarsi sparsely set with long, fine setae ventrally; penultimate segment entire, scarcely produced beneath ultimate. Greatest pronotal width, 0.4–0.5 mm; median pronotal length, 0.4–0.5 mm; greatest elytral width, 0.5–0.7 mm; median elytral length, 1.0–1.3 mm.

Diagnosis.—*Lorelus bicolor* NEW SPECIES is similar to *L. exilis* Champion and *L. glabratus* NEW SPECIES, described below. It differs from *L. exilis* in the exserted, tuberculiform anterior pronotal angles (rounded in *L. exilis*), in the weakly arcuate pronotal base (much more strongly arcuate in *L. exilis*) and in the minutely reticulate, submatte interpunctal cuticle on the head and pronotum (cuticle polished, shining in *L. exilis*). *Lorelus bicolor* differs from *L. glabrata* in its pubescent dorsum (subglabrous in *L. glabrata*). Additional differences are described under the latter species.

Discussion.—All specimens were collected from the rotten rachi of *Prestoea montana*.

Material Examined.—See types.

Lorelus glabratus, NEW SPECIES

Types.—Holotype female, from: PUERTO RICO. Cordillera Central, SW of Lago Matrullas (Road 564), 914 m (3000 ft), 23 Dec 1986, J. Doyen and J. Santiago-Blay. Thirteen paratypes, from: PUERTO RICO. Sierra Luquillo, Caribbean National Forest, 20 km (12 mi) S of Palmer (Road 191), 761 m (2500 ft), 22 Dec 1986, J. Doyen and J. Santiago-Blay. Holotype deposited in California Academy of Sciences, San Francisco.

Description.—Very slender, elongate, parallel sided beetles with red-brown body and head, pale yellow-brown elytra and legs; dorsum subglabrous. Vertex with punctures about 2.0× diameter of eye facets, separated by about one to two puncture diameters; punctures becoming sparser anteriorly behind epistomal suture; interpunctal cuticle polished; genae swollen, polished above antennal sockets, slightly depressed just behind epistomal suture; epistomal suture entire, fine, becoming expanded and darkened at epistomal margins; epistoma very sparsely punctate in anterior two-thirds, with shagreened transverse crescentic band just before epistomal suture. Eyes nearly round, without trace of emargination; diameter subequal to length of second antennal segment; postgenae prominent behind eyes, then abruptly constricted. Antenna as in *L. bicolor*. Pronotal length and width subequal, disk widest just behind anterior angles, about 0.9× as wide across posterior angles, with punctures about 3.0× eye facets in diameter, separated by about one to three puncture diameters; interpunctal spaces polished, obscurely reticulate; anterior border slightly, convexly arcuate, faintly margined; anterior angles rounded; lateral borders slightly arcuate, converging evenly to hind angles; lateral carina complete, closely subtended by about 10 evenly spaced monosetiferous papillae; posterior angles sharp, slightly obtuse; posterior border very weakly bisinuate, unmargined. Elytra at base about 1.17 (one and one-sixth)×

as broad as pronotal base, sides almost parallel to third abdominal segment; confusedly punctate, punctures about 4.0–5.0× eye facet diameter, separated by about 0.5× puncture diameter; interpunctal spaces shining, polished; disk with very sparse, short, fine, erect setae laterally and on declivity, otherwise almost glabrous; epipleuron narrowing slightly to hind coxa, then subparallel almost to elytral apex. Hypomeron finely reticulate-granulate, with few obscure, fine punctures; prosternum very sparsely punctate; prosternal process horizontal, gradually expanded behind coxae, subtruncate posteriorly; pterothoracic venter with punctures about 2.0× eye facets in diameter, separated by about one to three puncture diameters; interpunctal spaces with finely reticulate microsculpture; abdominal sternites with punctures slightly denser and bearing short, fine, declined setae, otherwise similar to metasternum. Tarsi with ventral vestiture of long, fine setae; penultimate segment scarcely produced beneath ultimate. Greatest pronotal width, 0.40–0.42 mm; median pronotal length, 0.35–0.40 mm; greatest elytral width, 0.47–0.51 mm; elytral length, 1.2–1.4 mm.

Diagnosis.—*Lorelus glabratus* NEW SPECIES is most similar to *L. exilis* Champion. The most obvious difference is in the dorsal pubescence, which is almost absent in *L. glabratus,* but dense and obvious in *L. exilis.* Other differences are: (1) In *L. glabratus,* the hypomeron is finely reticulate-granulate, with only a few obscure punctures; in *L. exilis* the hypomeron is punctate. (2) In *L. glabratus,* the posterior pronotal margin is very weakly bisinuate; in *L. exilis* the margin is more strongly curved, and is arcuate rather than bisinuate. (3) In *L. glabratus,* the lateral pronotal margin is subtended by 8 to 11 setiferous tubercles; in *L. exilis* there are 13 to 17 such tubercles, and the margin appears crenulate. Characters 1 and 3 above also separate *L. glabratus* from *L. bicolor* NEW SPECIES, which is of similar size and color. In addition, in *L. bicolor,* the anterior pronotal angles are in the form of an exserted tubercle and the dorsal microsculpture is finely reticulate-granulate, producing a matte or weakly shining luster. In *L. glabratus,* the anterior pronotal angles are rounded and the dorsal microsculpture is largely obliterated, producing a polished, shining appearance.

Discussion.—All specimens were collected from the rotten rachi of *Prestoea montana.*

Material Examined.—See types.

Acknowledgment

Syntypes of *Lorelus exilis* and *L. trapeziderus* were kindly made available by S. L. Shute of the Natural History Museum, London. Jorge Santiago-Blay ably assisted with the field work in Puerto Rico, and identified the palm host.

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STUDIES ON *TIMULLA* ASHMEAD (HYMENOPTERA: MUTILLIDAE): NEW DISTRIBUTION RECORDS AND SYNONYMIES, AND DESCRIPTIONS OF PREVIOUSLY UNKNOWN ALLOTYPES

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Abstract.—Sex associations permitted us to find and describe the previously unknown allotypes of: *Timulla nisa* Mickel, 1938, male; *T. absentia* Mickel, 1938, male; *T. bradleyi* Mickel, 1938, female. Eleven names are synonymized: *Timulla porcata* (Cameron), 1894 (*T. bituberculata* Mickel, 1938, NEW SYNONYM, male and *T. phiala* Mickel, 1938, NEW SYNONYM, female); *T. centroamericana* (Dalla Torre), 1897 (*T. proclivis* Mickel, 1938, NEW SYNONYM, male); *T. heterospila* (Gerstaecker), 1874 (*T. thura* (Cameron), 1894, NEW SYNONYM, male); *T. mexicana* (Cameron), 1894 (*T. amulae* (Cameron), 1894, NEW SYNONYM, male); *T. runata* Mickel, 1938 (*T. buscki* Mickel, 1938, NEW SYNONYM, male); *T. connexa* (Cameron), 1894 (*T. selene* Mickel, 1938, NEW SYNONYM, female); *T. adrastis* Mickel, 1938 (*T. pilatrix* Mickel, 1938, NEW SYNONYM, female); *T. taygete* Mickel, 1938 (*T. aureata* Mickel, 1938, NEW SYNONYM, female); *T. cordillera* Mickel, 1938 (*T. mulfordi* Mickel, 1938, NEW SYNONYM, female); *T. labdace* Mickel, 1938 (*T. raui* Mickel, 1938, NEW SYNONYM, female). Eight new distribution records are presented: *T. heterospila* (Gerstaecker), Venezuela, previously known from Panama and Colombia; *T. mexicana* (Cameron), Costa Rica, previously known from Mexico and Honduras; *T. adrastis* Mickel, Costa Rica, previously known from Mexico and Guatemala; *T. rufogastra* (Lepeletier), 1845, Panama, previously known from Colombia through French Guiana and Trinidad; *T. sieberi* Mickel, 1938, Perú, previously known only from Brazil, from the holotype and one paratype; *T. brancoensis* Mickel, 1938, Perú, previously known only from the holotype from Brazil; *T. prominens prominens* (Cameron), 1894, Panama, previously known from Mexico through Costa Rica; *T. daedala* (Cameron), 1894, Nicaragua, previously known only from holotype specimen collected in Yucatán, Mexico.

Key Words.—Insecta, sex associations, systematics, *Timulla* distributions, sex pheromones, Mutillinae

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Timulla Ashmead, 1899 (Mutillinae), the largest and most cosmopolitan genus within the Mutillidae (Cambra & Quintero 1992), is widely distributed in the Americas, from Argentina to British Columbia, Canada, and the Caribbean islands (Mickel 1937a, 1938). The strongly sexually dimorphic species of *Timulla* have prompted descriptions of numerous species based on a single sex. Of a total of 172 Neotropical species and three subspecies of the subgenus *Timulla,* of *Timulla* (Mickel 1938, Nonveiller 1990), both sexes are known for only 27. In the present contribution, part of a series on the taxonomy, distribution, ecology and mating behavior of *Timulla,* we make 13 new sex associations, placing 11 names as junior synonyms (for five species previously known only from their males, and six only from their females), and describing the allotypes of three species (two males and one female). We also present new distribution records for eight species of *Timulla.*

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Methods and Materials

Methods.—Diagnostic characters used to recognize the species were those used by Mickel (1938) in his revision of the Neotropical species of *Timulla.* Male genitalia were not used by Mickel (1938) to separate species. Instead, he used and illustrated many very reliable diagnostic characters present on the surface of the last tergum. Morphological terminology used in descriptions of previously unknown allotypes follows Mickel (1938), except for wing terminology, and the use of tergum (terga) and sternum (sterna) instead of tergite(s) and sternite(s), which follow Bohart & Menke (1976).

Male and female conspecificity was established by finding one, or several, of the following: phoretic pair(s) in nature (i.e., airborne male carrying female in his mandibles); experimental attraction, in nature, of flying male(s) by pheromones released from a caged female (in *Timulla,* we have not been able to find the opposite [e.g., males attracting females, in either nature or the laboratory]); finding individual(s) of both sexes in the field in close proximity and later obtaining, in a closed container, positive experimental mating(s) of at least one of the assorted pair(s). Erroneous heterospecific sexual associations are not known for *Timulla* (unpublished data); we have determined this by experimental attraction of males, in nature, using caged females (males fly upwind to caged females—otherwise, the male captured might be one just coincidently flying by). Only after conspecific sex association, can the following take place: courtship by the male (quite elaborate in some species [unpublished data], see Fig. 1) and copulation (Fig. 2) if the female submits (courted females often refuse mating by flexing the distal part of the abdomen forward so that the male cannot have access to the genitalia) (unpublished data).

Materials.—Females were captured with forceps, and males (in phoretic pairs) were captured with entomological nets (kept alive for experimental matings) and Malaise traps (killed in alcohol). Sex association experiments were carried out in the laboratory, in 15 cm diameter glass petri dishes, at about 27° C. The 11 × 13 × 5 cm cages, used to enclose females for the experimental attraction of conspecific males, were built of wood, and each had two lateral openings covered with fine metallic mesh, to allow air circulation. Care was taken to wash each cage after every experimental run, to remove female pheromones remaining in the cage that might give erroneous results if the cage were used later with another species.

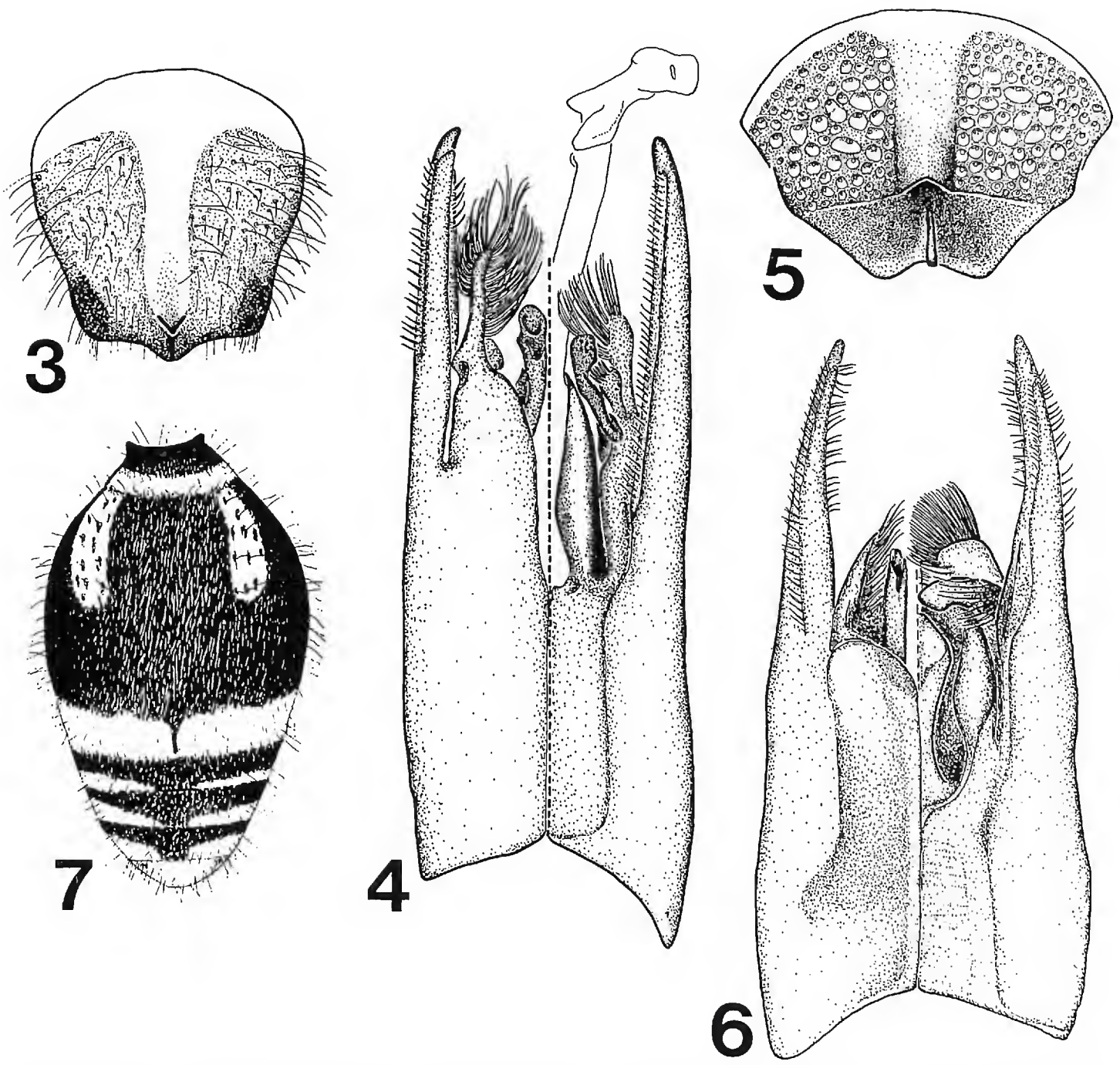
Institutional Abbreviations.—Specimens studied (and deposited, as indicated) were from the British Museum (Natural History) [BM(NH)]; Cornell University Insect Collection, Ithaca (CUIC); U.S. National Museum of Natural History, Smithsonian Institution (NMNH); Museum National d'Histoire Naturelle, Paris (MNHN); Insect Collection, Dept. of Entomology, University of Minnesota, St. Paul (ICUM); U.S.D.A. Bee Biology and Systematic Laboratory, Utah State University, Logan (BLCU); Museo de Invertebrados "G. B. Fairchild", Panama (MIUP); Zoologisches Museum, Humboldt Universitat, Berlin (ZMHB).

Allotype Descriptions

Timulla (*Timulla*) *nisa* Mickel, 1938
(Figs. 1–4)

Timulla nisa Mickel, 1938: 592–593. Type locality: PANAMA. Ancon, [ex] Canal

Figures 1–2. *Timulla nisa,* living pair. Figure 1. Courtship; female hangs from male's mandibular clasp, her legs folded. Figure 2. Mating, winged male about to insert genitalia into receptive female.



Figures 3–7. Allotypes. Figure 3. *Timulla nisa,* male tergum 7. Figure 4. *Timulla nisa,* male genitalia, dorsal view (right half), ventral (left half). Figure 5. *Timulla absentia,* male tergum 7. Figure 6. *Timulla absentia,* male genitalia, dorsal view (right half), ventral (left half). Figure 7. *Timulla bradleyi,* female abdomen, dorsal.

Zone. Holotype female deposited NMNH, No. 52132, examined; Cambra & Quintero 1992: 468–469.

Allotype.—Male, designated here (deposited MIUP), "Cerro Cara de Iguana, El Valle de Antón, Coclé Province, 2–3 Oct 1988, R. Cambra."

