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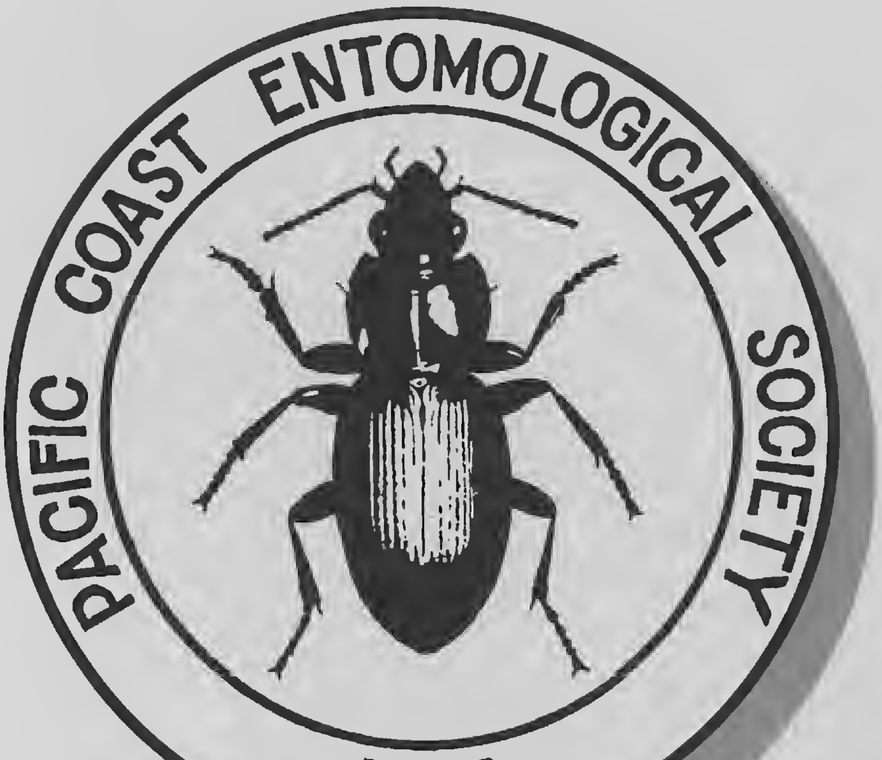

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THE GENUS *NOTOBITOPSIS* BLÖTE WITH THE DESCRIPTION OF TWO NEW SPECIES (HEMIPTERA: HETEROPTERA: COREIDAE: COREINAE: MICTINI)

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Abstract.—Two new species of *Notobitopsis, N. novoguinensis* and *N. sandaracinus,* collected in New Guinea are described and illustrated. New records for *N. limbativentris* and *N. militaris* are given and a key to the five known species is provided.

Key Words.—Insecta, Hemiptera, Heteroptera, Coreidae, Mictini, *Notobitopsis,* new species, New Guinea.

Stål (1863) and Distant (1911a, b) described the three previously known species of *Notobitopsis* and included them in the genus *Mictis: M. aruana* Distant, *M. limbativentris* Stål and *M. militaris* Distant. Blöte (1938) placed *limbativentris* and *militaris* in a new subgenus of *Mictis* (*Notobitopsis*). O'Shea and Schaefer (1980) revised the tribe Mictini in the Asian and Australian region, recognizing nineteen genera, and including *Notobitopsis* which they elevated to generic status and redescribed.

Within the tribe Mictini, the genus *Notobitopsis* is characterized by the lack of a tubercle at the apex of scutellum; the cylindrical fore tibia; pronotum not steeply declivent with humeral angles rounded, not angulate; middle third of posterior margins of abdominal sternites III and IV not produced posteriorly; abdominal sternite III with large tubercle on each side; and posterior margin of abdominal sternite VI without a median tubercle.

This contribution adds two noteworthy records, two new species and a key to the five known species of *Notobitopsis.*

Notobitopsis aruana (Distant)

Mictis aruana Distant 1911b: 389–390.

This is the largest known species of *Notobitopsis* (length over 34 mm) and readily distinguishable by the following combination of characters: antennal segment IV and clavus black, and apical margin of corium yellow to orange yellow.

Distribution.—This species was described from the Aru Islands and is only known from the type specimen.

Material Examined.—1 male; data: Aru Islands. Type deposited in The Natural History Museum, London.

Notobitopsis limbativentris (Stål)
(Figs. 5 and 6)

Mictis limbativentris Stål 1863: 603.

This species is easily identified within the genus by having the clavus and apical margin of corium black, and the paramere tip stout and almost straight (Figs. 5

and 6). In *N. aruana* and *N. militaris* the corial apical margin is yellow to orange yellow, and the clavus orange yellow or black with reddish reflections. *Notobitopsis limbativentris* is much smaller than the two other species with a total body length of less than 30.00 mm.

Distribution.—This species was originally described from Dory, New Guinea (Stål), and subsequently reported from Salawatti, New Guinea (Blöte 1938).

Material Examined.—1 female; data: NE New Guinea. Adelbert Mts., Wanuma, 800–1000 m, 23 October 1958, J. L. Gressitt. Deposited in Bernice P. Bishop Museum, Honolulu, Hawaii. 12 males, 11 females; data: Indonesia Irian Jaya. Baliem Valley nr., Jiwika, 5800–6000′, 24 October 1990, P. J. Clausen. Deposited in University of Minnesota, Insect Collection.

NOTOBITOPSIS MILITARIS (Distant)
(Figs. 7 and 8)

Mictis militaris Distant 1911a: 595–596.

This species is similar to *N. aruana* (Distant) but slightly smaller, less than 33.00 mm, with clavus orange yellow to dull sanguineous. *Notobitopsis aruana* is longer than 34.00 mm, with clavus black.

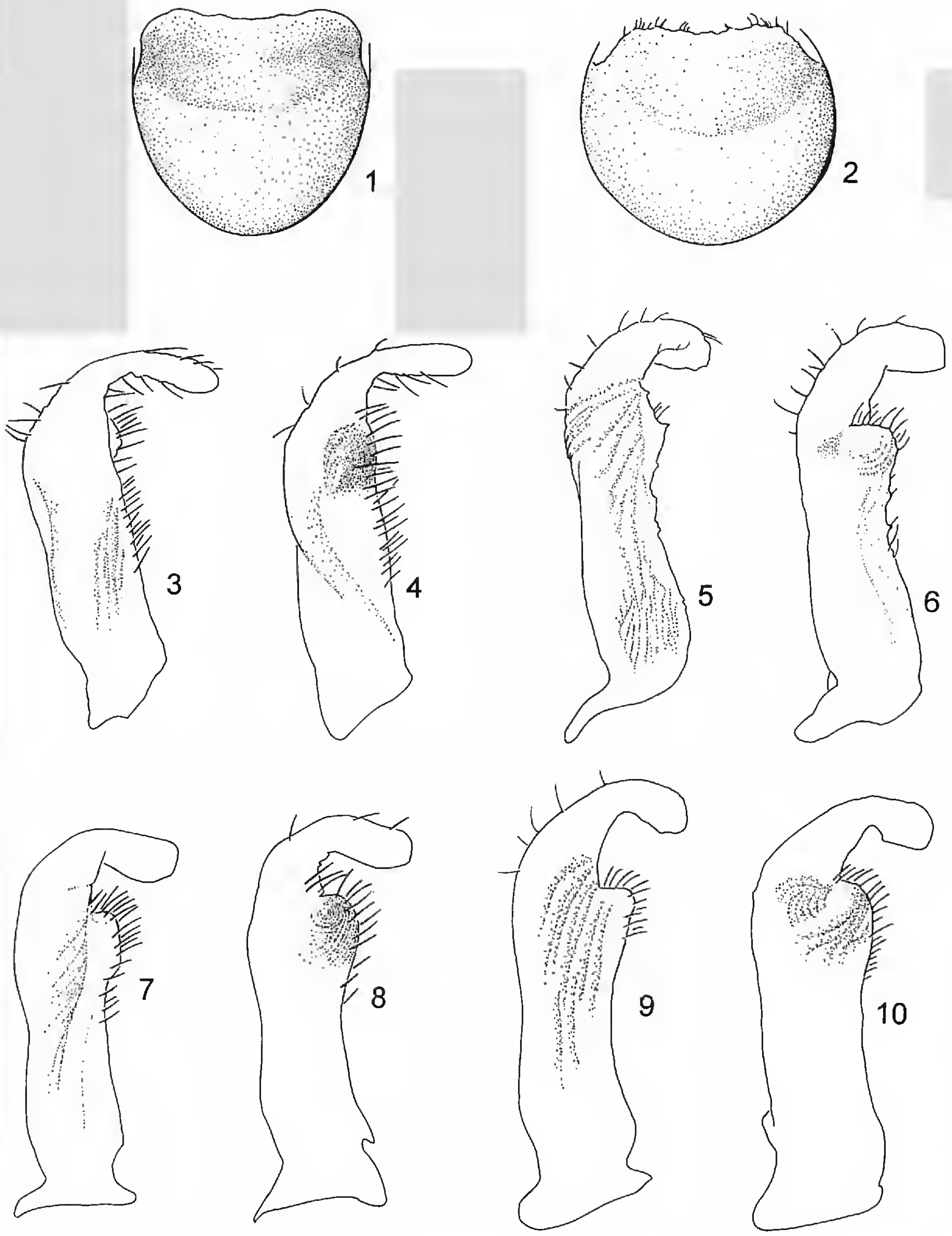
Distribution.—This species previously was known from Wataikwa River and Hollandia in New Guinea (Distant 1911a, Blöte 1938).

Material Examined.—1 female; data: New Guinea. Saidor Apo 321, March–May 1944, O. H. Graham. Deposited in Bernice P. Bishop Museum, Honolulu, Hawaii. 1 male, 2 females; data: NE New Guinea. Kar Kar Is., Kurum Bagiai Crater trail, 0–100 m, August 1968, N. L. H. Krauss. Deposited Instituto de Biología, UNAM, México.