Description.—Allotype, male. Head, thorax, legs and first abdominal segment black, remainder of abdomen ferruginous; head, thorax and legs covered with pale pubescence, except mesonotum with sparse, black pubescence; abdomen beneath clothed with sparse, pale pubescence, except distal portion of final sternum, with sparse, fulvous pubescence; terga clothed with fulvous pubescence. Head, mandibles deeply excised beneath and with conspicuous tooth beneath near base; posterior, elevated margin of glabrous clypeal area, evenly arcuate; scape distinctly bicarinate beneath; antennal scrobes carinate above; ocelli small, distance between eye margin and lateral ocelli equal to 3× greatest diameter of latter; parapsidal furrows present and deep on posterior two-thirds of mesonotum; scutellum evenly convex, not gibbous, punctate throughout; enclosed area of propodeum elevated posteriorly into a distinct tubercle; tegula glabrous, impunctate, except for anterior and inner margins and postero-inner quadrant, all with fine punctures and sparse, pale pubescence. Abdomen, second tergum with sparse, moderate punctures on the disk, becoming closer laterally. Median impunctate area of last tergum

(Fig. 3) terminating in very short, almost obsolete arms of Y-shaped carina; posterior margin of last tergum not emarginate medially; sixth sternum without posterolateral tubercles; seventh sternum with pair of weak, posterolateral tubercles; last sternum with pair of weak, lateral ridges on anterior one-half, ridges not elevated posteriorly in dentiform tubercles. Legs, postero-mesal angles of intermediate coxae tuberculate; calcaria pale. Wings, proximal one-third subhyaline, distal two-thirds fuscous; submarginal cell II receiving first recurrent vein distinctly beyond middle; submarginal cell III present but less distinct than II and receiving second recurrent vein at three-fifths distance from base to apex. Body length, 11.5 mm.

Discovery of the male of Timulla nisa.—Numerous females, which we identified as *T. nisa,* and males, not matching the description of any previously known species of *Timulla,* were collected in close proximity to each other. The subsequent courtship and mating of one pair (Figs. 1, 2), when placed together in a closed container, confirmed their conspecificity. The male specimen of that pair, is designated here as the allotype of the species. Males of *T. nisa* will key to *T. taygete* Mickel in couplet 38 of Mickel's keys (1938: 539), a species distributed from Mexico to Guatemala, Honduras, Belize and Costa Rica. It differs from *T. taygete* in having the enclosed area of the propodeum elevated posteriorly into a distinct tubercle, and the postero-inner angles of the intermediate coxae tuberculate.

Distribution.—Panama, Colombia, Venezuela, and Trinidad, in lowland and premontane rain forests.

Material Examined.—COLOMBIA. Valle Restrepo, Campo Alegre (1100 m), 10 Feb 1984, O. Cepeda, 1 female (MIUP); Risaralda, Ucomari, Oct 1990, 1 female (MIUP).

Timulla (*Timulla*) *absentia* Mickel, 1938
(Figs. 5, 6)

Timulla absentia Mickel, 1938: 653–654. Type locality: COSTA RICA (no additional data). Holotype female deposited Museo Civico di Historia Naturale, Genoa, Italy; Cambra & Quintero 1992: 467.

Allotype.—Male, designated here (deposited MIUP), "Playa Venado, Veracruz, [Panama Province], Panama, 8 Nov 1988, R. Cambra" (female and allotype male mounted in same pin).

Description.—Allotype, male. Head, thorax and legs integument, black, clothed with pale pubescence, except for mesonotum with sparse, black pubescence; abdomen integument entirely ferruginous, clothed with sparse, pale pubescence, terga clothed with sparse, fulvous pubescence. Head, mandibles deeply excised beneath and with conspicuous tooth beneath near base; posterior elevated margin of glabrous clypeal area, subarcuate, with a very slight angle medially; scape distinctly bicarinate beneath; antennal scrobes carinate above; ocelli small, distance between eye margins and lateral ocelli equal to 3.5× greatest diameter of latter. Thorax, parapsidal furrows obsolete on anterior one-third of mesonotum; scutellum evenly convex, not gibbous, punctate throughout; enclosed area of propodeum not elevated posteriorly to form a distinct tubercle, sides converging towards tip to form distinct angle; tegula glabrous, impunctate, except anterior and inner margins and postero-mesal quadrant, all with fine punctures and sparse, pale pubescence. Abdomen, second tergum with sparse, moderate punctures on disk, becoming closer laterally, and the broad, posterior margin with distinct, very small punctures; median impunctate area of last tergum (Fig. 5) terminating in an inverted V-shaped carina; posterior margin of last tergum emarginate medially; sixth sternum with pair of weak posterolateral tubercles; seventh sternum with pair of distinct, posterolateral tubercles; last sternum with pair of lateral ridges on anterior one-half, ridges elevated posteriorly forming dentiform tubercles. Legs, postero-mesal angles of intermediate coxae not tuberculate; calcaria pale. Wings, proximal three-fourths are subhyaline, distal fourth forming broad fuscous margin; submarginal cell II receiving first recurrent vein very slightly before middle; submarginal cell III present but less distinct than II and receiving second recurrent vein distinctly beyond middle. Body length, 9.5 mm.

Variation.—Body length varies, in males from 8–12 mm (n = 4), in females from 4–8.5 mm (n = 50).

Discovery of the male of Timulla absentia.—One phoretic pair was captured in Playa Venado. We identified the female as *T. absentia.* The male was undescribed and the specimen is designated here as the allotype of that species. The allotype male will key to *T. tyro* in couplet 8 of Mickel's key (1938: 537) which ranges from Arizona and California through Mexico. It differs from *T. tyro* in having the inverted carina on the final abdominal tergum V-shaped (U-shaped in *T. tyro*) and the legs entirely black (tibiae and tarsi are ferruginous in *T. tyro*).

Distribution.—Costa Rica and Panama. In Panama this species is confined to open land at sea level, and is rather common on sandy beaches of the Pacific coast.

Material Examined.—See allotype.

Timulla (*Timulla*) *bradleyi* Mickel, 1938
(Fig. 7)

Timulla bradleyi Mickel, 1938: 632–633. Type locality: COSTA RICA. *LIMÓN PROVINCE:* Suretka. Holotype male deposited CUIC; Cambra & Quintero 1992: 467.

Allotype.—Female, designated here (deposited MIUP), "El Copé, Coclé Province, Div. Continental (900 m), 22 Sep 1990, R. Cambra."

Description.—Allotype, female. Head, abdomen and legs black, except tip of scape and basal one-third of femur, ferruginous; thorax ferruginous; head clothed with sparse, pale pubescence, except vertex with sparse, black pubescence; thorax clothed with sparse, pale pubescence, except dorsum clothed with sparse fuscous pubescence; legs clothed with sparse pale pubescence; abdomen beneath clothed with sparse, pale pubescence, thick at posterior margins of sterna; abdominal terga for most part, black pubescent, pale pubescent markings as follows: first tergum with narrow, complete, posterior marginal band; second tergum with pair of anterior, longitudinal stripes not extending to transverse midline, and a posterior marginal band narrowly interrupted medially with black; terga 3–5 each with pair of transverse spots extending along the posterior margin to the posterolateral angle (Fig. 7). Head, antennal scrobes carinate above; front and vertex with large, deep punctures. Thorax, not broader posteriorly than anteriorly, lateral margins of dorsum of thorax shallowly emarginate at mesonotal area; scutellar scale present; lateral margins of posterior face of propodeum not denticulate; sides of propodeum with moderate close punctures posteriorly; second tergum with large, distinct punctures visible through the pubescence. Abdomen, pygidial area microgranulate, almost smooth; second sternum with large, distinct, closely set punctures. Body length, 8.5 mm.

Discovery of the female of Timulla bradleyi.—After two years of intense collecting of mutillids in El Copé, near the Continental Divide (approx. altitude, 900 m), Coclé Province, Panama, *T. bradleyi* was the only species of *Timulla* whose female was unknown to us. In 1990, we were fortunate to collect a series of males of *T. bradleyi* in close proximity to females not previously described; one of these females, placed in an entomological net, attracted a male, later identified as *T. bradleyi* (the male flew upwind toward the female, confirming their conspecificity). That female specimen is designated here as the allotype of the species. The female of *T. bradleyi* keys to *T. manni* Mickel in couplet 98 of Mickel's keys (1938: 551), a species known from Bolivia, Argentina, and Chile. It differs from *T. manni,* and all the species of the genus, in the following combination of characters: pale pubescent bands on terga three to five not reaching anterior margins and inter-

rupted medially, pygidial area microgranulate, posterior pale pubescent band of second tergum narrowly interrupted medially with black.

Distribution.—Costa Rica and Panama, in premontane rain forests.

Material Examined.—COSTA RICA. *CARTAGO PROVINCE:* Turrialba, CATIE, 26–29 Jun 1986, G. Bohart, W. Hanson, 3 males (BLCU); Turrialba Experim. Station, 20 Aug 1989, F. D. Parker, 1 male (BLCU). PANAMA. *COCLÉ PROVINCE:* El Copé, 21 Feb 1990, R. Cambra, 3 males (MIUP); 14 Jun 1990, D. Quintero & A. Mena, 3 males (MIUP); 1–2 Sep 1990, R. Cambra, 12 males (MIUP); 9–10 Oct 1990, R. Cambra, 1 female (MIUP).

New Synonymy, Including Three Species with New Distribution Records

Timulla (*Timulla*) *porcata* (Cameron), 1894
(Figs. 8, 9)

Mutilla porcata Cameron, 1894: 275–276 (in part, not variety from Caldera, Chiriquí). Type locality: PANAMA. *CHIRIQUÍ PROVINCE:* Volcan de Chiriquí, 760–1220 m. Holotype female deposited BM(NH), examined. *Timulla porcata:* Mickel 1938: 656; Cambra & Quintero 1992: 469.

Timulla bituberculata Mickel, 1938: 634–635. Type locality: MEXICO. *OAXACA:* Tuxtepec. Holotype male deposited NMNH, No. 52147, examined. NEW SYNONYMY.

Timulla phiala Mickel, 1938: 663–664. Type locality: COSTA RICA. (no additional data). Holotype female deposited MNHN, examined. NEW SYNONYMY.

Notes on Synonymy.—New synonymies are based on the finding of two phoretic pairs in Guanacaste. We identified the males of these phoretic pairs as *Timulla bituberculata* Mickel and the females as *T. phiala* Mickel, and we are confident that both names refer to the same species. *Timulla porcata* (Cameron), known only from the holotype female collected in Panama, is nearly identical to *T. phiala,* except for one detail of coloration: the pale pubescent band on the posterior margin of the fifth abdominal tergum is narrowly discontinuous in *phiala* and widely separated by a median band of black hairs in *porcata.* We consider that this small difference in color does not represent a valid species difference and, thus, we place *T. phiala* as a junior synonym of *T. porcata.*

Distribution.—Mexico, Belize, Nicaragua, Costa Rica and Panama, in lowland and premontane rain forests.

Material Examined.—COSTA RICA. *GUANACASTE PROVINCE:* 14 km S of Cañas (Malaise trap), 11–15 Mar 1989 (phoretic pair in same pin), 1–11 Apr 1990 (phoretic pair in same pin), F. D. Parker (BLCU). NICARAGUA. Masaya, Laguna de Apollo, Nov 1991, E. van den Berghe, 3 females. PANAMA. *BOCAS DEL TORO PROVINCE:* Changuinola, 1–15 Jul 1991, R. Rodríguez, 1 female (MIUP); *Coclé Province:* El Valle de Antón, 9 Jan 1991, R. Contreras, 1 male (MIUP); 6 Jul 1991, R. Contreras, 1 female (MIUP).

Timulla (*Timulla*) *centroamericana* (Dalla Torre), 1897

Mutilla centralis Cameron, 1894: 271 (nec Burmeister 1875). Syntype locality: GUATEMALA. Paso Antonio, 123 m; PANAMA. *CHIRIQUÍ PROVINCE:* Volcan de Chiriquí, 760–1220 m. Syntype female deposited BM(NH), examined.

Mutilla centroamericana Dalla Torre, 1897: 22 (replacement name); *Timulla*

Figures 8–9. Phoretic pair, pinned. Figure 8. *Timulla porcata,* lateral view. Figure 9. Close-up, male's mandibular clasp of neck of female; arrow, male right mandible.

centroamericana: Mickel, 1938: 665, lectotype designation; specimen from Guatemala apparently was lost from BM(NH); Cambra & Quintero 1992: 467–468.

Timulla proclivis Mickel, 1938: 565–566. Type locality: COLOMBIA. *MAGDALENA:* Río Frío. Holotype male deposited ICUM. NEW SYNONYMY.

Notes on Synonymy.—Synonymy is based on the capture of two mating pairs in Panama Province: one, resting on the surface of a leaf of maize, in Tocumen, and the other, captured in Capira. We identified the females of these two pairs as *T. centroamericana* (Dalla Torre) and the males as *T. proclivis* Mickel; we are confident that both names refer to the same species, thus *Timulla centroamericana* (Dalla Torre) is a senior synonym of *T. proclivis* Mickel.

Variation.—Body length varies, in males 12–16.5 mm (n = 20), in females 6–10.5 mm (n = 54).

Distribution.—Panama, Colombia and Ecuador (Mickel 1938, Cambra & Quintero 1992). This species has a wide distribution in Panama, ranging from sea level up to 1100 m, on both the Atlantic and Pacific slopes.

Material Examined.—PANAMA. *COLÓN PROVINCE:* Santa Rita, 20–21 Dec 1990, R. Cambra, 1 female; *PANAMA PROVINCE:* Estación Experimental Universidad Panama, Tocumen, 1 Jul 1987, B. Gray, mating pair (MIUP); Capira, 24 Apr 1991, J. Coronado, [mating pair mounted in same pin] (MIUP); Río Perequeté, Corregimiento Playa Leona, La Chorrera, 17 Jan 1992, R. Cambra, 1 male, 2 females (MIUP).

Timulla (*Timulla*) *heterospila* (Gerstaecker), 1874

Mutilla heterospila Gerstaecker, 1874: 299. Type locality: COLOMBIA. Bogotá. Holotype female deposited ZMHB, No.19282. *Timulla heterospila:* Mickel 1938: 616–617.

Mutilla thura Cameron, 1894: 289–290. Type locality: PANAMA (no additional data). Holotype male deposited BM(NH), examined. *Timulla thura:* Mickel 1938: 599. NEW SYNONYMY.

Notes on Synonymy.—Synonymy is based on the experimental attraction, by a caged female of *Timulla heterospila,* of eleven males that we later identified as *T. thura.* On all occasions, the males flew upwind toward the caged female, thus indicating that they had detected the presence of the female not by sight but by pheromones liberated by her into the air. One of the captured males, attracted by the caged female, mated with her in the lab, confirming its conspecificity.

New Distribution Record.—The finding of *T. heterospila* in Venezuela represents a new distribution record, as this species was previously known only from the lowlands of Panama and Colombia. *Timulla heterospila* lives in open and modified habitats, from sea level up to 200 m altitude.

Material Examined.—PANAMA. *PANAMA PROVINCE:* Capira, 19 Jul 1991, J. Coronado, 1 female (MIUP); 4 Aug 1991, 2 males (MIUP); 21 Aug 1991, 5 males (MIUP); 22 Aug 1991, 2 males (MIUP); 26 Aug 1991, 2 males (MIUP). VENEZUELA: *GUARICO [STATE]:* Hato Masaguaral (44 km S of Calabozo), 3–10 May 1985, A. Menke & [J. M.] Carpenter, 1 female (NMNH).

Timulla (*Timulla*) *mexicana* (Cameron), 1894

Mutilla mexicana Cameron, 1894: 265. Type locality: MEXICO. Oaxaca. Holotype female deposited BM(NH), examined. *Timulla mexicana:* Mickel 1938: 638.

Mutilla amulae Cameron, 1894: 277. Type locality: MEXICO. *GUERRERO:* Amula. Holotype male deposited BM(NH), examined. *Timulla amulae:* Mickel 1938: 637–638. NEW SYNONYMY.

Notes on Synonymy.—New synonymy is based on the capture of one phoretic pair (we identified the female as *Timulla mexicana* and the male as *T. amulae*),

in Guanacaste, indicating that they are conspecific. We are confident that both names refer to the same species; the name of the male, *T. mexicana,* has page precedence over that of the female, *T. amulae.* Mickel (1938) suggested that *T. amulae* might be the male of *T. mexicana.*

New Distribution Record.—The finding of *Timulla mexicana* in Costa Rica represents a new distribution record, as this species was previously known only from Mexico and Honduras.

Material Examined.—COSTA RICA. *GUANACASTE PROVINCE:* EJN, 14 km S of Cañas, 15 Apr–6 May 1991, F. D. Parker [mounted in same pin] (BLCU); 17–18 Mar 1990, F. D. Parker, 4 males (BLCU); 18–19 Apr 1990, F. D. Parker, 1 male (MIUP); *SAN JOSÉ:* Escazú, 18–19 Mar 1988, F. D. Parker, 1 male (MIUP).

Timulla (*Timulla*) *runata* Mickel, 1938

Timulla runata Mickel, 1938: 592. Type locality: PANAMA. Gamboa. Holotype female deposited NMNH, No. 52131, examined; Cambra & Quintero 1992: 469.

Timulla buscki Mickel, 1938: 601–602. Type locality: PANAMA. *PANAMA PROVINCE:* Isla Taboga. Holotype male deposited NMNH, No. 52138, examined. NEW SYNONYMY.

Notes on Synonymy.—One female, that we identified as *Timulla runata,* and one male, identified as *T. buscki,* were captured in close proximity on the open, grassy edge of a gallery forest of the Santa María River. Minutes after their capture, they readily mated, after being placed together inside a plastic container, confirming their conspecificity. In addition, we examined a phoretic pair (we identified the female as *T. runata* and the male as *T. buski*) from Caballero.

Variation.—Body length, in males 9.5–12 mm ($n = 24$), in females 4.5–7.5 mm ($n = 57$).

Distribution.—Panama and Colombia (Mickel 1938). This species, the most common *Timulla* in Panama (Cambra & Quintero 1992), is widely distributed in the lowlands of Panama, on both the Atlantic and Pacific slopes, from sea level up to 200 m.

Material Examined.—PANAMA. *COCLÉ PROVINCE:* Caballero, Antón, 30 Jan 1988, R. Rodríguez, 1 male, 1 female (MIUP); *VERAGUAS PROVINCE:* Santa María River, 20 km S of Santa Fé, 8 Aug 1987, 1 male, 1 female (MIUP).

Timulla (*Timulla*) *connexa* (Cameron), 1894

Mutilla connexa Cameron, 1894: 279–280. Type locality: PANAMA. *CHIRIQUÍ PROVINCE:* Bugaba. Holotype male deposited BM(NH), examined. *Timulla connexa:* Mickel 1938: 629–630 (reports males from Limón, Costa Rica).

Timulla selene Mickel, 1938: 655–656. Type locality: PANAMA. *CHIRIQUÍ PROVINCE:* Bugaba. Holotype female deposited BM(NH), examined. NEW SYNONYMY.

Notes on Synonymy.—New synonymy is based on the following evidence: (1) Collection of numerous males (that we identified as *Timulla connexa*) and females (that we identified as *T. selene*) at the same time and in close proximity to each other, at El Copé, and their subsequent matings when placed together in the laboratory; (2) Collection of two females, which we identified as *T. selene,* from Alajuela; males (*T. connexa*) were known already from Costa Rica but females

were not. *Timulla connexa* Cameron is a senior synonym of *T. selene* and we are confident that both names refer to the same species.

Variation.—Body length, in males 13.5–18.5 mm ($n = 24$), in females 6.5–10.5 ($n = 17$).

Distribution.—Costa Rica and west of Panama, in premontane, wet rain forests, at elevations ranging from 800 to 1000 m.

Material Examined.—COSTA RICA. *ALAJUELA PROVINCE:* Finca Josephina, 5–27 Sep 1988, F. D. Parker (BLCU). PANAMA. *COCLÉ PROVINCE:* El Copé, 24 Sep, 10 Oct 1990, 10 males, 8 females (MIUP).

Timulla (*Timulla*) *adrastis* Mickel, 1938

Timulla adrastis Mickel, 1938: 631–632. Type locality: MEXICO. Tuxpan. Holotype male deposited NMNH, No. 52146, examined.

Timulla pilatrix Mickel, 1938: 651. Type locality: MEXICO (no additional data). Holotype female deposited NMNH, No. 52151, examined (additional records for Guatemala). NEW SYNONYMY.

Notes on Synonymy.—New synonymy is based on one phoretic pair captured in Guanacaste; we identified the male in that phoretic pair as *Timulla adrastis* Mickel and the female as *T. pilatrix* Mickel. We are confident that both names refer to the same species. The name of the male has page precedence over that of the female, *T. pilatrix.*

New Distribution Record.—The finding of *Timulla adrastis* in Costa Rica represents a new distribution record, as the species was known previously only from Mexico and Guatemala.

Material Examined.—COSTA RICA [All specimens, except as indicated, were collected by F. D. Parker and deposited BLCU]. *ALAJUELA PROVINCE:* Bijagua, 20 km S of Upala, 6 Jan 1991, 1 male; same loc., 7 Feb 1991, 2 males; same loc., 16 Feb 1991, 1 male; same loc., 5 Mar 1991, 1 male; same loc., 28 Mar 1991, 2 males; same loc., 2 Apr 1991, 1 male; same loc., 12 Apr 1991, 1 male; same loc., 29 Apr 1991, 1 male; *GUANACASTE PROVINCE:* 14 km S of Cañas, 21–22 Jan 1989, 1 male, 1 female, mounted in same pin; 14 km S of Cañas, 8–18 Mar 1988, 1 male; same loc., 3–9 Jul 1988, 1 male; same loc., 1 Aug 1988, 1 male; same loc., 28–29 Jan 1989, 2 males; same loc., 9–14 Feb 1989, 1 female; same loc., 18 Feb 1989, 1 male; same loc., 28 Feb 1989, 1 male; same loc., 1–5 Mar 1989, 1 male; same loc., 10 May 1989, 1 male; same loc., 7–10 Oct 1989, 1 male; La Taboga Forest Reserve, 9 km SW of Cañas, 17–27 Feb 1987, W. L. Rubink, 2 males.

Timulla (*Timulla*) *taygete* Mickel, 1938

Timulla taygete Mickel, 1938: 639–640. Type locality: MEXICO. *YUCATÁN:* Chichen Itza. Holotype male deposited ICUM.

Timulla aureata Mickel, 1938: 651–652. Type locality: COSTA RICA. Navarro Farm, near Cartago. Holotype female deposited NMNH, No. 52152, examined. NEW SYNONYMY.

Notes on Synonymy.—New synonymy is based on examination of two phoretic pairs captured by F. D. Parker in Guanacaste. We identified the males in these phoretic pairs as *Timulla taygete* and the females as *T. aureata,* confirming their conspecificity. Mickel (1938) suggested that *T. aureata* might be the female of *T. taygete.* The name of the male, *T. taygete,* has page precedence over that of the female, *T. aureata.*

Distribution.—Mexico, Guatemala, Honduras, Belize, and Costa Rica.

Material Examined.—COSTA RICA. *GUANACASTE PROVINCE:* 14 km S of Cañas, Costa Rica, 11–31 Jan, 15–24 Feb 1990, two phoretic pairs, each pair mounted in same pin (BLCU).

Timulla (*Timulla*) *cordillera* Mickel, 1938

Timulla cordillera Mickel, 1938: 566–567. Type locality: PERU. Río Pichio, Puerto Bormadez. Holotype male deposited CUIC.

Timulla mulfordi Mickel, 1938: 617. Type locality: BOLIVIA. Río Beni, near the mouth of Río Mapiri. Holotype female deposited NMNH, No. 52140, examined. NEW SYNONYMY.

Notes on Synonymy.—New synonymy is based on the attraction, in Pakitza, by a living female, which we identified as *Timulla mulfordi,* of a male, identified as *T. cordillera,* that flew into the open mouth of a glass vial containing the female and attempted to mate her, confirming their conspecificity. We are confident that both names refer to the same species; the name of the male, *T. cordillera,* has page precedence over that of the female, *T. mulfordi.* In addition, we captured in Pakitza 11 males and 29 females, from 14 Feb to 10 Mar 1992.

Distribution.—Perú and Bolivia (Mickel 1938). This species ranges from the Amazonian forests of Perú, near sea level, to the eastern Andean slopes of Perú and Bolivia, at elevations from 300 to 1200 m.

Material Examined.—PERU. *LORETO DEPARTMENT:* Explorama Lodge, Yanamono River, 80 km NE Iquitos, 1–2 Nov 1990, D. Quintero & R. Cambra, 4 females (MIUP); *MADRE DE DIOS DEPARTMENT:* BIOLAT Biological Station, Pakitza, Río Manu, Perú, 8 Mar 1992, R. Cambra, 1 male, 1 female mounted in same pin (MIUP); 14 Feb–10 Mar 1992, 11 males, 29 females (NMNH, ICUM, BLCU, MIUP).

Timulla (*Timulla*) *labdace* Mickel, 1938

Timulla labdace Mickel, 1938: 630–631. Type locality: PANAMA. Barro Colorado Island. Holotype male deposited NMNH, No. 52145, examined.

Timulla raui Mickel, 1938: 656–657. Type locality: PANAMA. Barro Colorado Island. Holotype female deposited NMNH, No. 52153, examined. NEW SYNONYMY.

Notes on Synonymy.—New synonymy is based on the capture of one phoretic pair in Cana (we identified the female as *Timulla raui* and the male as *T. labdace*), indicating their conspecificity. We are confident that both names refer to the same species; the name of the male, *T. labdace,* has page precedence over that of the female, *T. raui.*

Distribution.—Lowland tropical rain forests of central and eastern Panama, and in Colombia.

Material Examined.—PANAMA. *DARIEN PROVINCE:* Cana, Parque Nacional del Darién, 6 Apr 1991, R. Cambra, phoretic pair mounted in same pin (MIUP); 4–9 Apr 1991, R. Cambra, 10 males (MIUP); 5–12 Apr 1991, R. Cambra, 12 males, 1 female; 12 Apr 1991, R. Cambra, 4 females (MIUP).

New Distribution Records

Timulla (*Timulla*) *rufogastra* (Lepeletier), 1845

Mutilla rufogastra Lepeletier, 1845: 629. Syntype locality: "Amer. Mer." Syntype male deposited Spinola Collection, Torino, Italy, No. 198.1. *Timulla rufogastra:* Mickel 1937b: 174–175 (lectotype designation); 1938: 598 (distribution records).

Variation.—Body length, 9.5–13 mm (n = 14), specimens from Panama.

Distribution.—This species was previously known from Colombia (Muzo, Boyacá; Río Frío, Magdalena), Venezuela, Trinidad, and French Guiana (Mickel 1938).

Material Examined.—(The capture from Panama, below, represents a new distribution record.) PANAMA. *DARIÉN PROVINCE:* Trocha Yaviza-Pinogana, 27–29 Mar 1990, R. Cambra, 14 males (MIUP).

Timulla (*Timulla*) *sieberi* Mickel, 1938

Mutilla lineola: Klug 1821: 307 (not Fabr.). Type locality: BRAZIL. Pará. Type female deposited ZMHB, No. 6627.

Timulla sieberi Mickel, 1938: 626–627 (Klug's specimen designated as holotype; one paratype, Brazil, Rio Arrayodos).

Distribution.—This species inhabits humid forest in the Amazonian basin, and was known previously only from Brazil.

Material Examined.—(The capture from Peru, below, represents a new distribution record.) PERU. *Loreto Department:* Explorama Napo Camp, Río Sucusari (affluent of Napo River), 157 km NE Iquitos, 10 Nov 1990, R. Cambra, 1 female (MIUP).

Timulla (*Timulla*) *brancoensis* Mickel, 1938

Timulla brancoensis Mickel, 1938: 623–624. Type locality: BRAZIL. *AMAZONAS:* Río Branco [Acre State]. Holotype female deposited ZMHB.

Distribution.—This species was known previously only from the holotype from Brazil (the type locality is in northwestern Brazil, some 400 km NE of Pakitza). *Timulla brancoensis* lives in the humid tropical forests of the Amazonian basin.

Material Examined.—(The captures from Peru, below, represent a new distribution record.) PERU. *MADRE DE DIOS DEPARTMENT:* BIOLAT Biological Station, Pakitza, Río Manu, 26 Feb 1992, R. Cambra, 1 female (MIUP); Malaise trap, 1–6 Mar 1992, R. Cambra, 1 female (MIUP); 5 Mar 1992, D. Quintero, 1 female (MIUP); 4 Mar 1992, R. Cambra, 1 female (MIUP).

Timulla (*Timulla*) *prominens prominens* (Cameron), 1894

Mutilla prominens Cameron, 1894: 273. Type locality: GUATEMALA. Capetillo. Holotype female deposited BM(NH), examined. *Timulla prominens:* Mickel 1938: 569–570.

Distribution.—The typical form of this species was known previously from the Isthmus of Tehuantepec, Mexico, through Costa Rica (Mickel 1938), while the only other subspecies, *T. prominens forreri* (Cameron), 1894, is a disjunct endemic of the highlands of Sierra Occidental, in the Mexican Nearctic.

Material Examined.—(The capture from Panama, below, represents a new distribution record.) PANAMA: *BOCAS DEL TORO PROVINCE:* Changuinola, 1–15 Jul 1991, R. Rodríguez, 2 females (MIUP).

Timulla (*Timulla*) *daedala* (Cameron), 1894

Mutilla daedala Cameron, 1894: 269. Type locality: MEXICO: North Yucatán. Holotype female deposited BM(NH), examined. *Timulla daedala:* Mickel 1938.

Distribution.—This species was known previously only from the holotype.

Material Examined.—(The capture from Nicaragua, below, represents a new distribution record.) NICARAGUA. *MANAGUA:* Laguna de Xiloa, 9–10 Nov 1991, E. van den Berghe, 2 females (MIUP).

Discussion

The sex associations of 13 species of *Timulla* presented in this paper number more than the eleven such associations presently known for all of North America. This brings to 40 the number of Neotropical species for which both sexes are known. With this new information, sexes have been associated for 24.8% (40 out of a total of 161) of Neotropical species of *Timulla.* This is still lower than for North America, 28.9%; however, only 38 species and subspecies are known from North America (Krombein 1979), about one-fourth as many as the Neotropics.

The new distribution records have expanded the ranges of several species of *Timulla.* The emerging pattern is one with few sympatric species (maximum number found is three) and numerous species with wide distributions. We need to obtain sex associations for well over 50% of the known species in order to be able to answer two troublesome questions: First, is the size of the geographic distribution of a species of *Timulla* directly correlated with degree of sexual dimorphism? That is, do species with females distinctly smaller than the males (and thus more easily transported to more distant localities in their phoretic flights), have larger ranges than those with less sexual dimorphism?; or, are their geographic distributions correlated to some other factor(s) (i.e., ecology, historical aspects, host distributions, etc.)? Second, do females "pay" males with sex after completing their phoretic flight? Further, if females allow mating to occur in flight, are they immediately dropped from the air by their satisfied males, as may be the case in bethylids and tiphiids?.

Most species of *Timulla,* both in the Neotropics and temperate areas, have males with a common color pattern: orange abdomen, and black head and thorax. This is probably a Batesian mimicry of widespread aculeate wasps, and an anti-predatory strategy by the defenseless sex. Although males of *Timulla* possess similar body coloration, their specific diagnosis is relatively easy because of numerous valid morphological details; contrastingly, females have fewer morphologic diagnostic characters and, in some groups of species, are very similar and difficult to identify.

We have stressed the importance of pheromone attraction and experimental pairing for increasing sex matching records of mutillid species. In addition, it is also important to attempt to obtain information through laboratory experiments of parasitism (useful for rearing unknown conspecific males, and completing, or verifying, sex associations) an effort not successful in our hands with *Timulla* (personal observations). We recommend the illustration of the male genitalia in future descriptions of *Timulla,* as it has valuable species diagnostic characters and it should prove valuable for future cladistic work. The penial valves (ventral face) are distinctly asymmetrical and the illustration of only half of the genitalia (Figs. 4, 6) does not show it.

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Diversity in Latin America Project (BIOLAT), NMNH, in particular D. E. Wilson (director), Marsha Sitnick and Judy Sansburry, for providing funds, facilities and logistic support during our February–March 1992 expedition to the BIOLAT Biological Station, Pakitza, Perú; Utah State University, Terry Griswold (Curator), and Wilford J. Hanson, Dept. Biology, for providing us with multiple loans of specimens from Costa Rica and Panama and much encouragement; Eric van den Berghe, Univ. of Maryland, for his generous donation of mutillid specimens from Nicaragua; Arnold S. Menke, Systematic Entomology Lab, USDA, for being an excellent host, and for providing encouragement, help in many ways and loans of specimens. We are most thankful to Philip J. Clausen (Curator), Univ. of Minnesota, for providing numerous loans of specimens and much help. We are also thankful to David Nickle for arrangements that permitted us to join the Smithsonian Institution-Earthwatch group that visited Explorama facilities, along the Peruvian part of the Amazon River, in 1990. Our thanks to Marcos Guerra, STRI, for photographic work, and James Coronado, for help in field work. This is contribution No. 57 of the BIOLAT Project Series.