NOTOBITOPSIS NOVOGUINENSIS BRAILOVSKY AND BARRERA, NEW SPECIES
(Figs. 1, 3 and 4, 11)

Types.—Holotype: male; data: Papua New Guinea. Eastern Highlands, Ubagubi, 20 mi S Goroka, 6°22′ S, 145°11′ E, June 1986, G. Dodge. Deposited in Cornell University, Insect Collection, Ithaca, New York. Paratype: 1 male: same data as holotype. Deposited in the Colección Entomológica del Instituto de Biologia, UNAM, México.

Description.—Male (holotype). Dorsal coloration: Head, antennal segments I–IV, pronotum, scutellum, and abdominal segments black; head below each postocular tubercle with small yellow discoidal spot; clavus shiny reddish dark; corium shiny reddish dark, with costal margin black; hemelytral membrane shining metallic blue; connexival segments III–VI and anterior half of VII shiny orange; posterior half of connexival segment VII black. *Ventral coloration.* Ground color including rostral segments and legs black; propleura, mesopleura, and metapleura with large carmine-red spot, one on each segment; anterior and posterior lobe of metathoracic peritreme yellow; pleural margin of abdominal sterna III–VII orange, with spiracles black. *Structure.* Head: Rostrum reaching posterior margin of mesosternum. Pronotum: Lateral margins finely dentate; humeral angles slightly produced. Legs: Fore and middle femora with two distinct spines near apex; hind femur longer, incrassate, slightly curved, attenuated at base, densely granulate, without apical spine; fore and middle tibiae sulcate, cylindrical; hind tibia sulcate, moderately dilated ventrally, with strong spine at inner face before apex. Abdomen: Abdominal sternite III with small tubercle on each side. *Genitalia* (Figs. 1, 3 and 4).—Genital capsule (Fig. 1): Posteroventral edge thickest, scarcely cordiform; body without tubercles. Parameres (Figs. 3 and 4): Stout, with elongate and almost straight tip. *Measurements.* Total body length: 26.90 mm. Head length: 2.04 mm; width across eyes: 2.66 mm; interocular space: 1.36 mm; interocellar space: 0.68 mm. Antennal segments length: I, 5.70 mm, II, 5.16 mm, III, 4.18 mm, IV, 4.18 mm. Pronotal length: 5.47 mm; width across frontal angles: 2.43 mm; width across humeral angles: 7.52 mm. Scutellar length: 3.11 mm; width: 2.96 mm.



Figures 1 and 2. Male genital capsule of *Notobitopsis* spp. Figure 1. *N. novoguinensis* Brailovsky and Barrera, NEW SPECIES. Figure 2. *N. sandaracinus* Brailovsky and Barrera, NEW SPECIES. Figures 3–10. Parameres of *Notobitopsis* spp. Figures 3 and 4. *N. novoguinensis* Brailovsky and Barrera, NEW SPECIES. Figures 5 and 6. *N. limbativentris* (Stål). Figures 7 and 8. *N. militaris* (Distant). Figures 9 and 10. *N. sandaracinus* Brailovsky and Barrera, NEW SPECIES.

Female.—Unknown.

Discussion.—This handsome species is readily separable by having the clavus and corium shiny reddish dark, and the hemelytral membrane metallic blue. The other known species have black or orange yellow clavus, the corium black, and the hemelytral membrane shiny dark olivaceous or black. The parameres are distinct (Figs. 3–10).

Distribution.—Only known from New Guinea.

Etymology.—Named for its occurrence in New Guinea.

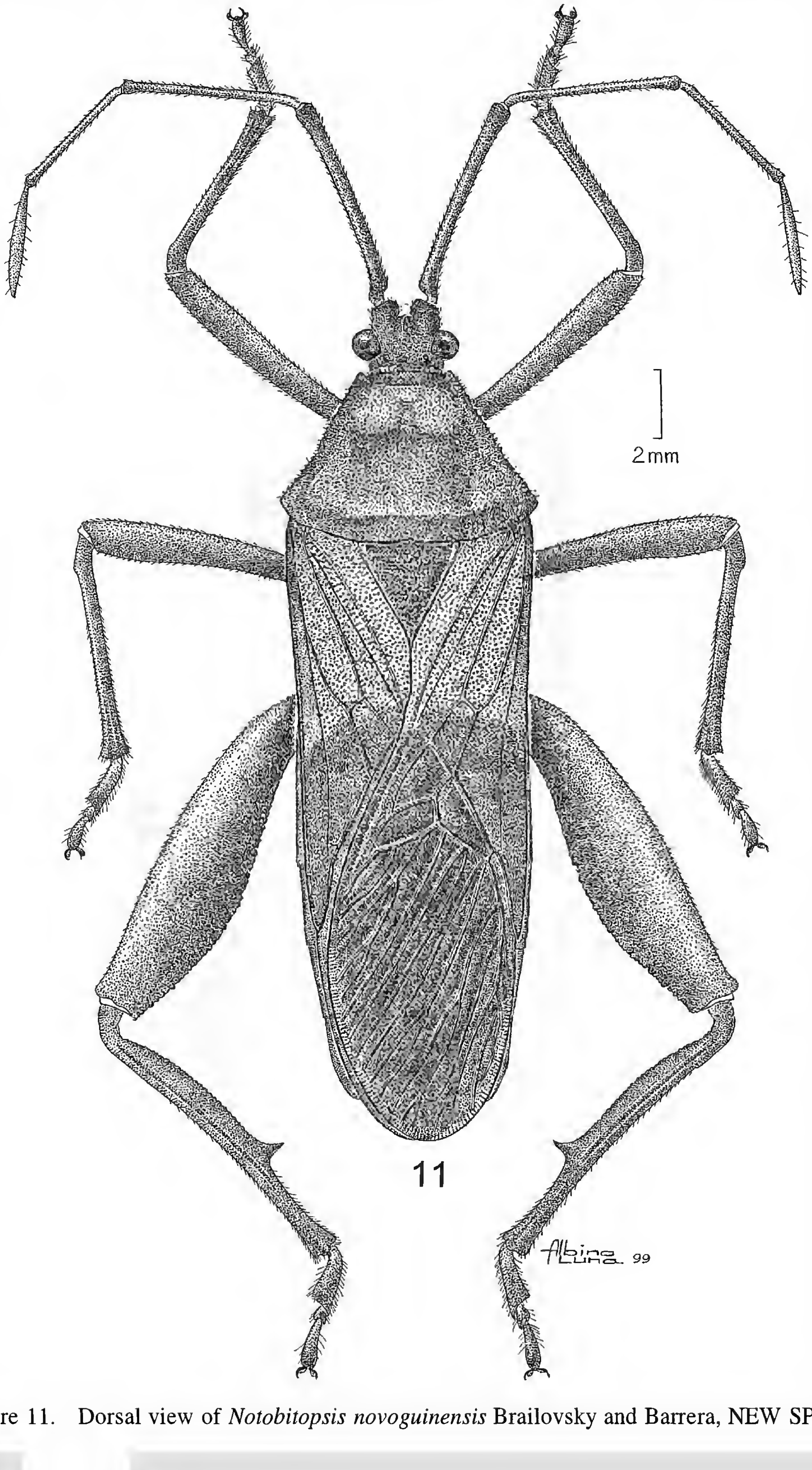


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Figure 11. Dorsal view of *Notobitopsis novoguinensis* Brailovsky and Barrera, NEW SPECIES.

NOTOBITOPSIS SANDARACINUS BRAILOVSKY AND BARRERA, NEW SPECIES
(Figs. 2, 9 and 10, 12)

Types.—Holotype: male; data: New Guinea. Finschhafen, 16–21 April 1944, E. S. Ross. Deposited in California Academy of Sciences, San Francisco, California (CAS). Paratypes: 9 males, 9 females; data: same locality and date as holotype. Deposited in California Academy of Sciences, San Francisco California and Colección Entomológica del Instituto de Biología, UNAM, México.

Description.—Male (holotype). Dorsal coloration: Head black; antennal segments I–III black reddish brown, IV shiny orange with basal joint black; pronotum chestnut orange with anterior margin, lateral margins, and humeral angles black, and lateral border orange; scutellum chestnut orange with apex orange; clavus chestnut orange; corium chestnut orange with costal margin black, and costal border yellow; hemelytral membrane dark shining olivaceous, with blue, green and pink metalic iridiscence; connexival segments dark chestnut orange with upper margin densely granulate with black; dorsal abdominal segments dark chestnut orange. *Ventral coloration.* Head and bucculae shiny orange with the space close to eyes black; rostral segments I–IV black with chestnut orange reflections; prosternum, mesosternum, and metasternum chestnut orange; propleura, mesopleura, and metapleura with large and wide carmine-red spots, one on each segment; upper margin of propleura and mesopleura black, and upper margin of metapleura reddish orange; acetabulae reddish brown to shiny orange; anterior and posterior lobe of metathoracic peritreme shiny orange; coxae with inner face chestnut orange and outer face reddish brown; trochanters reddish brown; femora chestnut orange with apical joint black; fore and middle tibiae dark reddish brown, with chestnut orange reflections; hind tibia chestnut orange with subapical spine and apical third reddish brown; tarsi reddish brown; abdominal sterna dark chestnut orange with spiracles, apex of the tubercle of abdominal sternite III, and posterior margin of abdominal sternite VII black; pleural margin of abdominal sterna III–VII dirty yellow; genital capsule black. *Structure.* Head: Rostrum reaching posterior margin of mesosternum. Pronotum: Lateral margins densely crenulate; humeral angles obtuse, not exposed. Legs: Similar to *N. novoguinensis.* Abdomen: Abdominal sternite III with large and prominent tubercle on each side; upper margin of connexival segments densely granulate. *Genitalia* (Figs. 2, 9 and 10).—Genital capsule (Fig. 2): Posteroventral edge thickest, simple, with small tubercles close to middle third and sinuate. Parameres (Figs. 9 and 10): Stout with broad curved tip. *Measurements.* Total body length: 30.80 mm. Head length: 2.26 mm; width across eyes: 2.96 mm; interocular space: 1.52 mm; interocellar space: 0.82 mm. Antennal segments length: I, 6.30 mm, II, 5.92 mm, III, 4.71 mm, IV, 4.86 mm. Pronotal length: 6.08 mm; width across frontal angles: 2.66 mm; width across humeral angles: 7.82 mm. Scutellar length: 3.42 mm; width: 3.02 mm.