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A NEW SPECIES OF *AURATONOTA* (LEPIDOPTERA: TORTRICIDAE) FROM DOMINICA, WEST INDIES

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Abstract.—*Auratonota dominica* J. W. Brown, NEW SPECIES, from Dominica, West Indies, is described and figured. The new species is most similar to *A. aenigmatica* (Meyrick) and *A. dispersa* J. W. Brown, from which it can be distinguished superficially by the wider transverse fasciae and darker ground color of the forewing, and genitalically by the club-shaped uncus with fine setae from the venter, and the free, thornlike process from the sacculus. Because the genus is defined primarily by symplesiomorphies of the male genitalia, *Auratonota* Razowski, as currently circumscribed, probably is not monophyletic. *Auratonota dominica* is only the second species in the tortricid tribe Chlidanotini documented from the Antilles; the other is the widespread "*Conchylis*" *tricesimana* Zeller, previously recorded from Jamaica.

Key Words.—Insecta, Lepidoptera, Chlidanotini, Caribbean, *Auratonota dominica,* taxonomy

Auratonota Razowski includes six previously described species confined to the New World tropics (Razowksi 1987, Brown 1990). Members of the genus are phenotypically diverse; the group is characterized primarily by symplesiomorphies of the male genitalia. Although it is likely that *Auratonota* is para- or polyphyletic, limited knowledge of Neotropical Chlidanotini has inhibited elucidation of phylogenetic relationships among described genera and species. The discovery of a new species from the island of Dominica in the Lesser Antilles represents the second species of the tortricid tribe Chlidanotini from the Caribbean. The other is the widespread "*Conchylis*" *tricesimana* Zeller, which is known from Jamaica (NMNH specimens).

Depositories, Procedures, and Abbreviations.—Taxonomic material for this study was borrowed from the National Museum of Natural History, Washington, D.C. (NMNH). Dissection methodology followed that presented by Powell (1964). Terminology for wing venation and genitalic structures follows Horak (1984): FW = forewing; HW = hindwing; DC = discal cell.

AURATONOTA DOMINICA BROWN, NEW SPECIES
(Figs. 1–3)

Types.—Holotype, male, deposited in U.S. National Museum of Natural History, Washington, D.C., data: (WEST INDIES.) DOMINICA. 2.8 km (1.7 mi) E of Point Casse, 24 Mar 1965, light trap, W. Wirth (NMNH). 2 male, 9 female paratypes as follows: (WEST INDIES.) DOMINICA. Point Casse: 1 male, 2 females, 12–14 Oct 1964; 1 female, 23 Nov 1964; 1 male, 27–30 Nov 1964, all Bredin-Archibold-Smithsonian Biol. Surv. Dominica (all P. Spangler, NMNH); 0.6 km (0.4 mi) E of Point Casse: 1 female, 6 May 1964 (O. Flint, NMNH); 3.3 km (2 mi) NW of Point Casse: 1 female, 20 May 1965 (D. Davis, NMNH); Freshwater Lake: 3 females, 5 Nov 1966; 1 female, 8 Nov 1966 (E. Todd, NMNH).

Figure 1. Female paratype of *Auratonota dominica.*

Description.—Adult Male. FW length 7.0–7.6 mm ($\bar{x}$ = 7.2; n = 3). *Head:* Scaling on frons yellow-gold, sparse and smooth below mid-eye, dense and roughened above. Maxillary palpus inconspicuous. Labial palpus moderately long, weakly upturned, white-ocherous to yellow-gold mesally, brown and gold-brown laterally; segment II expanded distally by scaling; segment III approximately one-third as long as II, exposed, smooth-scaled. Ocelli present, small. Chaetosema with few setae. Antenna gold-brown, thick, laterally compressed; sensory cilia inconspicuous. *Thorax:* Smooth-scaled, shiny white-ocherous, tegulae brown. Legs unmodified, without tibial hairpencil; apical and preapical spines on fore-tarsomeres inconspicuous. *Forewing:* Ground color pale yellow-gold overlaid with diffuse light brown and gray-brown scaling; 3 well-defined, transverse, brown fasciae from costa to dorsum: 1 in subterminal region, moderately uniform in width, with yellow overscaling between 0.6–0.8 from costa to dorsum; 1 from costa about 0.55–0.75 from base, attenuate immediately below DC and overscaled there with yellow-gold, divided at costa by small, irregular, yellow-gold spot; 1 from costa about 0.4–0.5 from base, obsolete immediately below DC; moderate, brown, basal patch at costa. Entire surface rather shiny, but metallic scales absent. Fringe checked gray-brown and white-ocherous. *Hindwing:* Unicolorous light tan. Fringe white-ocherous. *Abdomen:* Dorsal pits and hairpencil absent. *Genitalia:* As in Fig. 2 [drawn from NMNH slide no. 96331 and JWB slide no. 345 (NMNH); n = 2]. Uncus club-shaped, with fine setae from venter of distal one-third. Hami slender, weakly undulate. Socii elongate, digitate, with long, fine setae; closely associated with, but free from hami. Gnathos poorly-defined. Transtilla a broad, arched band, contiguous with anellus laterally. Valva broad, nearly uniform in width, rounded apically; faint longitudinal invagination in basal one-fourth of costa; sacculus undulate, broadest subbasally, confined to basal one-third of valva, with free, short, blunt, subapical, thornlike process extending perpendicular to venter of valva. Saccus-vinculum complex large, weakly attenuate distally. Aedeagus simple, straight, unmodified; cornuti absent.

Adult Female.—FW length 7.3–8.5 mm ($\bar{x}$ = 7.8; n = 9). As described for male, except antenna more slender. *Genitalia:* As in Fig. 3 [drawn from JWB slide no. 346 (NMNH); n = 2]. Papillae anales with unusually developed mesad ventral portion. Apophyses slender, posteriores approximately two-thirds as long as anteriores. Dorsum of VIII with sparse, strong, spine-like setae. Sterigma a simple ring; anterior edge narrowly sclerotized, with wide, shallow depression immediately posterad of ostium. Corpus bursae irregularly round-triangular; signum a patch of curved spines of variable length and a patch of sclerotized dimples. Accessory bursa long, frail, from elongate, narrow ductus originating slightly anterad of signum. Ductus seminalis from near junction of ductus and corpus bursae.

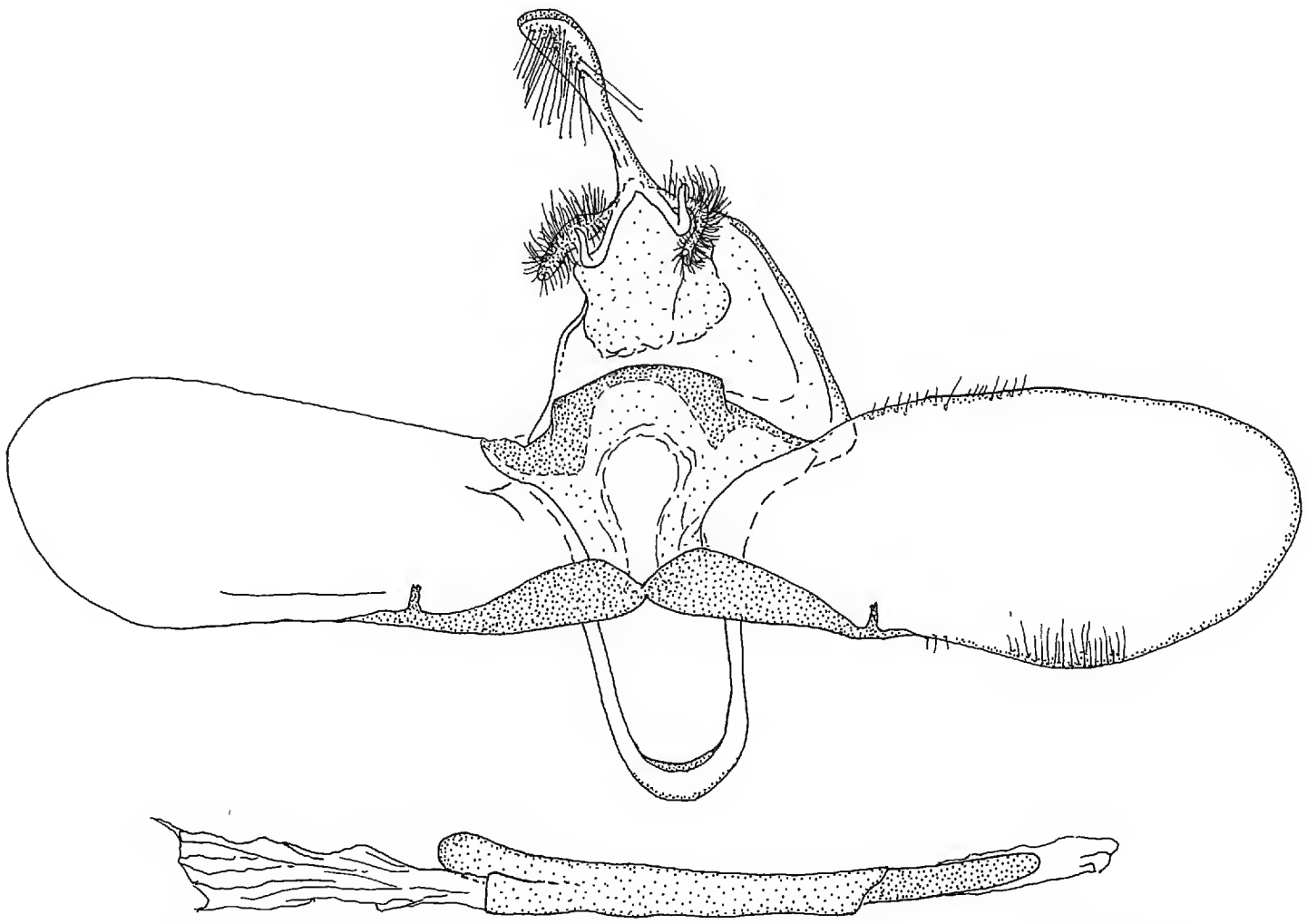

Figure 2. Male genitalia of *Auratonota dominica*; valvae spread, aedeagus removed.

Diagnosis.—*Auratonota dominica* NEW SPECIES can be distinguished from *A. aenigmatica* (figured in Clarke 1958: 116) and *A. dispersa* (figured in Brown 1990: 155) by the broader, undivided, more uniform transverse fasciae of the forewing, darker ground color, and overall more somber appearance. The male genitalia are easily distinguished from the latter two by the club-shaped uncus and short, thornlike process of the sacculus. Although the forewing pattern of *A. dominica* is reminiscent of some species of *Monortha* Razowski and Becker [e.g., *M. illaqueata* (Meyrick)], the male genitalia are not similar to members of this genus. The male genitalia of *Monortha* have large spine-like setae from the venter of the uncus and from the socii; in addition, the socii are short and fused to the hami.

Discussion.—The seven described species of *Auratonota* make up three fairly distinct groups on the basis of facies, in part correlated with male genitalia form. *Auratonota petalocrossa* (Meyrick), *A. hydrogramma* (Meyrick), and *A. aporema* (Dognin) are large (FW length 11.0–17.0 mm), mostly dark-colored species. *Auratonota aurantica* (Busck) is medium-sized (FW length 9.0–11.0 mm) with a nearly uniform shiny gold forewing. *Auratonota aenigmatica* (Meyrick), *A. dispersa* Brown, and *A. dominica* are small (FW length less than 9.0 mm) with a pale ground color and darker transverse forewing fasciae. In the former two groups the valvae are broadest subapically and narrowest basally; in the latter group the valvae are more nearly uniform in width.

Material Examined.—See types.

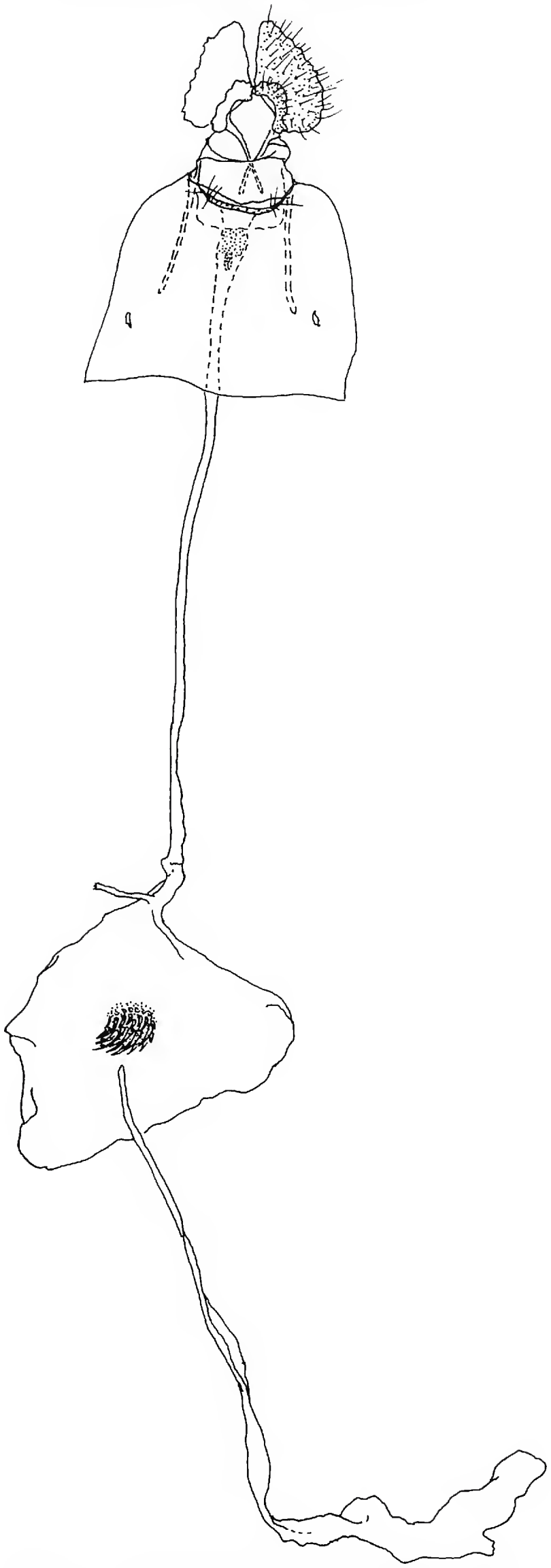

Figure 3. Female genitalia of *Auratonota dominica.*

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OBSERVATIONS ON THE NESTS OF *PARANTHIDIUM JUGATORIUM PERPICTUM* (COCKERELL) (HYMENOPTERA: MEGACHILIDAE: ANTHIDIINI)

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Abstract.—Nests of *Paranthidium jugatorium perpictum* (Cockerell) are described from a small aggregation in Larimer County, Colorado. Nests are dug from the ground surface and contain cells in closely packed series, each cell lined with plant gums.

Key Words.—Insecta, Hymenoptera, Megachilidae, *Paranthidium,* nesting behavior

The nests of anthidiine bees are diverse, some being dug in the soil, others built in preexisting holes, still others built of resin, often mixed with pebbles, above ground. All species use materials brought in from outside the nest, including plant resins, pieces of leaves, down, or pebbles [references in Hurd (1979)]. Nests of members of the genus *Paranthidium* have not previously been described. Nests attributed to *P. jugatorium* (Say) were described by Michener (1975). However, voucher specimens in the Snow Entomological Museum, University of Kansas, have shown that these nests were actually those of *Dianthidium curvatum* (Smith) (Linsley et al. 1980).

A nesting aggregation of *P. jugatorium perpictum* (Cockerell) was found 22 Aug 1991, on a south-facing, 20 degree slope above a gulley, 22 km west of Livermore, Larimer County, Colorado, at an elevation of about 2130 m. The slope was covered with clumps of grasses and with scattered sage [*Artemisia frigida* Willd.], sunflowers [*Helianthus pumilus* Nutt.], and bitterbrush [*Purshia tridentata* (Pursh) DC.]. The soil was a powdery sandy-loam containing many stones and plant roots. In 1991, 16 nests were found, all within an area about 2 × 3 m, each nest in a bare spot, often close to the base of a clump of grass. Each nest had an open entrance, 4 mm in diameter, with a small tumulus, about 4 × 6 cm and 1 cm deep, down-slope of the hole. Some nests were separated by no more than 10 cm, but most were more widely spaced. Pollen-laden females were seen descending to the nests and plunging in without pause.

In 1992, 12 nests were noted at this same site beginning 25 Jul. On this date, several females were digging, backing out of their holes every 30 to 90 sec, pushing soil behind them with their legs, the hind legs working in a side-to-side manner. Over the next few days pollen-laden females were collected from flowers of gumweed [*Grindelia squarrosa* (Pursh) Dunal] and rough sunflower [*Helianthus pumilus*], and a female not bearing pollen was taken on golden aster [*Heterotheca villosa* (Pursh) Shinners]. Males were collected on flowers of these same three plants and also on *Helianthus annuus* L. All of these yellow-blossomed composites grew in abundance within 30 m of the nesting site. No males were seen in the nesting area and no matings were observed.