Female.—Coloration: Similar to male. Connexival segments VIII and IX dark chestnut orange; dorsal abdominal segments VIII and IX, and genital plates black. *Structure.* Legs: Hind femur slightly incrassate, granulate with distinct spine near apex; hind tibia sulcate, moderately dilated, unarmed. *Measurements.* Total body length: 31.30 mm. Head length: 2.35 mm; width across eyes: 2.99 mm; interocular space: 1.53 mm; interocellar space: 0.91 mm. Antennal segments length: I, 6.46 mm, II, 5.39 mm, III, 4.25 mm, IV, 4.94 mm. Pronotal length: 6.46 mm; width across frontal angles: 2.87 mm; width across humeral angles: 8.05 mm. Scutellar length: 3.64 mm; width: 3.19 mm.

Discussion.—Antennal segment IV of *N. sandaracinus,* is shiny orange with basal joint black, and general color of body chestnut orange. In other species, antennal segment IV is always black, and the general color of the body black or black with yellow stripes. Additionally, the shape of the parameres of *N. sandaracinus, N. limbativentris* (Stål), and *N. militaris* (Distant) are distinct (Figs. 5–10).

Distribution.—Only known from New Guinea.

Etymology.—From the greek *sandaracinos,* orange colored.

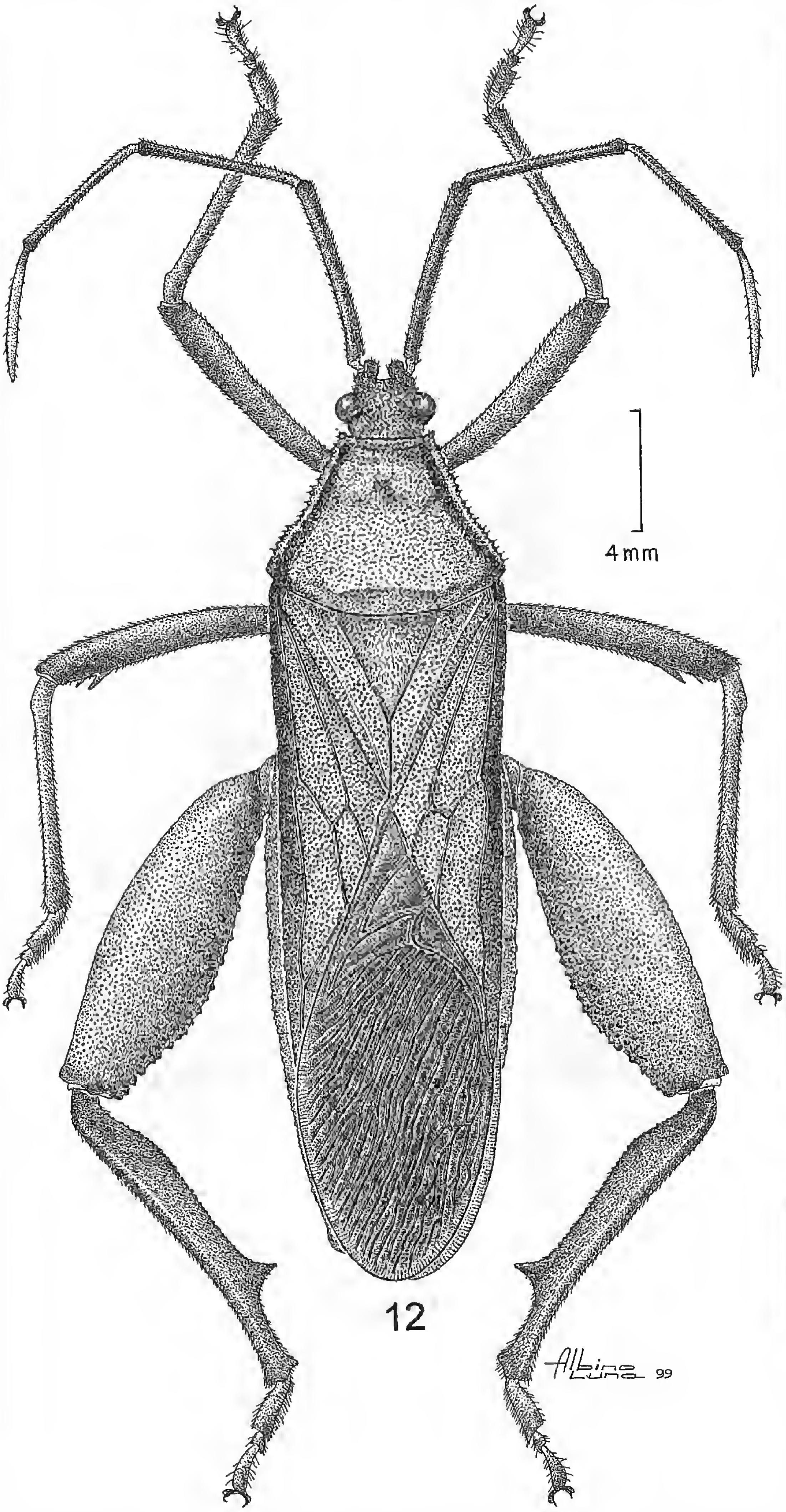

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Figure 12. Dorsal view of *Notobitopsis sandaracinus* Brailovsky and Barrera, NEW SPECIES.

KEY TO SPECIES OF THE GENUS *NOTOBITOPSIS*

1. Antennal segment IV shiny orange; scutellum chestnut orange; fore and middle femora chestnut orange .... *N. sandaracinus* Brailovsky and Barrera, NEW SPECIES

1′. Antennal segment IV black; scutellum black; fore and middle femora black 2

2. Clavus shiny reddish dark; corium shiny reddish dark with costal margin black; hemelytral membrane shining metallic blue .... *N. novoguinensis* Brailovsky and Barrera, NEW SPECIES

2′. Clavus black or orange yellow; corium almost entirely black; hemelytral membrane dark shining olivaceous or black 3

3. Apical margin of corium black; body length less than 30.00 mm. .... *N. limbativentris* (Stål)

3′. Apical margin of corium yellow to orange yellow; body length longer than 30.00 mm 4

4. Clavus orange yellow; body length less than 32.00 mm .... *N. militaris* (Distant)

4′. Clavus black with reddish reflections; body length longer than 34.00 mm. .... *N. aruana* (Distant)

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LITERATURE CITED

Blöte, H. C. 1938. Catalogue of the Coreidae in the Rijksmuseum van Natuurlijke Historie Part IV. Coreinae, Third Part. Zool. Meded., 20: 275–508.

Distant, W. L. 1911a. An Enumeration of the Rhynchota collected during the Expedition of the British Ornithologists Union to Central Dutch New Guinea. Trans. Ent. Soc. London, 3: 591–604.

Distant, W. L. 1911b. Rhynchota from the Aru Islands. Ann. Mag. Nat. Hist. (Series 8), 8: 389–390.

O'Shea, R. & C. W. Schaefer. 1980. A generic revision of the Asian and Australian Mictini (Heteroptera: Coreidae). Oriental Insects, 14: 221–251.

Stål, C. 1863. Hemipterorum exoticorum generum et specierum nonnullarum novarum descriptiones. Trans. Ent. Soc. London, 1: 571–603.

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THREE NEW SPECIES OF *HELICOPSYCHE* FROM VIETNAM (TRICHOPTERA: HELICOPSYCHIDAE)

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Abstract.—Three new species of *Helicopsyche* are described from Vietnam: *Helicopsyche khemoiensis* NEW SPECIES, *Helicopsyche azunensis* NEW SPECIES and *Helicopsyche dacklestensis* NEW SPECIES. *Helicopsyche khemoiensis* is most closely related to *H. coreana* Mey, the two species comprising the subgenus *Galeopsyche*. *Helicopsyche khemoiensis* is distinguished from *H. coreana* by the shape of the gonocoxite and armature of tergite X. Immature stages of *H. khemoiensis* are described. *Helicopsyche azunensis* and *H. dacklestensis*, subgenus *Helicopsyche*, are most closely related to *Helicopsyche chrysothoe* (Schmid), *H. xenothoe* (Schmid) and other species characterized by four-segmented maxillary palps, absence of mesoscutal warts and distally hooked gonocoxal secondary branch. *Helicopsyche azunensis* and *H. dacklestensis* are distinguished from other species in that group by the presence on the phallus of large endothecal sclerites.

Key Words.—Insecta, Trichoptera, Helicopsychidae, *Helicopsyche*, Vietnam, NEW SPECIES.

Biologists from the Centre for Biodiversity and Conservation Biology at the Royal Ontario Museum, Toronto, are collecting insects, reptiles and amphibians, and small mammals from the forests of Vietnam in an effort to determine the diversity and uniqueness of their faunas. Deforestation is proceeding rapidly and environmentalists are racing to find areas of high endemicity which should be protected from further degradation. Collections brought back to the Museum for identification have yielded a number of species unknown to science. Terrestrial and aquatic insect collections, including Trichoptera, are particularly rich in undescribed species. This paper describes three new species of *Helicopsyche* (Trichoptera) from streams in Vietnam.

Originally described as a pulmonate snail (Say 1821), the larva of the caddisfly *Helicopsyche* builds a dextrally coiled sand grain case within which it grazes periphyton from rock surfaces. The case which bears an uncanny resemblance to that of a snail provides protection from predators and its shape enhances the larva's ability to maintain position in the current of a freshwater lotic habitat; its sturdy construction resists crushing, and permits the larva to burrow deeply into the substrate (Williams et al. 1983).