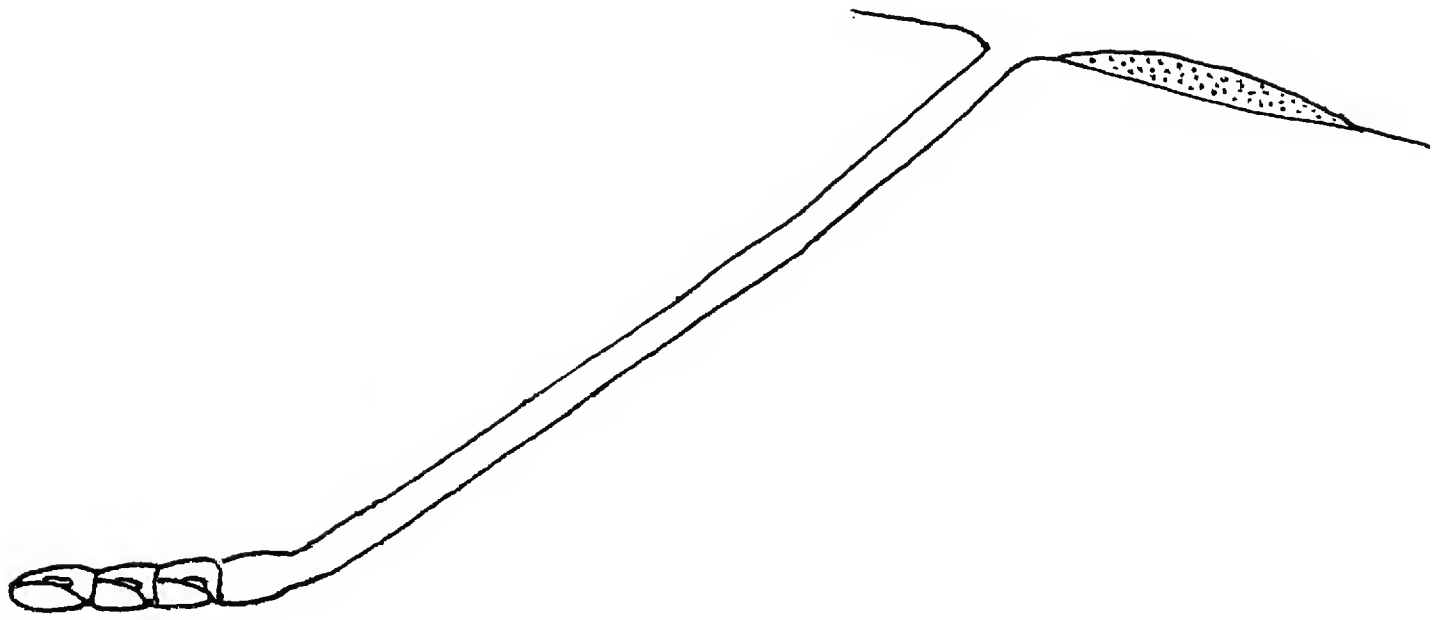

Figure 1. Diagram of a four-celled nest of *Paranthidium jugatorium perpictum.* In this nest the outermost cell has been lined with plant resins but not yet provisioned or closed off. The other three cells each contain a pollen mass on which an egg has been laid.

Three nests were excavated in 1991 and two in 1992. The 25 cells found in these five nests varied in vertical depth from 8 to 11 cm and were from 12 to 21 cm from the nest entrances. Cells were in closely packed series and measured about 7 mm in diameter and 9 to 10 mm long. One nest had two cells in close series when excavated, two others had four, another five cells in two branches of the burrow. The fifth nest had 10 cells in three branches that appeared to diverge from the bottom of the burrow; it is possible that some of these cells belonged to a closely adjacent nest.

Cell walls had a very thin lining (ca. 0.5 mm) of a sticky, translucent substance that was semifluid in fresh cells but became stiffer and plastic-like in cells containing cocoons. Partitions between cells were built of the same substance and were similarly very thin. Each fresh cell was partially filled with a yellow, semisolid, globular mass of pollen, with an egg about 3 mm long laid longitudinally on its top. Older cells contained larvae or cocoons, the latter brown, parchment-like, each with a short, tubular projection, as common in Anthidiini (illustrated in Stephen et al. 1969: fig. 318; Michener 1975: fig. 3). Cells were always immediately adjacent. The substance used for partitions and cell linings had a consistency very similar to that found on the buds and beneath the corollas of gumweed, and it seems probable that the females gather this substance and use it in their nests. However, this could not be confirmed.

Many cells from previous years were discovered during nest excavations, all 7 to 12 cm deep, indicating that this site had been used for several years previously. Some of the cells contained workers and cocoons of ants, *Lasius alienus* Foerster, which evidently found the cavities useful as nests. A female mutillid, *Dasymutilla vestita* Lepeletier, was seen walking about the nesting area, but was not seen to enter burrows. This mutillid has been found to parasitize bees of several genera, including other Megachilidae.

Discussion

Many bees dig their own nests in the soil, but the burrows are most commonly vertical, resulting in a more or less circular tumulus, with the hole in the center. In contrast, *P. jugatorium perpictum* females make a short, oblique burrow into a slope, leaving a tumulus downslope from the hole. Similar burrows, dug by the female, are unusual but not unknown in the Anthidiini. *Trachusa* (*Trachusomimus*) *perdita* Cockerell was found by Michener (1941) to nest in a group on a hillside in Monterey County, California. Burrows were slanted into the hillside and were only 12 to 15 cm long, with the cells in series, firmly glued together, separated by thin partitions. In this instance the cells were lined with bits of leaves cemented together with a gum that was sticky when fresh but later became hard. *Trachusa* (*Heteranthidium*) *larreae* (Cockerell) was studied by MacSwain (1946) in southern New Mexico. Several dozen nests were found to have been dug by females, the burrows slanting and only 10 to 16 cm long. In this case, the end of the burrow dipped downward 2 to 4 cm and entered a cavity from which the cells radiated. Cells were lined with a resinous material into which particles from the surrounding soil were incorporated. Grigarick & Stange (1968) mention observations of R. W. Thorp on the nests of *Trachusa* (*Trachusomimus*) *gummifera* Thorp and provide a photograph of a three-branched burrow. The nests of this species are basically similar to those of *T.* (*T.*) *perdita*. A photograph of a two-branched burrow of the latter species is also provided by these authors, as well as an opened earth-resin brood cell of *T.* (*Heteranthidium*) *larreae*.

Cells of *Paranthidium jugatorium perpictum* differed in being lined with pure plant gums, with no inclusion of soil or leaves, although soil particles often adhered to the outside of the cell linings. However, because other Anthidiini nest in preexisting cavities or make free nests above ground, the resemblances between the nests of the known members of these three groups are more striking than the differences.

Acknowledgment

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A NEW *RHOPALOSIPHUM* ON CATTAIL (HOMOPTERA: APHIDIDAE)

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Abstract.—*Rhopalosiphum laconae* NEW SPECIES is described from adult females, both winged and wingless morphs. This aphid is endemic to the coastal plain of North Carolina, where its sole host is the cattail (*Typha* spp.). Photomicrographs of both life cycle morphs are provided.

Key Words.—Insecta, Aphididae, *Rhopalosiphum laconae* Taber NEW SPECIES

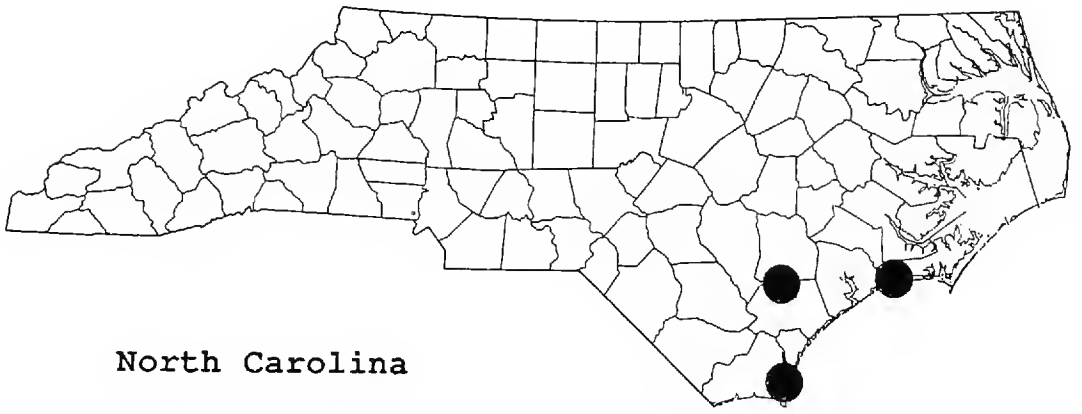
This paper describes a new species of aphid that was discovered in the insect collection of the Entomology Department of North Carolina State University, Raleigh, North Carolina. The specimens had been ironically misidentified as *Rhopalosiphum enigmae* Hottes & Frison. *Rhopalosiphum laconae* Taber, NEW SPECIES is endemic to the southern coastal plain of North Carolina (Fig. 1), a region with an abundance of swamps and freshwater marshes. Cattail (*Typha* spp.), or reed-mace, is a semiaquatic plant and the only host of *R. laconae.* The distinctive new aphid was taken at three localities on three different dates, spanning more than five years. The description of this new species is an essential part of the ongoing revision and reconstruction of phylogeny of the economically important aphid genus *Rhopalosiphum* Koch.

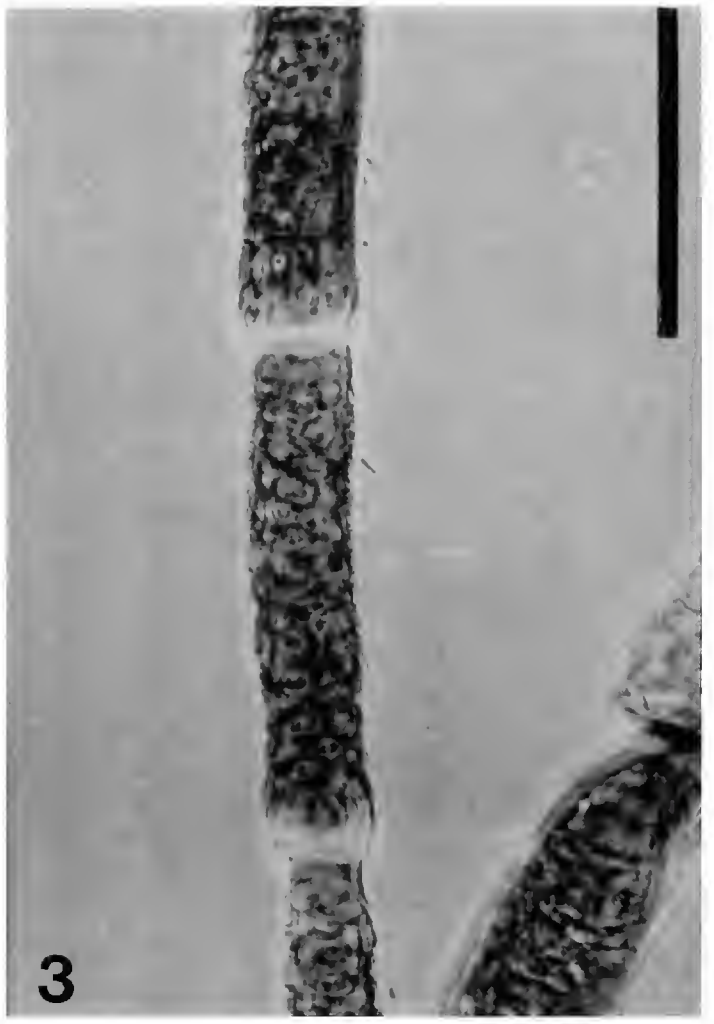
MATERIALS AND METHODS

Measurements were obtained with a Bausch and Lomb Galen phase contrast microscope equipped with ocular and stage micrometers. Photographs were obtained with an Olympus BH-2 phase contrast microscope equipped with a Pentax P3 35mm camera, a Diagnostic Instruments camera tube, and an Olympus NFK 2.5XLD 125 adapter lens. Prints were obtained from Kodak Ektachrome 160T tungsten color slides (2×2).

RHOPALOSIPHUM LACONAE TABER, NEW SPECIES
(Figs. 1–10)

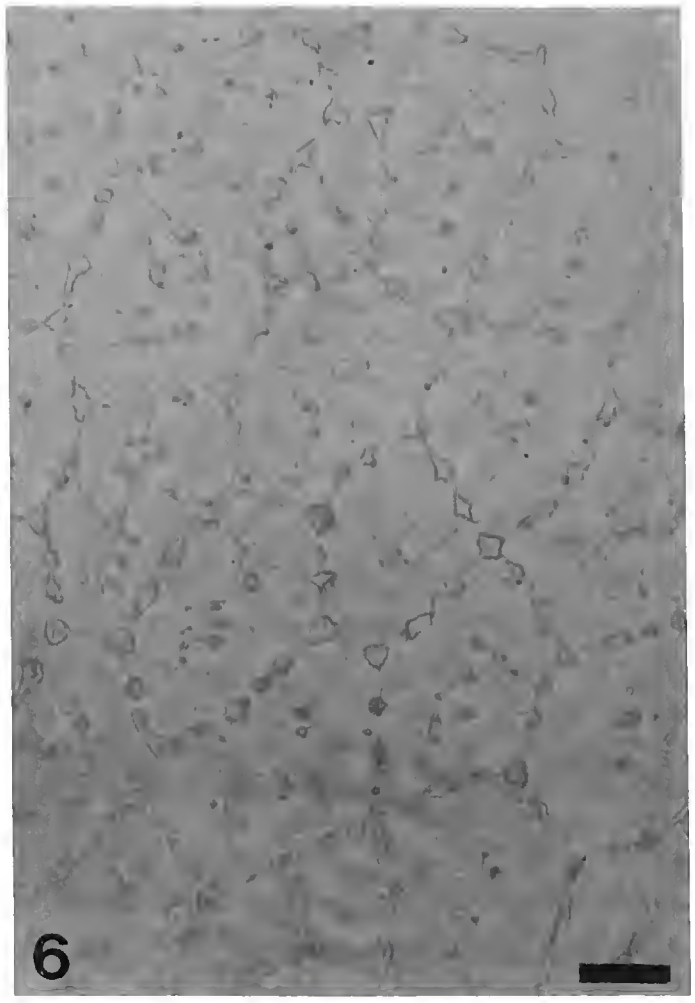
Types.—Holotype: female (apterous vivipara morph) (Fig. 2); data: USA. NORTH CAROLINA. *BRUNSWICK Co.:* Orton Plantation, 1 May 1959; deposited: United States National Museum of Natural History, Washington, D.C. Nine paratypes: same data as holotype, 1 adult apterous vivipara, 1 nymph, and 1 alate vivipara; NORTH CAROLINA. *CARTERET Co.:* Bogue, 26 Apr 1964, 2 apterous viviparae and 3 nymphs; *PENDER Co.:* Willard, 24 Apr 1964, 1 alate vivipara: one alate vivipara paratype deposited in USNM, the remaining paratypes deposited in the insect collection of the Entomology Department, North Carolina State University, Raleigh, North Carolina.

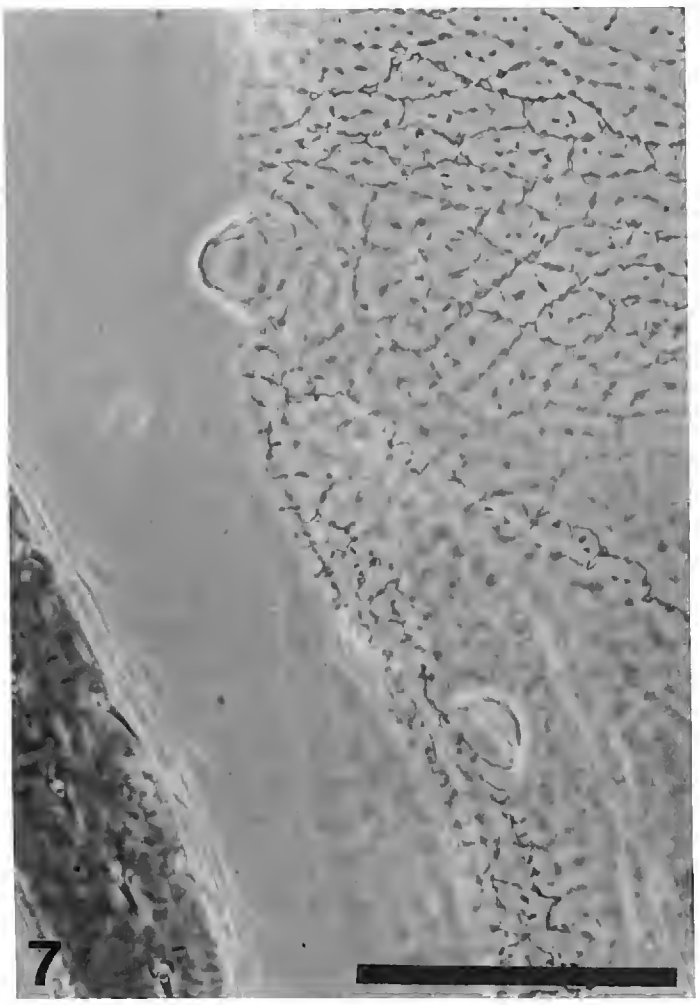




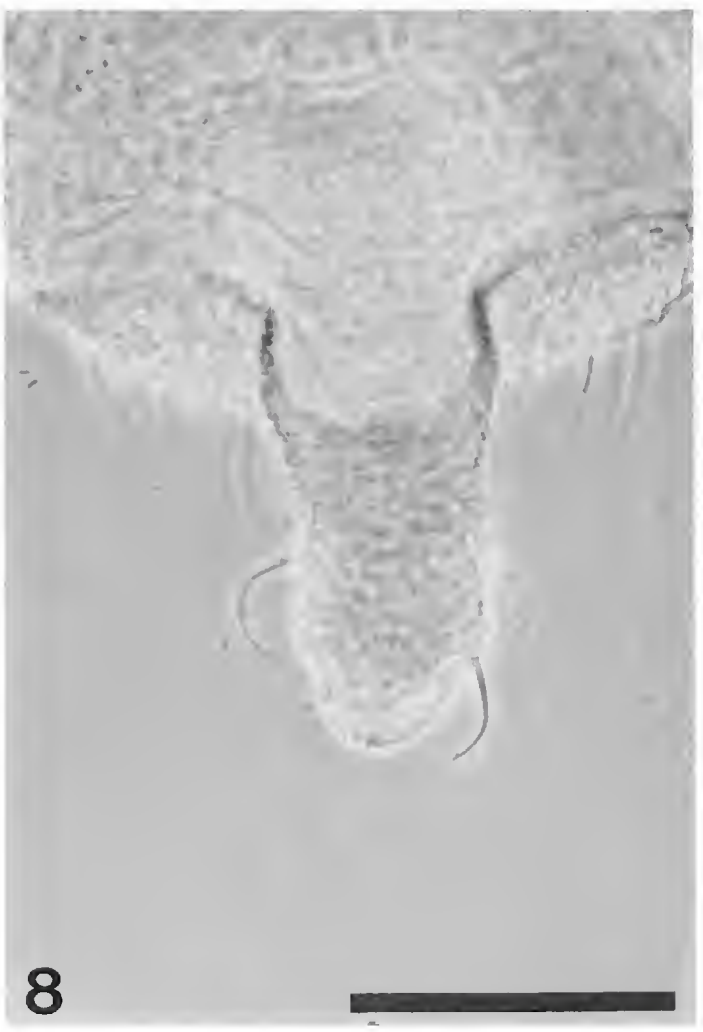
Figures 1–3. *Rhopalosiphum laconae* Taber NEW SPECIES. Figure 1. Distribution. Figure 2. Apterous vivipara (holotype) from *Typha* sp., scale = 0.5 mm. Figure 3. Antenna segment V and part of IV and VI (holotype), scale = 0.1 mm.

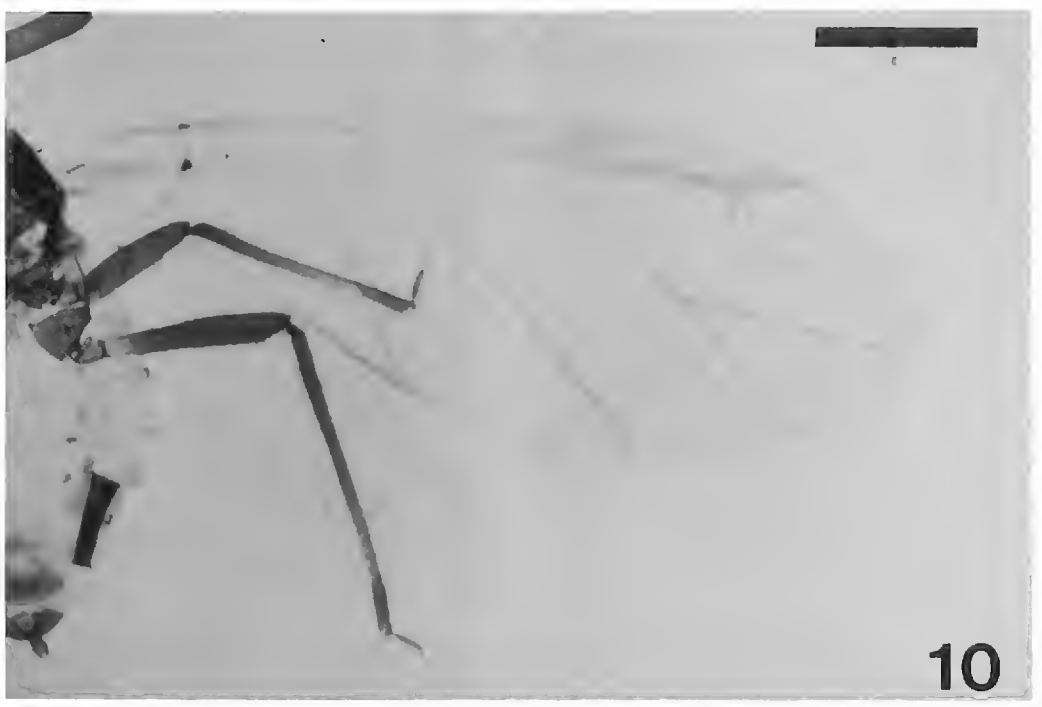
Description.—Adult apterous vivipara: Color in life: "greenish-red bronze" (from microscope slide data), color in macerated specimens; antenna segments dark brown except segments I and II light brown. Apex of siphunculus dark brown. Apex of tibia light brown, base dark brown; distal one-half of femur dark brown, basal one-half lighter; tarsi dark brown. Anal plate dark brown. Remainder of appendages light brown. Body pale, tinged with brown. *Head:* Antenna densely imbricated, giving rugous appearance; antenna setae extremely short, robust, and strongly capitate (Fig. 3). Setae of lateral frontal tubercle, median frontal tubercle, and cephalic disk like those of antenna; cephalic disc with 6 setae, 1 anterior and 2 posterior pairs. Rostrum reaching mesothoracic coxa; ultimate rostrum segment robust (Fig. 4). *Thorax:* Prothoracic tubercles extremely large; prothorax with 6 setae, 1 pair near each tubercle, 1 pair located mesally. All second tarsi very robust (Fig. 5); all hind tibia setae very short and capitate except distal ventral setae, many of which are blunt or acute; capitate setae





Figures 4–7. *Rhopalosiphum laconae* (holotype). Figure 4. Ultimate rostrum segment, scale = 0.1 mm. Figure 5. Hind tarsi, scale = 0.1 mm. Figure 6. Dorsal polygonal reticulation (synapomorphy for the genus), scale = 0.01 mm. Figure 7. Lateral abdominal tubercles (autapomorphy for this species), scale = 0.1 mm.





Figures 8–10. *Rhopalosiphum laconae.* Figure 8. Cauda (holotype), scale = 0.1 mm. Figure 9. Alate vivipara (paratype), scale = 0.5 mm. Figure 10. Alate vivipara (paratype); forewing, scale = 0.5 mm.

frequently with apical spur. *Abdomen:* Dorsum of each thoracic and abdominal segment (except VII and VIII) with small but distinct muscle attachment sclerites; dorsum of abdomen covered with strongly developed polygonal reticulation, polygons containing several to many spinules (Fig. 6). All dorsal abdominal setae very short and strongly capitate; dorsum of eighth abdominal segment with 2 setae. Metathorax and abdominal segments I–VII with very large lateral tubercles (basal diameter of tubercle VII, 0.04–0.05 mm) (Fig. 7). Siphunculus cylindrical or only slightly swollen, densely imbricated, imbrications small, coarse, and strongly spiculose; flange strongly developed. Cauda elongate, coarsely spiculose basally but weakly spiculose distally (Fig. 8); cauda with four setae, two on each side.

Measurements: body length 1.93–2.27 mm, width 1.18–1.38 mm. Head length 0.20–0.25 mm, width 0.48–0.54 mm. Length of antenna segments: I, 0.08–0.10 mm; II, 0.07–0.09 mm; III, 0.24–0.30 mm; IV, 0.13–0.16 mm; V, 0.13–0.16 mm; VI [base], 0.09–0.10 mm; VI [processus terminalis], 0.35–0.48 mm; total antennal length 1.10–1.32 mm; width of base of antenna segment III, 0.03 mm; ratio of length of VI [processus terminalis]/VI [base], 4.00–4.95; length of longest seta on III, 0.01 mm. Length of ultimate rostrum segment 0.12–0.13 mm, width 0.08–0.09 mm. Length of longest lateral frontal tubercle seta 0.01 mm; length of longest cephalic disc seta 0.01 mm. Length of hind tibia 0.83–0.96 mm; length of hind tarsus II, 0.10–0.13 mm. Length of siphunculus 0.32–0.33 mm, width [at base] 0.12–0.13 mm. Length of longest seta on abdominal segment VIII, 0.02 mm. Length of cauda 0.15–0.16 mm, width 0.11–0.12 mm.

Adult alate vivipara (Fig. 9): Color in life: "Greenish-red bronze" (from microscope slide data), color in macerated specimens; head, thorax (except mesal portions of tibia are light brown or pale), and siphunculus dark brown. Cauda, anal plate, genital plate light brown. Abdomen pale. *Wing:* Media of forewing with 2 forks (distal fork small and near margin) (Fig. 10). *Head:* Number of sensoria on antenna segments: III, 12–15; IV, 1–3; V, 0. *Abdomen:* Huge lateral abdominal tubercles present on segments I–VII (basal diameter of tubercle VII, 0.03–0.06 mm); setae on dorsum of abdomen all very short and strongly capitate; dorsum of abdomen without polygonal reticulation; muscle attachment sclerites much larger and more distinct than on apterae; cauda with distinct mesal constriction. *Measurements*: body length 1.70–2.07 mm, width 0.81–0.99 mm. Head length 0.21–0.24 mm, width 0.47–0.49 mm. Length of antenna segments: I, 0.10–0.11 mm; II, 0.08 mm; III, 0.36 mm; IV, 0.20–0.21 mm; V, 0.20 mm; VI [base], 0.11 mm; width of base of antenna segment III, 0.02 mm; length of longest seta on III, 0.01 mm. Length of ultimate rostrum segment 0.13 mm, width 0.07–0.08 mm. Length of longest lateral frontal tubercle seta 0.01 mm; length of longest cephalic disc seta 0.01 mm. Length of hind tibia 0.92–0.98 mm; length of hind tarsus II, 0.10–0.12 mm. Length of siphunculus 0.28–0.30 mm, width [at base] 0.08–0.10. Length of longest seta on abdominal segment VIII, 0.02 mm. Length of cauda 0.13–0.15 mm, width 0.09–0.10 mm.

Diagnosis.—*Rhopalosiphum laconae* NEW SPECIES is easily separated from its 11 congeners by the enormous lateral abdominal tubercles possessed by both female morphs (Figs. 5, 7). The new species is most likely to be confused with *R. padi* (L.) and *R. enigmae.* It differs from *R. padi* by both the size and number of lateral abdominal tubercles: in *R. padi,* abdominal tubercles are found only on segments I and VII, and they are very small. It differs from *R. enigmae* by the size of the lateral tubercles: the average basal diameter of tubercle VII of *R. laconae* apterae is 0.05 mm, whereas the average is 0.02 mm for an equal number of *R. enigmae* apterae from Pennsylvania and Florida. The average diameters for alatae are 0.04 mm and 0.02 mm, respectively. Furthermore, the ultimate rostrum segment and the second tarsi of *R. enigmae* are more slender than those of *R. laconae.* These differences are not due to an artifact of slide preparation.

Etymology.—From "Lacone" (lady of the lake); virgin water goddess of ancient Sparta (Graves 1960). This name was chosen because the aphid is parthenogenetic and restricted to a semiaquatic plant.

Material Examined.—See types.

Acknowledgment

I thank Craig M. Pease for the use of microscope equipment and computer facilities. Robert L. Blinn of North Carolina State University, Raleigh, North Carolina, kindly loaned more than 600 microscope slide preparations of aphids that made both this research and several other projects, including a revision of *Rhopalosiphum,* possible. This research was undertaken in partial fulfillment of

the requirements for the Doctorate of Philosophy in Biological Science at the University of Texas at Austin.

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A NEW SPECIES OF *PROTOSTELIS* FROM MEXICO (HYMENOPTERA: MEGACHILIDAE)

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Abstract.—*Protostelis pardita,* NEW SPECIES, represents the first record of this rare parasitic genus from Mexico. The probable host is *Trachusa* (*Heteranthidium*) *catinula* (Brooks & Griswold). *Protostelis australis floridensis* (Mitchell), NEW SYNONYM, is synonymized with *P. australis* (Cresson). New records extend the range of *P. australis* from the east coast to Texas.

Key Words.—Insecta, *Protostelis, Trachusa,* host, distribution, synonymy

The Holarctic genus *Protostelis* Friese, which is represented in North America by species previously placed in *Heterostelis* Timberlake (Griswold & Michener 1988), is an anthidiine group that is known to parasitize *Trachusa* Panzer (Thorp 1966). In the Nearctic, *Protostelis* has been known only from the southern United States. A series of this rarely collected genus was recently obtained in central Mexico, greatly extending its range. These specimens prove to represent a new species that is here described.

Abbreviations.—The description uses T1, T2, etc., and S1, S2, etc., for the apparent dorsal and ventral segments of the metasoma respectively.

PROTOSTELIS PARDITA PARKER & GRISWOLD, NEW SPECIES
(Figs. 1–2)

Types.—Holotype male. MEXICO. *MORELOS:* Cuernavaca, 8 Nov/6 Dec 1987, F. D. Parker. Holotype deposited at the Bee Biology and Systematics Laboratory collection in Logan, Utah. Paratypes: same data as holotype, 1 male, 10 females. Paratypes deposited at Logan and in the collections of The University of Kansas, Lawrence, and the Instituto de Biologia, Universidad Nacional Autonoma de Mexico, Mexico City.

Male.—Length 11 mm. Black except for yellow markings as follows: V-shaped mark on frons adjacent to eye, stripe along anterolateral and lateral margins of scutum, transverse mark on axilla, transverse stripes on T1-5, broadly interrupted on T1, progressively less so on succeeding segments. Wings dusky, especially around veins. Labrum evenly covered with dense, fine punctures; width of eye in lateral view approximately equal to genal width; frons without impunctate area adjacent to eye; ocelli reduced, diameter of median ocellus approximately equal to pedicel width, no greater than distance between it and lateral ocellus. Axilla rounded; scutellum rounded; mesopleuron with anterior face closely punctate, angle between anterior and lateral surface sharply carinate on dorsal half; apical tibial projections on fore-, mid-leg spine-like, subbasal, projections on hind tibia reduced to enlarged carina; hind basitarsus with distinct dorsal groove. Gradular crease on T1-6 deep, hooded more so laterally;

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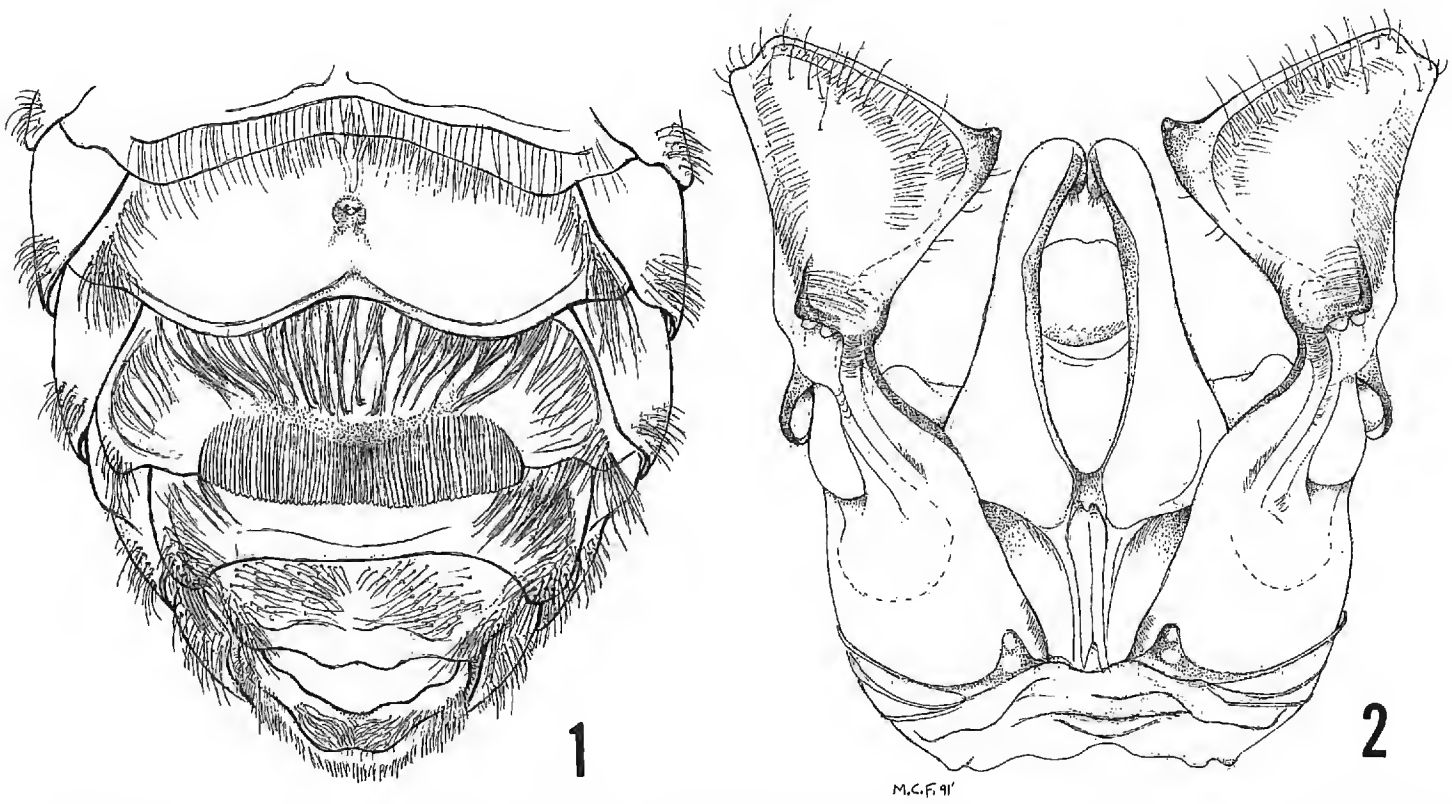

Figures 1–2. *Protostelis pardita.* Figure 1. Male abdomen in ventral view. Figure 2. Male genitalia, dorsal view.

apical margins of T1-5 with hyaline lamellae; pseudomargin of T7 carinate, shallowly emarginate medially (Fig. 1); S1 with high, shallowly emarginate, preapical carina; S2 with low preapical carina; margin broadly, shallowly excised medially; S3 apical fringe long occupying full width of segment; S4 with stout comb extending over apical margin for nearly entire width of sternum, teeth of comb thick, black, area behind comb depressed with patch of stiff setae at base of sternum hidden beneath fringe of S3, tufts of long hair laterad of comb (Fig. 1); S6 with broad U-shaped excision; apical margin of S8 widely, very shallowly emarginate with sparse fringe of long hair; genitalia as in Fig. 2.