The family Helicopsychidae occurs in all faunal regions and is most diverse in the Oriental and Neotropical regions. Of the nearly 180 species which have been described approximately 150 are in the genus *Helicopsyche*. Only two species of *Helicopsyche*, *H. coreana* Mey from North Korea and *Helicopsyche azwudschgal* Malicky from northern Vietnam were previously known as adults from the East Asian Subregion (sensu Banarescu 1992) (central and northern Vietnam, China, Korea, the Japanese archipelago, Sakhalin Island, Taiwan, Hainan); *Helicopsyche yamadai* Iwata from Japan was described from larval material and undescribed larvae of the family were also reported from Hong Kong (Dudgeon 1988). The three species described in this paper, *Helicopsyche khemoiensis* Schefter & Johanson NEW SPECIES, *Helicopsyche azunensis* Schefter & Johanson NEW SPECIES and *Helicopsyche dacklestensis* Schefter & Johanson NEW SPECIES substantially increase the known helicopsychid fauna of the subregion. The neighboring South Asian Subregion (sensu Banarescu 1992) (southwestern Vietnam, Thailand, Malaysia, Laos, Myanmar, the Indonesian archipelago, southern India and Sri Lanka) harbours approximately 50 species of *Helicopsyche,* sensu lato (Malicky & Chantaramongkol 1993; Schmid 1993; Malicky 1994, 1995; Johanson 1998).

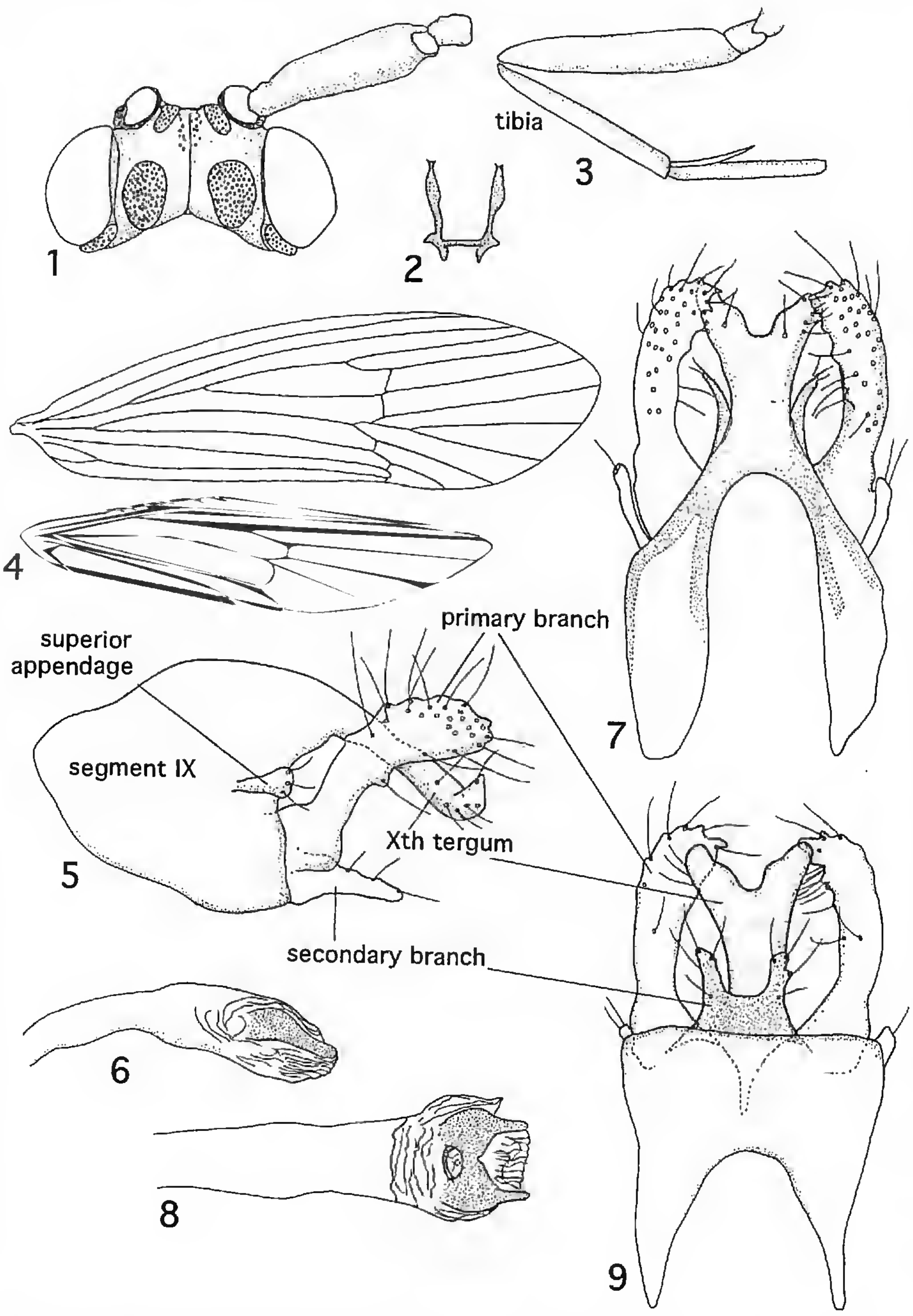
Morphological terms used in this paper are adopted from Johanson (1998). Types are deposited in the Royal Ontario Museum, Toronto, Canada.

HELICOPSYCHE KHEMOIENSIS SCHEFTER AND JOHANSON, NEW SPECIES
(Figs. 1–26)

Types.—Holotype, male; VIETNAM. *NGHE AN*: West of Con Cuong, Khe Moi Forestry Camp, 28 Oct 1994, D. C. Currie, ROM946112, coal oil lantern, tropical forest, Khe Moi River margin. Paratype: female, same data as holotype. Paratypes, immatures: VIETNAM. *NGHE AN*: ca. 25 km SW of Con Cuong, Khe Moi River Forestry Camp, 6 June 1995, Brad Hubley, ROM956170, small stream 100 m upriver of camp, tropical forest edge, 18°56′N, 104°49′E (2 pupae, 2 larvae).

Description.—Male. Head (Fig. 1): postantennal warts small, ovoid; cephalic warts large, ovoid; eyes large, diameter equal to length of head (Fig. 1); antenna with scape swollen, four and one half times length of pedicel; pedicel and first flagellomere subequal, subsequent four segments graduated in length, remainder equal to fifth; tentorium (Fig. 2) with anterior arms subparallel, distally slightly expanded, short posterior arms and broad tentorial bridge; maxillary palps with segments 1 and 2 subequal, apical segment with long setae dorsally. Pronotum with one pair of setal warts. Legs: spur formula 1,2,4, apical tibial spur of anterior leg slightly longer than one half length of first tarsal segment (Fig. 3). Wings (Fig. 4): fore wing length 4.6 mm, forks 1,2 and 3 present; fork 1 originates on distal one third of Dc; R_2 subequal to Dc; A_1 and A_2 fused basally, A_{1+2} fused with Cu_2 without reaching posterior wing margin; hind wing 3.7 mm, with 16 hamuli. Abdomen with small, pointed VIth sternal process. Genitalia: segment IX, lateral view (Fig. 5), anteriorly nearly oval, with weakly developed apodemes; dorsally reduced to a sclerous transverse bridge (Fig. 7); in ventral view broad and deep (Fig. 9); gonocoxite divided into large primary and short secondary branch; in lateral view (Fig. 5) primary branch slender, arcuate; dorsal and ventral margins subparallel; secondary branches fused ventromesally forming shelf-like star shaped plate (Fig. 9); superior appendage inserted mesally, directed posteriad, clavate in lateral view (Fig. 5); Xth tergum depressed in lateral aspect, apices hooked dorsally; in dorsal view (Fig. 7) apices divergent, separated by V-shaped notch approximately one fourth length of segment, with short lobate lightly sclerous lateral processes inserted near base of tergum; macrosetae absent. Phallus slightly arcuate (Fig. 6), apically expanded, with bifurcate sclerous process inserted dorsally in endotheca (Figs. 6 and 8).