Female.—Length 10–12 mm. Markings as in male. Mandible tridentate, middle tooth nearer to lower than upper; clypeus finely punctate; ocelli as in male; thoracic structure as in male; apical tibial projections larger than male (differing from *Stelis* in that they are lop-sided and off-center). T1-5 with posterior one-third finely punctate; T6 with irregular median longitudinal preapical carina faint, not denticulate laterally; apical one-half of S6 flattened in lateral view, apical margin narrowly rounded, almost angulate.

Diagnosis.—The male of *P. pardita* NEW SPECIES is easily distinguished from all other *Protostelis* by the very wide apical comb on S4, which occupies more than two-thirds the width of the segment as opposed to one-third or less in other species. Females run to *P. australis* (Cresson) in Thorp's (1966) key. They are easily separated from *P. australis* by the rounded rather than truncate posterior margin of the scutellum. Further, females have larger ocelli, the preapical carina of T6 is not denticulate laterally, and S6 is narrowly rounded, almost angulate.

Biology.—The presumed host bee, *Trachusa* (*Heteranthidium*) *catinula* Brooks & Griswold, was nesting in a low bank near a creek in the city of Cuernavaca, Mexico. At least 20 nests were found during a five-week period. Females of this host were seen carrying balls of resin and the usual pollen loads into the nest entrances. Females of *Protostelis pardita* were observed entering and leaving these same nest entrances. Males of both genera were found hovering near these same holes. No attempt was made to excavate nests of this *Trachusa.*

Material Examined.—See types.

Protostelis australis (Cresson)

Heterostelis australis floridensis Mitchell 1962, N. Carol. Agr. Exp. Sta. Tech. Bull. 152: 33. NEW SYNONYMY.

Discussion.—As noted by Thorp (1966), *P. a. floridensis* differs from typical *P. australis* only in its markings. Both forms are found in Alachua County, Florida. As such, it seems inappropriate to recognize this color morph. Females from Salmon, Texas greatly extend the range of this species to the west.

Material Examined.—TEXAS. *ANDERSON Co.:* Salmon, 14–22 Jul/22 Jul–2 Aug 1974.

Acknowledgment

We take pleasure in naming *P. pardita* after the Pardita family, who assisted F. Parker in innumerable ways during his stay in Cuernavaca.

We thank Marianne Cha Filbert for producing the illustrations; K. W. Cooper and R. W. Thorp reviewed the manuscript. This is a contribution from Utah Agricultural Experiment Station, Utah State University, Logan, Utah, 84322-4810, Journal Paper Number 4362, and USDA-ARS Bee Biology and Systematics Laboratory, Utah State University, Logan, Utah 84322-5310.

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A NEW SPECIES OF *GRYLLITA* (GRYLLOPTERA: GRYLLIDAE) FROM BAJA CALIFORNIA, MEXICO

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Abstract.—A new species of *Gryllita* Hebard, *G. weissmani* NEW SPECIES, is described from Baja California Sur, Mexico. It is compared with its closest relative, *G. arizonae* Hebard, the type species of the genus.

Key Words.—Insecta, Grylloptera, Gryllidae, *Gryllita weissmani,* Baja California

Randell (1964a) placed the genus *Gryllita* in the subtribe Scobiina of the tribe Gryllinae, based upon the male internal genitalic structures.

The genus *Gryllita* was erected by Hebard (1935) for his new species *G. arizonae* Hebard from Arizona, and for two Mexican species *G. tolteca* (Saussure) from Córdoba and *G. forcipata* (Saussure) from Guerrero. Both *tolteca* and *forcipata* were placed in a new genus *Urogryllus* by Randell (1964a). Hebard (1935) mentioned three more undescribed species from Costa Rica, but these apparently have not been described. Later, Randell (1964b) described three additional species, *G. arndti* Randell, *G. bondi* Randell, and *G. uhleri* Randell, all from Haiti. I have not investigated these species that may or may not belong in *Gryllita.* The species described here from Baja California, Mexico, is more closely related to the type species, *G. arizonae,* but is clearly distinguishable and is widely separated from it, because the new species occurs only in the southern part of Baja California Sur, and *G. arizonae* is not known from the northern part of the peninsula. The specimens studied are part of the collection of orthopteroid insects assembled by D. B. Weissman for the study of this group of insects in Baja California, Mexico.

Depository Abbreviations.—California Academy of Sciences, San Francisco, California (CAS); San Diego Museum of Natural History, San Diego, California (SDM); California State University at Long Beach, Long Beach, California (CSLB); Lyman Entomological Museum, McGill University, Quebec (LEM).

GRYLLITA WEISSMANI NEW SPECIES
(Figs. 1–5)

Types.—*Holotype,* male, deposited in the California Academy of Sciences (CAS Type No. 16822), data: MEXICO. *BAJA CALIFORNIA SUR:* 5 km N of Los Barriles, at "Km 114.8" on highway, 4 Jan 1979, D. B. Weissman, R. E. Love, V. Lee, C. Mullinex, #79-28. *Allotype,* female, same data as holotype. *Paratypes:* MEXICO. *BAJA CALIFORNIA SUR:* ca 14 km E of Mex hwy 9 on road to La Burrera, 1 Jan 1979, D. B. Weissman, R. E. Love, V. Lee, C. Mullinex, #79-19. 4 males, 13 females (CAS) (1 female retained LEM); 19.5 km N of Todos Santos

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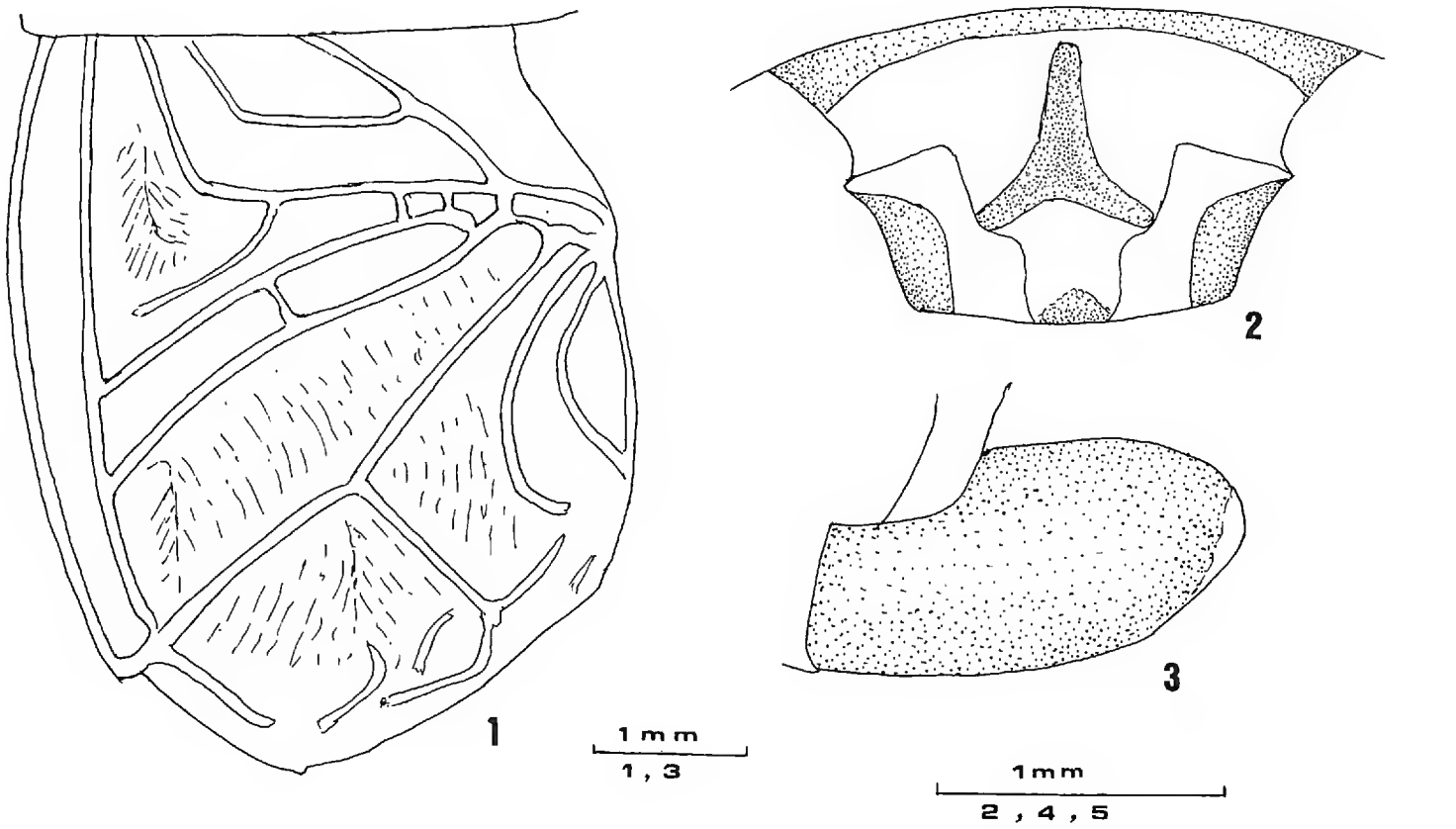

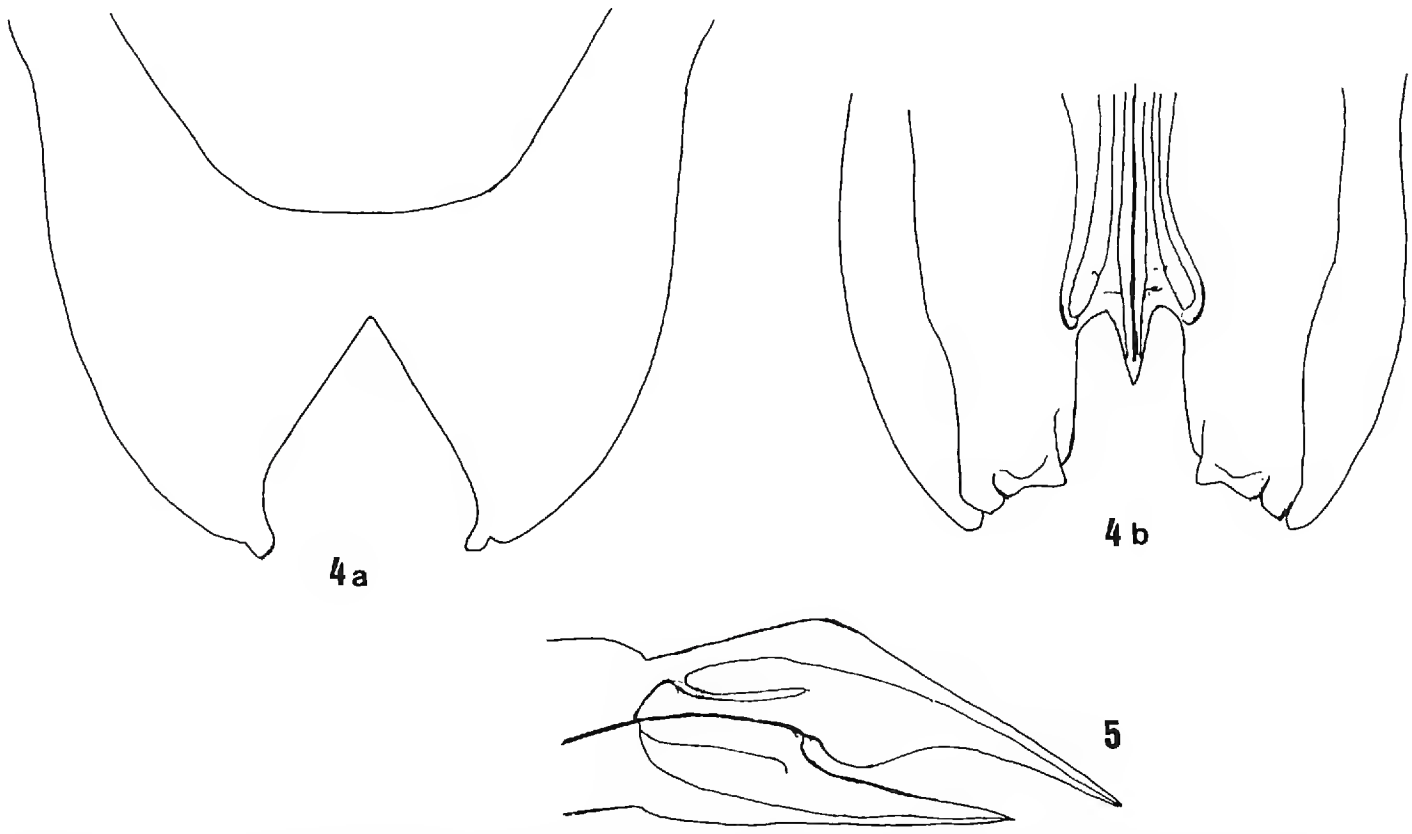

Figures 1–5. *Gryllita weissmani.* Figure 1. Left tegmen of male Paratype. Figure 2. Male supra-anal plate, postero-dorsal aspect, Paratype. Figure 3. Male subgenital plate, lateral aspect, Holotype. Figure 4. Male Genitalia, Paratype: 4a. dorsal view of epiphallus; 4b. ventral view showing ectophallic lobes. Figure 5. Ovipositor of female Paratype; length of illustrated part 1.9 mm.

at km 30 on Mex hwy 9, 1 Jan 1979. D. B. Weissman, R. E. Love, V. Lee, C. Mullinex, #79-18. 1 male, 1 female (CAS); ca 44 km NW of La Paz, at 0.2 km S of "km 44" on Mex hwy 1, 31 Dec 1978. D. B. Weissman, R. E. Love, V. Lee, C. Mullinex, #79-14. 1 female (CAS); 7.8 km N of Cabo San Lucas at "km 7.8" on Mex hwy 1, 2 Jan 1979. D. B. Weissman, R. E. Love, V. Lee, C. Mullinex, #79-23, 4 males, 1 female (CAS) (1 male retained in LEM); first wash on road to

Miraflores off Mex hwy 1, 3 Jan 1979, D. B. Weissman, R. E. Love, V. Lee, C. Mullinex, #79-27. 1 male (CAS); 6.7 km (4.2 mi) W of Miraflores, 30 Sep 1981, F. Andrews, D. Faulkner. 1 male (SDM); 5 km N of Barriles at "km 114.8" on hwy, 4 Jan 1979, D. B. Weissman, R. E. Love, V. Lee, C. Mullinex, #79-28, 1 male, 2 females (CAS); 10 km N of La Paz, 17 Nov 1974, (OR 7) [D.] Otte. 2 males (ANSP); Cabo San Lucas, 17 Sep 1974, (OR 11-12), [D.] Otte. 1 male (ANSP); 1.6 km (1 mi) W of La Burrera, 457 m (1500 ft), 17/18 Oct 1968, E. L. Sleeper, F. J. Moore, 1 male (CSLB); 9.6 km (6 mi) E of San Jose del Cabo, 609 m (2000 ft), 26/27 Oct 1968. E. L. Sleeper, F. J. Moore, 2 males (CSLB); Sta Victoria, 11.2 km (7 mi) W of Santiago, 30/31 Oct 1968, E. L. Sleeper, F. J. Moore, blacklite. 1 male (CSLB); 5.6 km (3.5 mi) SW of San Bartolo, 487 m (1400 ft), 31 Oct 1968, E. L. Sleeper, F. J. Moore, 1 male (CSLB); El Triunfo, 550 m, 22 Nov 1977. E. S. Ross, 2 males (CAS); 4.8 km (3 mi) N of San Antonio, 9/10 Oct 1968, 366 m (1200 ft), E. L. Sleeper, F. J. Moore, 1 female (in alcohol) (CSLB).

Description.—Male (Holotype). *Head:* not swollen, slightly narrower than anterior margin of pronotum; eyes not prominent, frons protruding between antennal sockets; antennae nearly as long as body, tip of right antenna broken; head black except pale ocelli, brown mandibles, pale apical margins of clypeus and labrum; eyes grey, mottled black. *Pronotum:* broader than long, anterior margin concave, posterior margin nearly truncate; median longitudinal sulcus only slightly impressed. *Tegmina:* (Fig. 1) short but longer than broad, dorsal fields flat; 2 oblique veins present; mirror without cross-vein; posterior margin somewhat obscured by reticulation on lateral fields, dark with second longitudinal vein brown; left tegmen removed, in gelatin capsule on pin; wings absent; stridulatory vein (n = 3) 1.85 (1.67–2.19) mm long, curved at extremity, 56 (53–61) file teeth, 30.3 (24.2–36.5) per mm. *Legs:* right middle leg missing; anterior tibiae with 3 apical spurs, mesad spur 2.0 × length of lateral spur, hearing organ on lateral face only; hind tibiae with rows of 6 paired spines plus 2 apical spurs, mesad spines and spurs longer than opposite lateral spurs; hindbasitarsus with paired short ventral spines. *Abdomen:* extends well beyond apices of tegmina, 4 + terga visible; supra-anal plate as in Fig. 2 but much darker basally; subgenital plate deep, elongate, broadly rounded apically, 3 mm long, 1.8 mm deep (Fig. 3). *Genitalia:* similar to *Gryllita arizonae* with bridge of epiphallus narrow (Fig. 4a), emargination of anterior margin broad, of posterior margin deeper, narrower with epiphallic lobes prominent [more than on *G. arizonae* (Randell 1964a: 1590, figs. 24a, 24b, 24c)]; in ventral view, apices of the ectoparameres shallowly divided into 3 lobes, the laterad lobe longer than mesad lobes (Fig. 4b) [opposite of the condition in *G. arizonae*]. *Measurements* (x + range, n = 10): Body length, 15 (13.2–17.2) mm; head width, 3.4 (3.1–3.7) mm; pronotum length, 2.8 (2.5–3.1) mm; pronotum width, 3.9 (3.8–4.2) mm; tegmen length (exposed part *in situ*) 5.7 (5.0–6.4) mm; forefemur length, 3.1 (2.8–3.5) mm; foretibia length, 2.8 (2.4–3.1) mm; hindfemur length, 8.2 (7.3–8.8) mm; hindtibia length, 5.3 (4.8–5.6) mm.

Female (Allotype).—Similar to male but completely apterous. *Head:* antennae longer than body including ovipositor; head and pronotum together broadly rounded anteriorly, head narrower than anterior margin of pronotum; eyes not prominent; color as male, mandibles and genae mahogany brown. *Pronotum:* flat dorsally, generally barrel-shaped in dorsal view; anterior margin broadly concave, posterior margin slightly convex, sides rounded, width of anterior and posterior margins about equal; shining black; median longitudinal sulcus only slightly impressed; apterous; (fore legs glued to card). *Abdomen:* broadening from segment 1 to segment 6, then narrowing to apex, terga 9 and 10 very narrow; terga 3 to 7 with very narrow brown posterior margins; ovipositor straight, directed dorsally, dorsal valves bent abruptly downward to acute apex, ventral valves shorter with acute apices (Fig. 5); subgenital plate small, scoop-shaped. *Legs:* all femora unarmed; foretibia with 3 apical spurs, midtibia with 4 apical spurs, hindtibia with 5 + 5 large ventral spines, mesad spines slightly longer than lateral spines, 4 long and 2 short apical spurs; hind basitarsus with 6 + 6 short, blunt spines and 2 apical spines. *Measurements* (x + range, n = 10): Body length (less ovipositor), 15.1 (12.8–19.0) mm; head width, 3.7 (3.4–4.4) mm; pronotum length, 3.3 (2.6–3.4) mm; pronotum width, 3.9 (3.5–4.9) mm; forefemur length, 3.2 (2.9–3.9) mm; foretibia length, 2.8 (2.6–3.4) mm; hindfemur length, 8.3 (7.4–9.6) mm; hindtibia length, 5.4 (5.4–8.8) mm; ovipositor length, 6.4 (5.4–8.8) mm.

Diagnosis.—*Gryllita weissmani* NEW SPECIES is slightly larger than *G. arizonae,* but the visible part of the tegmen is shorter (5.0–6.4 mm for the former, 7.1–7.7 mm for the latter); legs are shorter in both sexes than the figures given by Hebard (1935). The hindfemur length of *G. arizonae* males ranged from 8.3–9.2 mm, and females from 9.3–9.5 mm, as compared with *G. weissmani* males at 7.3–8.8 mm and females at 7.4–9.6 mm. The pronotum of *G. arizonae* males is 2.7 mm long by 3.8 mm wide, with females 3.3–3.5 mm by 3.8–4.7 mm, both slightly greater than in *G. weissmani.* The ovipositor of *G. weissmani* females averages 6.4 mm, considerably shorter than in *G. arizonae* at 9.0 mm. Comparison of male genitalia of *Gryllita weissmani* with the figures of Randell (1964: figs. 24a, 24b, 24c) reveals that that it belongs in *Gryllita* rather than in *Urogryllus* (Randell 1964: figs. 9a, 9b).

Discussion.—This species has been collected in the adult stage from September to January. It may occur earlier and later. No collections are known to have been made in the region in February. No specimens were found in late April, 1977, and no collections were made in March (D. B. Weissman, personal communication). It occurs only in the extreme southern part of Baja California Sur. The most northerly collection is 44 km northwest of La Paz, and another collection is from 10 km north of La Paz. All other collections are from south of La Paz.

Eytomology.—The species is named for David B. Weissman, the organizer of the project on orthopteroid insects of Baja California, and who also collected many of the specimens.

Material Examined.—See types.

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A NEW SPECIES OF *EBURIA* FROM THE ESTACION DE BIOLOGIA, LOS TUXTLAS, VERACRUZ, MEXICO (COLEOPTERA: CERAMBYCIDAE)

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Abstract.—A new *Eburia* Serville, *Eburia velmae* NEW SPECIES is described from the state of Veracruz, Mexico. The male holotype is illustrated.

Key Words.—Insecta, Coleoptera, Cerambycidae, Cerambycinae, *Eburia,* Mexico

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An undescribed species of *Eburia* was encountered during a recent collecting trip to the Estacion de Biologia, Los Tuxtlas, Veracruz, Mexico. Additional material on loan to J. A. Chemsak, from the Instituto de Biologia, Universidad Nacional Autonoma de Mexico, (UNAM), was examined.

EBURIA VELMAE MCCARTY, NEW SPECIES (Fig. 1)

Type Material.—Holotype, male; from: MEXICO. *VERACRUZ*: Los Tuxtlas, Estacion de Biologia 14 May 1989, at black and white lights (John D. McCarty). Allotype, same data: 12 May 1991 (John D. McCarty). Holotype deposited in the collection of Instituto de Biologia, Universidad Nacional Autonoma de Mexico, Mexico D.F. Seven paratypes, all from the holotype locality: 12 May 1991 (John D. McCarty), 1 female; 24 Apr–1 May 1991 (F. T. Hovore), 2 males and 2 females; 18 Feb 1985 (A. Ibarra), 1 female; 21 Jun 1971 (Figueroa), 1 female. Five additional paratypes: MEXICO. *VERACRUZ*: Playa Escondida, Sierra de Los Tuxtlas, 27 Mar 1976 (E. Barrera), 1 male; Sierra de Los Tuxtlas, 400 m, San Andreas Tuxtla, 27 Mar 1976 (Roberto Terron S.), 1 male; Playa Escondida 28 Mar 1976 (Figueroa), 2 females; May 1981 (Arce R.), 1 female. Allotype and one paratype male deposited in the John D. McCarty collection, other paratypes in collections of Essig Museum (University of California, Berkeley, California), UNAM, F. T. Hovore, and Roberto Terron.

Description.—Adult Male form moderate-sized, parallel; integument dark red-brown, appendages testaceous; genae, mandibles, scape (partially) and tubercles, black; each elytron with 2 pairs of subequal, subcontiguous, eburneous fasciae; pubescence dark yellow with faint green cast, dense, appressed, obscuring surface, long flying hairs numerous. *Head* small; front deeply impressed with triangularly-shaped area at middle; pubescence dense, appressed; punctures fine, dense; median line deep to vertex, ending in slightly elevated, glabrous spot between eyes; antennal tubercles prominent, obtuse; gular region deeply rugose, forming 3 or 4 transverse carinae, punctures deep, pubescence moderate; antennae slender, extending 4.5 segments beyond elytral apices, segments moderately clothed with very short appressed pubescence, segments 1 through 7 with fringe of long erect hairs on underside and few hairs sparsely scattered on dorsal surface; scape short, conical, longitudinally impressed at basal two-thirds, dorsal meso-basal margin fuscous, apically rufous, densely, coarsely, confluently punctate, moderately clothed with short, pale recumbent pubescence, third segment 1.3× length of scape, fourth shorter than third, fifth equal to fourth, remaining segments (5 through 10) subequal to fifth, eleventh longest, slender, appendiculate. *Pronotum* slightly broader than long; sides arcuate with short, acute, black spine at middle; disk densely, irregularly punctate; 2 dorsal tubercles glabrous, black, obtuse; each side with small raised callus near apical margin, and a short, glabrous median longitudinal callus behind middle; pubescence short, dense, appressed, interspersed with long erect hairs that are more

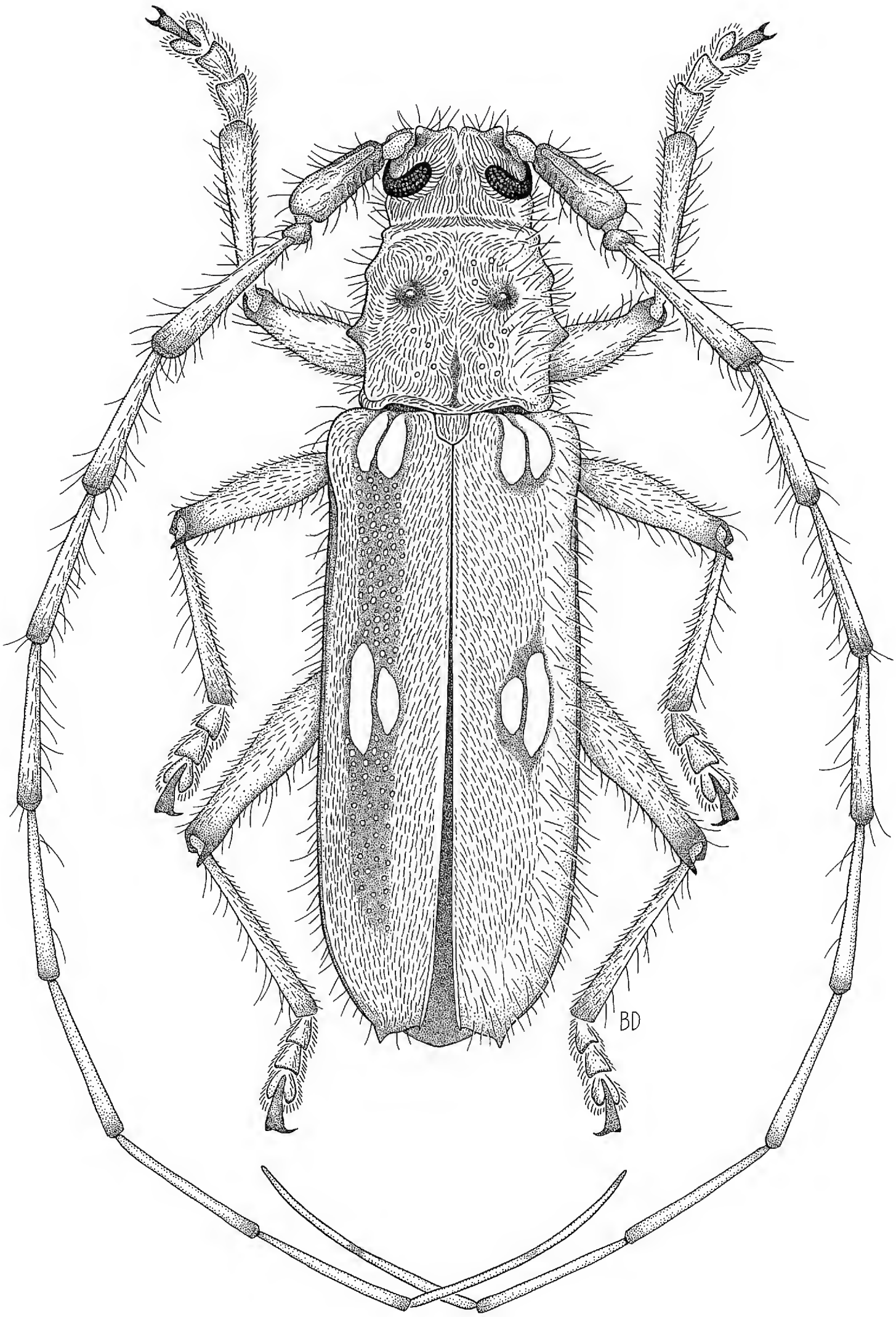

Figure 1. *Eburia velmae.*

numerous on lateral margins; prosternum impressed, deeply punctate, moderately pubescent, long hairs sparse; procoxal process abruptly declivous, meso- and metasterna finely, densely punctate, moderately pubescent, scent glands prominent at apex of metepisternum. Scutellum densely pubescent. *Elytra* 2.25× longer than wide; pubescence short, dense, appressed, long flying hairs numerous; each elytron with 2 pairs of eburneous fasciae, meso-basal pair longer and slightly wider, outside median pair 2.0× as long as inner, area around fasciae narrowly glabrous; vittae between basal and median fasciae moderately pubescent, exposing deep punctures; punctures behind median fasciae smaller and denser towards apices; apices obliquely truncate, bispinose, outer spine acute, 2.0× as long as inner. *Legs* short; middle and hind femora internally spined, inner spines longer than outer spines, subequal to elytral apices. Abdomen minutely, densely punctate, densely clothed with long recumbent pubescence; last sternite truncate at apex. Length 13.5–24.5 mm.

Female. Form similar, slightly more robust than male. Antennae slightly longer than body. Abdomen with last sternite broadly rounded at apex. Length 13–18 mm.

Diagnosis.—This species is apparently unique among known Mexican *Eburia* in its faint green cast to the dense appressed pubescence, as viewed in normal sunlight; in strong artificial light, the pubescence appears to have a gray or yellow cast.

Etymology.—This species is named for my wife, Velma.

Material Examined.—See types.

Acknowledgment

I am pleased to dedicate *Eburia velmae* to my devoted and understanding wife, Velma. I express my sincere appreciation to John A. Chemsak (Essig Museum of Entomology, University of California, Berkeley, California), for providing me with the confidence to write this paper, for offering his suggestions and criticisms and letting me examine additional material on loan from the Instituto de Biologia, Universidad Nacional Autonoma de Mexico. Additionally, I offer special thanks to Barbara Downs for the fine illustration of the adult male holotype; Harry Brailovsky (Instituto de Biologia, UNAM, Departmento de Zoologia, Mexico, D.F.), for providing me access to Estacion de Los Tuxtlas, Veracruz, Mexico, and for the loan of specimens in the collections of the Instituto de Biologia, UNAM, Mexico; Velma M. McCarty for her cooperation in preparing and typing the manuscript.

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Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in *Aedes albopictus*. Evolution, 42: 895–899.

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