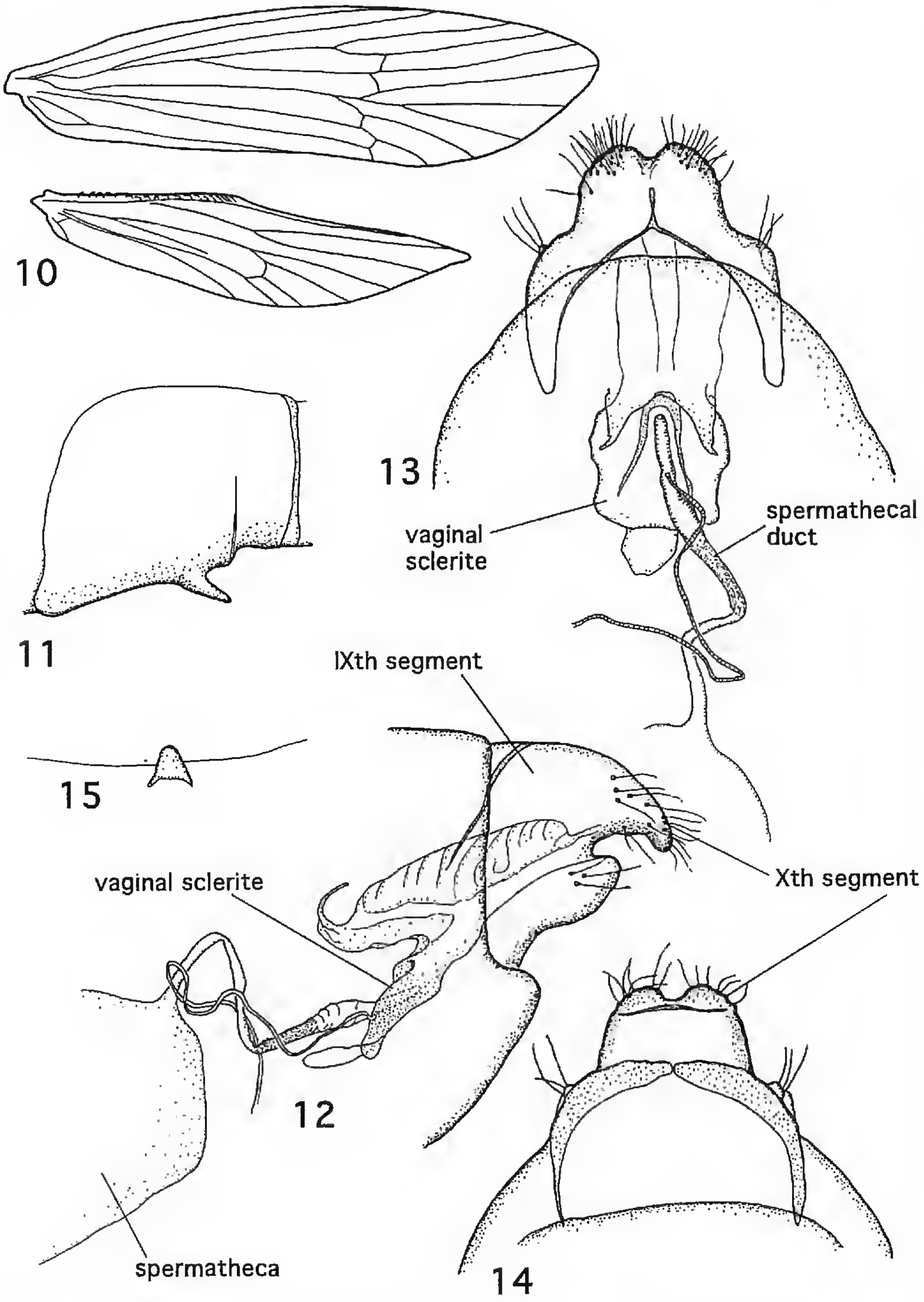
Female.—Head: eyes smaller than in male; cephalic warts small, round; antenna with scape not swollen, four and one half times length of pedicel, pecidel shorter than first and subsequent flagellomeres. Spur formula 1,2,4; apical tibial spur of foreleg one third length of first tarsal segment. Wings (Fig. 10): fore wing length 5.6 mm; venation as in male, except Dc longer than M_2; A_{1+2} reaches posterior wing margin at some distance before Cu_2; hind wing length 3.7 mm, with 19 hamuli; venation as in male, apex more acuminate than in male. Abdomen with short VIth sternal process, rounded in ventral view (Figs. 11 and 15). Sternite VIII with row of stiff, clear setae on apical margin. Genitalia: in lateral view (Fig. 12) segment IX with small group of ventrolateral setae, deep incision between the IXth and Xth segments includes the posterior vaginal opening; Xth segment with setae arranged along dorsal margin of dorsal branch; dorsal branches broad and slightly curved ventrad; in ventral view (Fig. 14) ventral branch of segment X very small, external part of gonopods IX narrow, arcuate;



Figures 1–9. *Helicopsyche khemoiensis* (male).
Figure 1. Head, dorsal view.
Figure 2. Tentorium, dorsal view.
Figure 3. Fore leg.
Figure 4. Wings.
Figure 5. Genitalia, lateral view.
Figure 6. Phallus, lateral view.
Figure 7. Genitalia, dorsal view.
Figure 8. Phallus, dorsal view.
Figure 9. Genitalia, ventral view.

spermathecal sclerite subquadrate; spermathecal duct with anterad-oriented microtrichia at midsection (Figs. 12 and 13).

Larva.—Head (Figs. 16–18): light tan with six darker spots on lateral surface, three or four minute setae posterolaterally (Figs. 16 and 17, setae 19,20,21); dorsally with dark spots scattered on surface, and postocular spot with several long setae (setae 13–16); frontoclypeus with characteristically shaped dark figure on posterior surface; ventrally unicolorous with pair of dark spots near postoccipital margin (Fig. 18). Thorax (Fig. 19): pronotum with anterior margin bearing large sharp spine-like setae; dorsally with scattered setae each surrounded by a dark spot; propleuron forming right angle, tipped by stout seta (Fig. 20). Legs: foreleg (Fig. 20) with long setae laterally on coxa, long ventral setae on trochanter and femur; mid leg (Fig. 21) and hind leg (Fig. 22) with thin setae laterally on coxa and

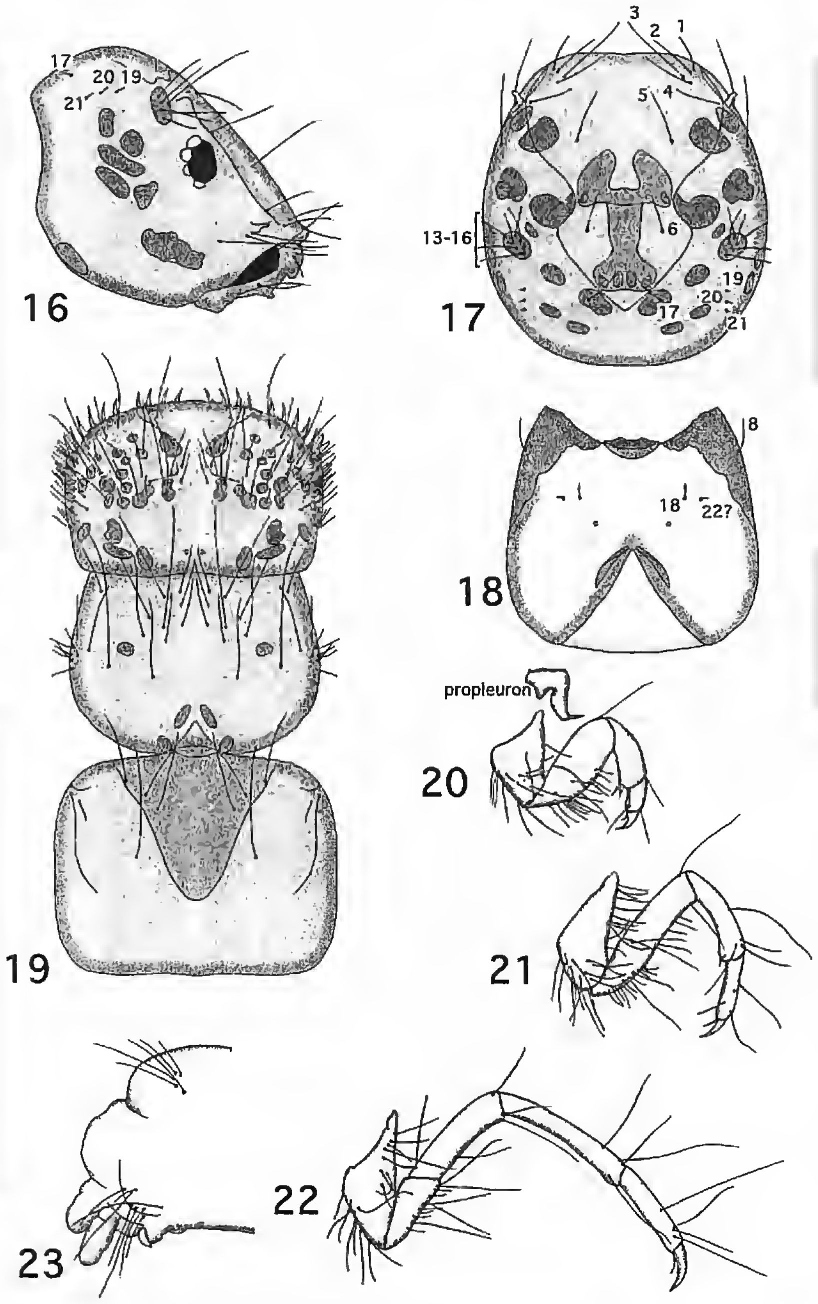


Figures 10–15. *Helicopsyche khemoiensis* (female).
Figure 10. Wings.
Figure 11. VIth sternal process of abdomen, lateral view.
Figure 12. Genitalia, lateral view.
Figure 13. Genitalia, dorsal view.
Figure 14. Genitalia, ventral view.
Figure 15. VIth sternal process of abdomen, ventral view.

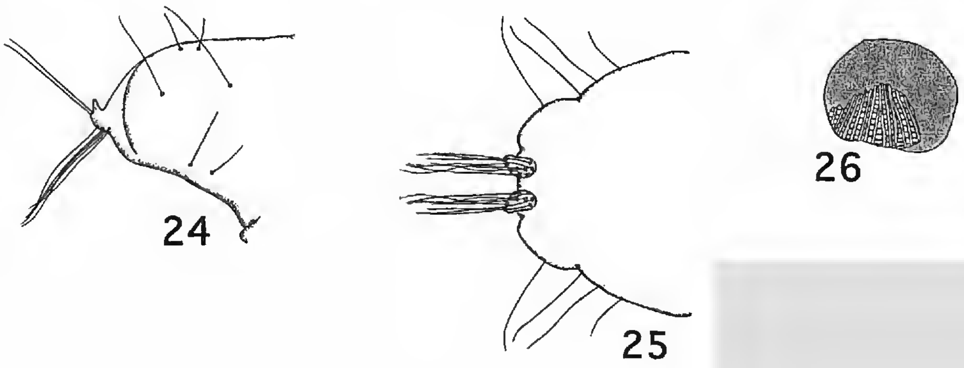
ventrally on trochanter. Abdomen (Fig. 23) with small group of setae dorsolaterally on segment IX; long setae dorsad of anal prolegs on segment X; abdominal gills absent; anal gills form pair of expanded lobes; anal claw minute with many teeth. The larval case is similar to that illustrated by Wiggins (1996a).

Pupal case: anterior enclosure (Fig. 26) of densely woven silk for 75% of surface; the inner, ventral quadrant with several open bands bearing transverse strands of silk. Pupa: pupal mandibles and hook-plates as illustrated by Wiggins (1996b, fig. 17–87). Segment IX with long setae; two pairs dorsolateral, two pairs lateral and two pairs ventrolateral; anal appendages, lateral view (Fig. 24) short, angled dorsad, with two pairs long setae posteriorly and six pairs ventrally; in ventral view (Fig. 25) oriented posteriad; the ventral setae in two longitudinal rows.

Diagnosis.—Males of *H. khemoiensis* can be separated from closely related *H. coreana* by the star-shaped gonocoxal plate formed by the fused secondary



Figures 16–23. *Helicopsyche khemoiensis* (larva).
Figure 16. Head, lateral view.
Figure 17. Head, dorsal view.
Figure 18. Head, ventral view.
Figure 19. Thorax, dorsal view.
Figure 20. Propleuron and fore leg, anterior view.
Figure 21. Mid leg, anterior view.
Figure 22. Hind leg, anterior view.
Figure 23. Abdominal segments IX and X, lateral view.



Figures 24–26. *Helicopsyche khemoiensis* (pupa).
Figure 24. Segment IX and anal appendages, lateral view.
Figure 25. Segment IX and anal appendages, ventral view.
Figure 26. Pupal case membrane.

branches of the gonocoxite; by the Xth tergum which lacks megasetae, is shallowly bifurcate and divergent apically, hooked dorsally and which bears short baso-lateral processes. Females are recognized by the acuminate hind wing, the short rounded VIth sternal process and by the large dorsal process of the Xth segment which curves ventrad concealing the small ventral branch.

Etymology.—*khemoiensis,* refers to river from which species was collected.

Material examined.—see Types.

HELICOPSYCHE AZUNENSIS SCHEFTER AND JOHANSON, NEW SPECIES
(FIGS. 27–33)

Types.—Holotype, male: VIETNAM. *GIA LAI*: An Khe Dist; Tram Lap, Azun R., 2 km NW on trail from forestry building, 17 Jun 1996, D.C. Currie, J. Swann, ROM 961056, UV light, at rainforest edge/coffee plantation, 14°27′ N, 108°33′ E.

Description.—Male. Head (Fig. 27): antennae with lobate scape about 2× length of pedicel, 1st flagellomere as long as pedicel; eyes very large; interantennal warts as long as scape breadth, spherical; cephalic warts large, ovoid, laterad of elevated, triangular vertex; maxillary palps 4-segmented, the basal two segments together longer than labial palp. Legs: spur formula 1,2,4; fore leg spur longer than first tarsal segment. Pronotum with 2 pairs setal warts. Wings (Fig. 28): fore wing length 3.0 mm; forks 1,2,3 and 5 present; fork 1 originating on distal one third of Dc, R_2 subequal to Dc, A_1 and A_2 form basal loop, A_{1+2} reaches wing margin close to Cu_2: hind wing 2.3 mm, with 14 hamuli. Abdomen with small VIth sternal process. Genitalia: segment IX in lateral view (Fig. 29) subtriangular, with well developed lateral apodeme; narrow ventrally (Fig. 31); anterior margin ogival in dorsal view (Fig. 30); gonocoxite with large primary and small secondary branch; primary branch in lateral view (Fig. 29) with dorsal margin gently concave, apically hatchet-shaped; secondary branch slender, arcuate with slight apical hook (Fig. 31); superior appendage originating dorsally on segment nine, directed ventrad, clavate in lateral view; Xth tergum depressed in lateral view, in dorsal view (Fig. 30) bifurcate for one half length, divided into two tapering processes; macrosetae absent. Phallus thick, slightly curved ventrad (Fig. 32), dorsoapical membranous part of endotheca bifurcate, lobate, with a pair of slender sigmoid processes each with a small lateral tooth (Figs. 32 and 33).

Female and immature stages.—Unknown.

Diagnosis.—Helicopsyche azunensis is most closely related to *H. chrysothoe* (Schmid) and can be separated from it and other species with 4-segmented maxillary palps by the following characters: gonocoxite lacking an internal branch (present in *H. chrysothoe*); with hatchet-shaped primary branch longer than the tapered slightly notched secondary branch (in most other species of this group the secondary branch is strongly notched); lobate Xth tergum lacking macrosetae or notches (in other species the Xth tergum is acuminate and frequently notched apically); and phallus with a pair of stout sigmoid sclerous processes each with a subapical tooth (these do not occur in other species in this group).

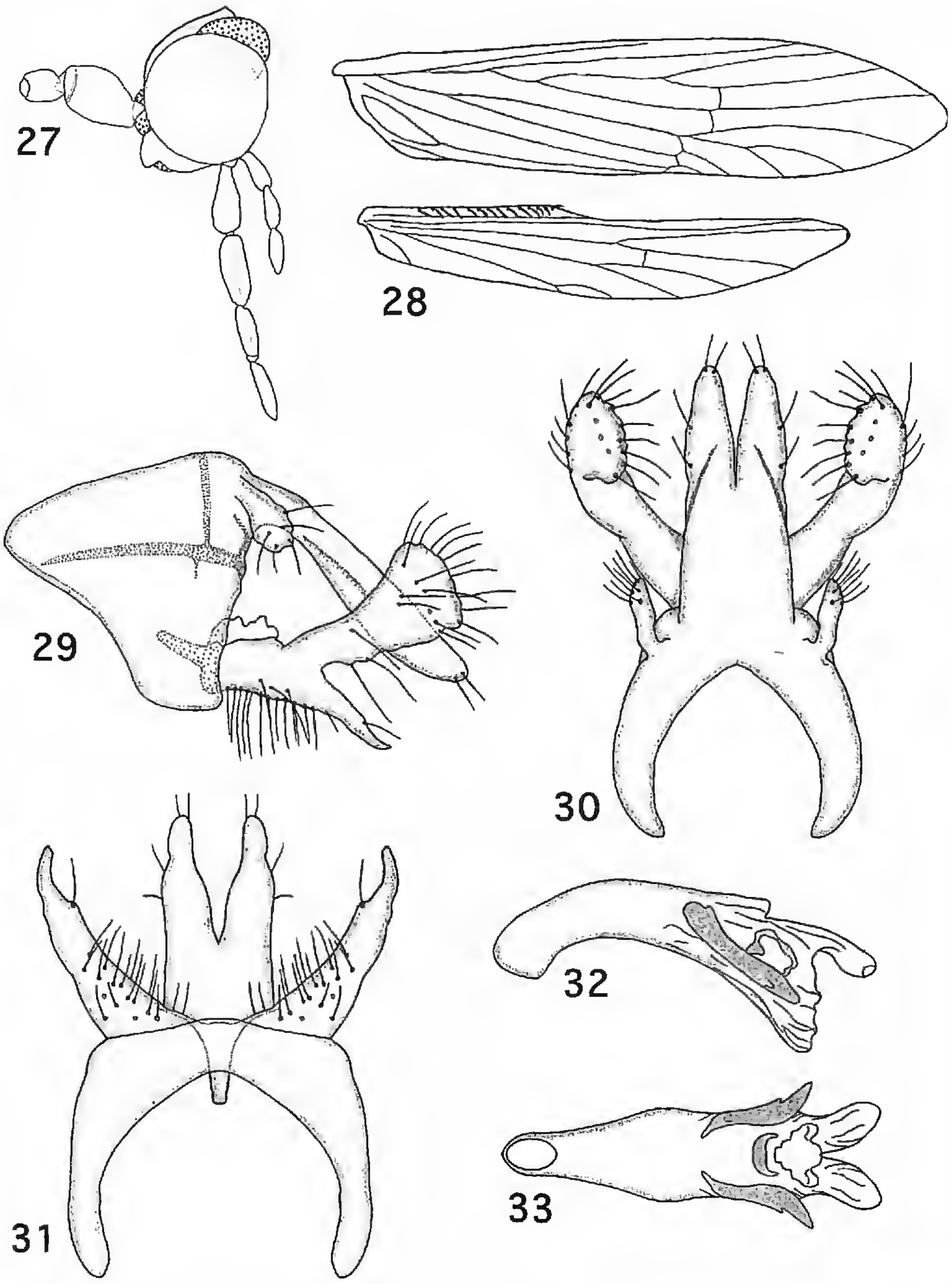
Etymology.—azunensis, refers to river at collection site.

Material examined.—see Types.

HELICOPSYCHE DACKLESTENSIS SCHEFTER AND JOHANSON, NEW SPECIES
(Figs. 34–39)

Types.—Holotype, male: VIETNAM: *GIA LAI,* An Khe Dist., Dacklest River, 5.2 km NE Tram Lap on forest road, 28 Jun 1996, D. C. Currie, J. Swann, ROM 961102, UV light, 200 m upstream bridge, 1° rainforest, 900 m, 14°24′ N, 108°33′ E.

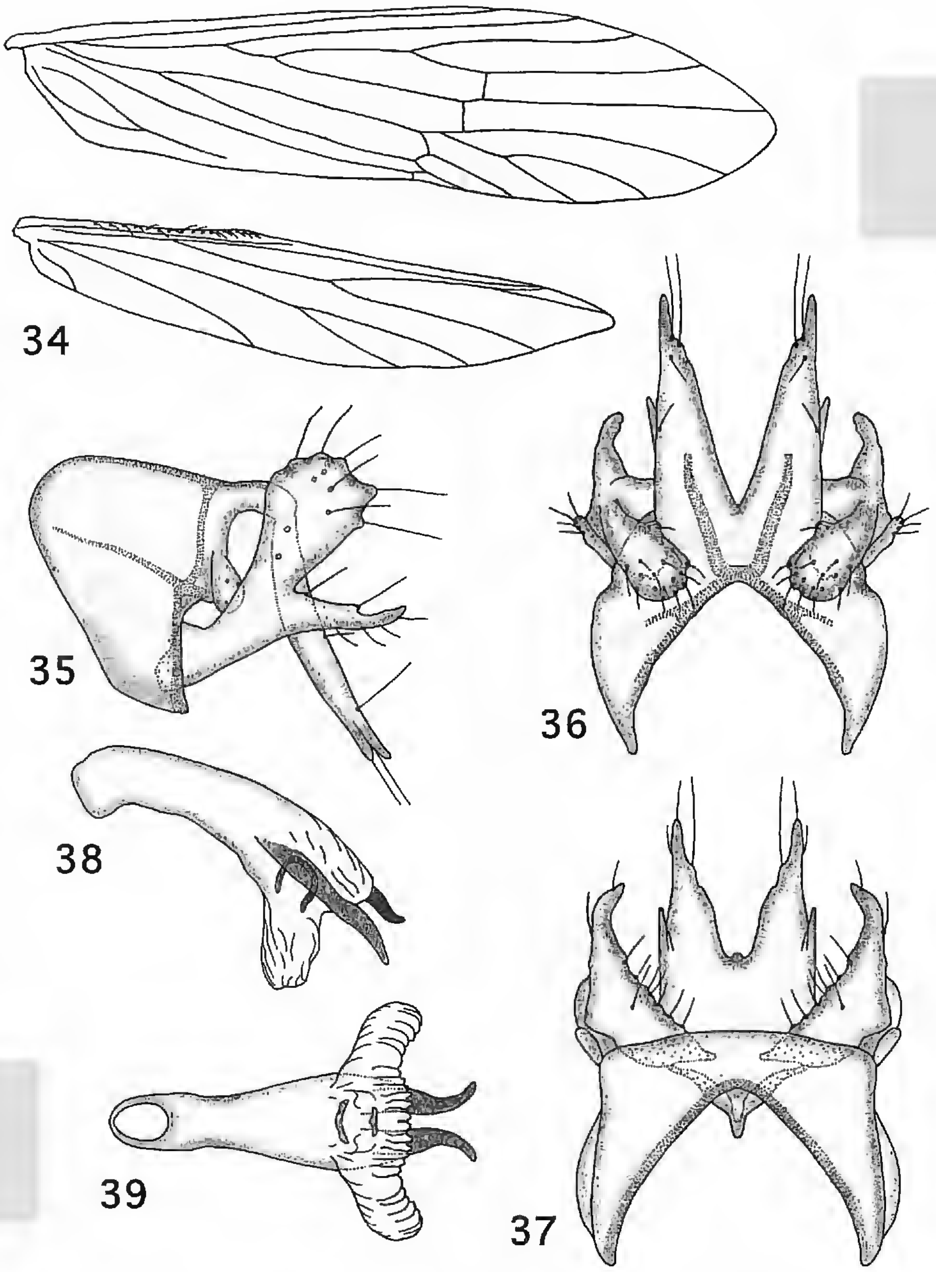
Description.—Male. Head: as in *Helicopsyche azunensis,* except vertex forming a smaller triangle.



Figures 27–33. *Helicopsyche azunensis* (male).
Figure 27. Head, lateral view.
Figure 28. Wings.
Figure 29. Genitalia, lateral view.
Figure 30. Genitalia, dorsal view.
Figure 31. Genitalia, ventral view.
Figure 32. Phallus, lateral view.
Figure 33. Phallus, dorsal view.

Legs and pronotum as in *H. azunensis.* Wings (Fig. 34): fore wing length 2.7 mm, forks 1,2,3 and 5 present, fork 1 originating at distal one third of Dc, R_2 subequal to Dc, A_{1+2} well separated from wing margin, does not reach wing margin; hind wing 2.1 mm; with 18 hamuli. Abdomen with well developed VIth sternal process. Genitalia: segment IX, lateral view (Fig. 35), subtriangular and longer dorsally, with well developed lateral apodeme. Gonocoxite divided into large primary and small secondary branch; primary branch in lateral view (Fig. 35) clavate with undulate apical margin; secondary branch slender, arcuate, notched at apex. Superior appendage originates medially on segment nine, directed ventrad, clavate in lateral view (Fig. 35); Xth tergum slender, slightly sinuate, strongly depressed in lateral view (Fig. 35), in dorsal view (Fig. 36) deeply bifurcate, each tapering lobe with a small ventrolateral process (Fig. 37); macrosetae absent. Phallus thick, slightly curved ventrally (Fig. 38) dorsoapical membranous endotheca expanded as posterior lobes with embedded paired slender sclerous processes curved apicolaterally (Figs. 38 and 39).

Female and immature stages.—Unknown.



Figures 34–39. *Helicopsyche dacklestensis* (male).
Figure 34. Wings.
Figure 35. Genitalia, lateral view.
Figure 36. Genitalia, dorsal view.
Figure 37. Genitalia, ventral view.
Figure 38. Phallus, lateral view.
Figure 39. Phallus, dorsal view.

Diagnosis.—Helicopsyche dacklestensis is most similar to *H. xenothoe* (Schmid) and can be separated from that and other species in this group by the slender and strongly arched Xth tergum, deeply bifurcate with small mesolateral processes, and the armature of the phallus.

Etymology.—dacklestensis, refers to river at collecting site.

Material Examined.—see Types.

DISCUSSION

Helicopsyche khemoiensis is most closely related to the North Korean *H. coreana* Mey. Both are restricted to the East Asian subregion (sensu Banarescu 1992), the two species comprising the subgenus *Galeopsyche* (Johanson 1998). Characteristics supporting monophyly of this group are (plesiomorphic states in parenthesis): reduction of the lateral pronotal setal warts (present, unreduced);

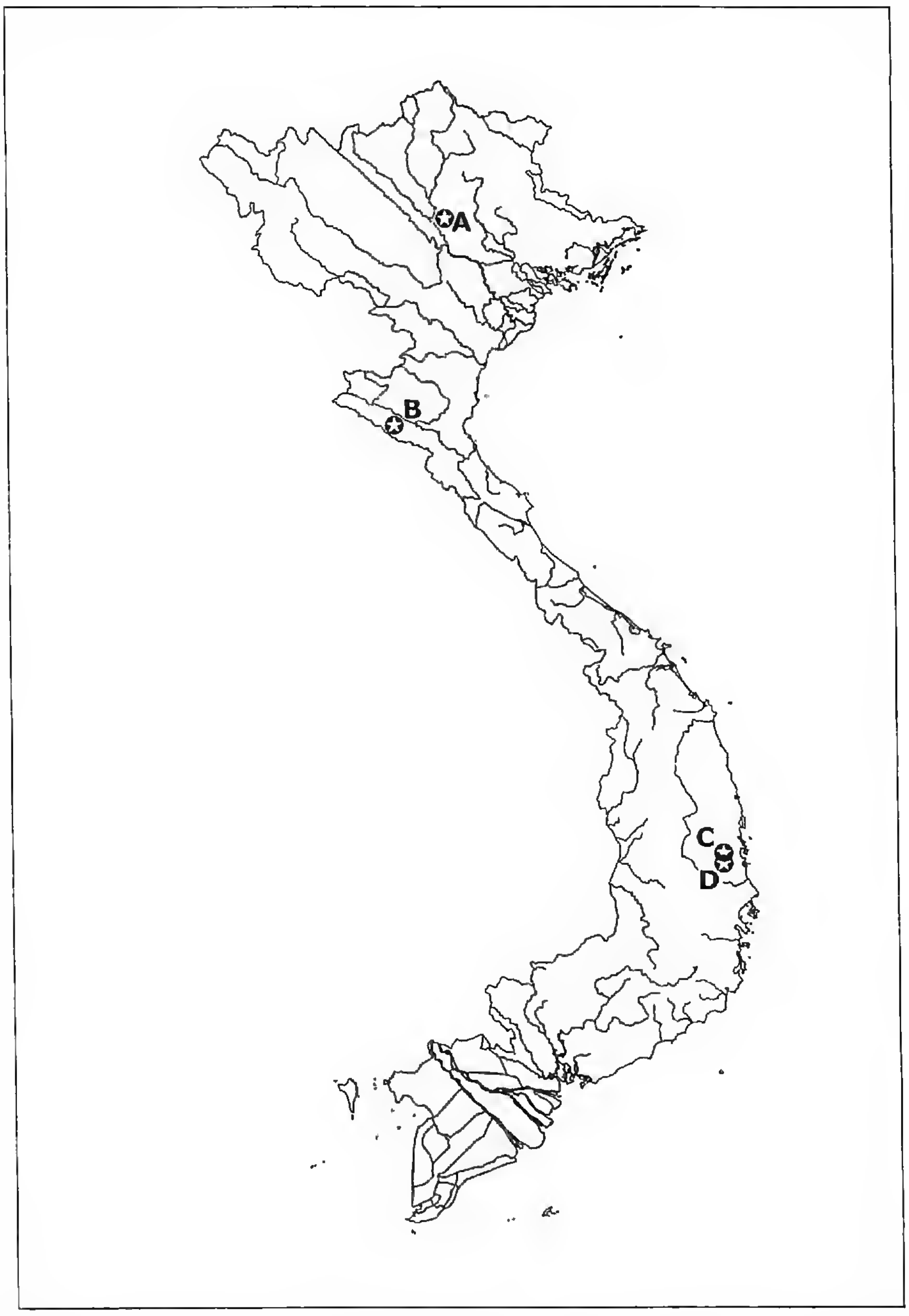


Figure 40. Collecting sites of Vietnamese *Helicopsyche*. A. *H. awudschgal* Malicky. B. *H· khemoiensis*. C. *H· azunensis*. D. *H. dacklenstensis*.

fore wing crossvein R_{2+3}–R_{4+5} directed posterobasad (directed ventrad), and fore wing A_{1+2} meeting Cu_2 or fusing with the posterior wing margin close to Cu_2 (distant to Cu_2). East Asian subgenus *Galeopsyche* and the South American subgenus *Cochliopsyche* are sister groups (Johanson 1998).

Species described in genus *Cochliophylax* (Schmid 1993) from northeastern India and Nepal were redesignated as a derived monophyletic clade within the subgenus *Helicopsyche* (Johanson 1998). *Helicopsyche azunensis* and *H. dacklestensis* are closely related to the many *Cochliophylax* species described by Schmid, and together with them have 4-jointed maxillary palps, mesoscutal warts absent, narrow hind wings without crossvein M-Cu, and the gonocoxal secondary branch tapered and with an apical hook. *Helicopsyche azunensis* and *H. dacklestensis* are considered sister species based on the presence of phallic endothecal sclerites. Their relationship to the remaining species in the group is as yet undetermined.

Distribution of the four known Vietnamese *Helicopsyche* species is shown in Fig. 40.

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LITERATURE CITED

Banarescu, P. 1992. Zoogeography of fresh waters. Volume 2. Distribution and dispersal of freshwater animals in North America and Eurasia. AULAG-Verlag Wiesbaden.

Dudgeon, D. 1988. Preliminary investigations on the faunistic and ecology of Hong Kong Trichoptera. pp. 111–117 *in* Bournaud, M. & H. Tachet (eds), Proc. 5th Int. Symp. Trichoptera. Junk, The Hague.

Johanson, K. A. 1998. Phylogenetic and biogeographic analysis of the family Helicopsychidae (Insecta: Trichoptera). Ent. Scand. Suppl., 53: 1–176.

Malicky, H. 1994. Zwei neue *Helicopsyche* (Helicopsychidae) aus Perak, Malaysia. Braueria, 22: 4.

Malicky, H. 1995. Neue Kocherfliegen (Trichoptera, Insecta) aus Vietnam. Linzer Biol. Beitr. 27: 851–885.

Malicky, H. & P. Chantaramongkol. 1993. Neue Trichopteren aus Thailand. Teil 2: Rhyacophilidae, Philopotamidae, Polycentropodidae, Ecnomidae, Psychomyidae, Xiphocentronidae, Helicopsychidae, Odontoceridae (Arbeiten über thailändische Köcherfliegen Nr. 12) (Fortsetzung). Linzer Biol. Beitr., 25: 1137–1187.

Say, T. 1821. Descriptions of univalve shells of the United States. J. Acad. Phil., 2, 1.

Schmid, F. 1993. Considérations sur les Hélicopsychidés (Trichoptera, Integripalpia). Beaufortia, 43: 65–100.

Wiggins, G. B. 1996a. Larvae of the North American caddisfly genera (Trichoptera) (2nd ed). University of Toronto Press, Toronto, Buffalo, London.

Wiggins, G. B. 1996b. Trichoptera families. *In* Merrit, R. W. & K. W. Cummins (eds). An introduction to the aquatic insects of America (3rd ed). Kendall/Hunt, Dubuque, Iowa.

Williams, D. D., A. T. Read & K. A. Moore. 1983. The biology and zoogeography of *Helicopsyche borealis* (Trichoptera: Helicopsychidae): a Nearctic representative of a tropical genus. Can. J. Zool., 61: 2288–2299.

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PREY OF THE SPIDER, *DICTYNA COLORADENSIS*, ON APPLE, PEAR, AND WEEDS IN CENTRAL WASHINGTON (ARANEAE: DICTYNIDAE)

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Abstract.—The cribellate spider, *Dictyna coloradensis* Chamberlin, constructed webs on the upper surface of apple and pear leaves (trees not treated with insecticide), and on weeds in adjacent, uncultivated ground, at a site in south central Washington. Prey found in *D. coloradensis* webs were assigned to one of three categories; pests, predators and parasitoids, or neutral in impact with respect to fruit trees. Pest taxa comprised 32%, predators and parasitoids 24%, and neutral groups 44% of 18,314 prey. Most prey were small, winged insects (length < 5 mm). Insects from 58 families in 10 orders were represented and small spiders in four families were occasionally trapped. Sciaridae and Chironomidae (Diptera) were the most numerous prey and made up 37% of the total. Most webs contained one or more of these flies and occasionally 25 or more were trapped. Alate aphids were the most frequently captured pest insects. Other pests included adults of the white apple leafhopper, the pear psylla, and thrips. Relatively non-mobile stages of the pests (leafhopper and pear psylla nymphs and apterous aphids) were less commonly found in the webs. Nineteen percent of all prey were parasitoid wasps, 14 families of which were identified. Known parasitoids of apple and pear pests were included. The only other predator or parasitoid taxon that comprised more than 1% of total prey was the Empididae (3%).

Key Words.—Arachnida, Araneae, spider, *Dictyna,* prey use, apple, pear.

The cribellate spider genus *Dictyna* is represented in the Nearctic region by more than 100 species (Roth 1993). *Dictyna* construct irregular mesh webs in a variety of situations, at times in considerable numbers and high densities (Chamberlin & Gertsch 1958, Heidger & Nentwig 1985). Species of *Dictyna* have frequently been reported from orchards where they are at times abundant. Muma (1975) found *D. florens* Ivie and Barrows common and widespread in Florida citrus where it constructed webs on leaves of orange and grapefruit. Putman (1967) reported *D. annulipes* Blackwall to be a common spider in Ontario, Canada peach orchards where it constructed webs on areas of rough bark. Also in Ontario, Hagley & Allen (1989) found *D. annulipes* to be the most abundant foliage-inhabiting spider in an apple orchard and they studied its prey utilization by examination of webs and assay of gut contents.

Dictyna coloradensis Chamberlin occurs throughout much of the central and northern United States and into the Northwest Territories of Canada. With females approaching 4 mm in length, it is among the larger species in the genus (Chamberlin & Gertsch 1958). Dondale (1956) reported *D. coloradensis* from apple trees in Nova Scotia, Canada. During 1997, 1998, and 1999 this spider was very abundant on foliage of apple trees at the USDA-ARS research farm near Yakima, Washington. Webs were less abundant on pear foliage. Large numbers of *D. coloradensis* also constructed webs on tall, dead stalks of annual weeds in adjacent, uncultivated ground in the spring, and later in the year utilized the current season's growth.

Webs of *D. coloradensis* were collected during 1997, 1998, and 1999 and their prey contents identified. Because spiders are considered generalist predators (Wise 1993), we were interested in determining the taxonomic range of prey captured and the relative proportions that fell into three broad categories. 1) Pests: Included taxa are generally regarded as plant pests although not all specimens were necessarily pests of apple and pear. 2) Predators and parasitoids: All predatory and parasitic groups were included although not all were known predators and parasitoids of apple and pear pests. 3) Neutral: Taxa in this category probably have little or no detrimental or beneficial impact on fruit trees.

MATERIALS AND METHODS

This study was conducted at the USDA-ARS research farm, 26 km east of Yakima, Yakima County, Washington. Several small blocks of fruit trees are planted at the 130 ha farm. Other crops grown include asparagus and potatoes, but some ground has never been cultivated and native vegetation, dominated by big sagebrush, *Artemisia tridentata* Nuttall (Asteraceae), remains within and surrounds parts of the farm. Uncultivated ground with mixed native and introduced vegetation partly surrounded some of the tree fruit blocks. Fruit trees were not treated with insecticides.

Pear and apple leaves and weed stems with *D. coloradensis* webs were placed in plastic vials with tight fitting lids and refrigerated until examined. Webs were immersed in 70% isopropyl alcohol in a petri dish and examined under 6.5×–50× for prey identification. Prey were identified to family, if possible, using keys in Borror, Delong, & Triplehorn (1976) and Goulet & Huber (1993). Exceptions included the following: Chironomidae and Sciaridae, the most abundant Dipteran prey, were difficult to distinguish when large numbers were present and specimens were damaged and entangled in webbing. Many specimens were therefore categorized as unidentified Nematocera. These two families made up the vast majority of prey in this category. Cyclorrhaphous Brachycera were categorized as medium size muscoid flies if larger than *Drosophila* but smaller than a housefly, and as small muscoid flies if *Drosophila*-size or smaller. Many chalcidoid wasps were identified only to superfamily (Chalcidoidea) and many small, non-chalcidoid, parasitoid wasps were classified as unidentified parasitoid wasps because small size, damaged specimens, and entanglement in webbing made identification difficult.

Webs were collected from three apple varieties (“Fuji”, “Golden Delicious”, and “Red Delicious”), pears (mixed “Anjou” and “Bartlett” varieties), and dead weed stems in uncultivated land adjacent to the “Fuji” apples. Weeds were primarily tumble mustard, *Sisymbrium altissimum* Linnaeus (Brassicaceae), an introduced species. A total of 984 webs was examined, distributed among the plant types as indicated in Table 1. Five to 15 webs were collected from a plant type per sample date at one to two week intervals. The sampling periods were 22 May to 16 Oct 1997, 30 Mar to 3 Nov 1998, and 20 Jul to 1 Oct 1999. Each plant type was not sampled throughout each sample period.

RESULTS

Web Placement.—Most webs on apple and pear were constructed on the upper, concave surfaces of leaves. The small webs of young spiders covered only 2 or 3 cm^2 and were usually near the leaf apex. Webs of older, larger individuals often

Table 1. Number of sample dates and total number of *Dictyna coloradensis* webs examined from different plants during 1997, 1998, and 1999.

Plant	No. of samples dates—No. of webs examined		
	1997	1998	1999
Apple–"Fuji"	11–141	19–192	—
Apple–"Golden"	10–57	10–56	—
Apple–"Red"	9–59	—	—
Pear	5–17	9–91	11–155
Weeds	—	18–216	—

covered most of the upper surface of a leaf. Leaves were up to 10 cm long. Prey accumulated in webs and older, larger webs contained up to 40 or more prey. Webs were occasionally found in the angle formed by two branches, among flower petioles, or between a leaf petiole and a branch. They were less visible in these locations and few were sampled. Webs on dead weed stalks were constructed among branches on the upper part of a stalk, 0.3–1.0 m above ground.

Prey Utilization.—Fifty-eight families of insects in 10 orders and four families of spiders were identified from webs of *D. coloradensis* (Table 2). Some taxa were represented by few specimens (two Ephemeroptera among 18,314 prey) whereas others made up a high proportion of prey in webs from all sources all three years.

Insects classified as neutral with respect to impact on fruit trees made up the largest proportion of prey items overall (7981 prey = 44%). Nematocerous Diptera, primarily Sciaridae (dark-winged fungus gnats) and Chironomidae (midges) were the most abundant prey of any kind (37% overall). Sciarids and chironomids were present throughout the season and were found in a majority of webs regardless of source. Webs occasionally contained 25 or more of these small insects. Other taxa of neutral prey rarely comprised more than 1% of the total from a plant in one year. Small muscoid flies, however, made up 5.4% of prey in webs from "Golden Delicious" in 1997.

Aphids were the most numerous pest insects found in *D. coloradensis* webs, and alates were generally much more abundant than apterous forms. Five to 30% of the total insects found in webs from each plant type each year were aphids. Aphids were not identified to species because of the large number captured and their often poor state of preservation (discoloration, damage, dehydration). Several species are considered pests of apple in Washington and many appeared to be green apple aphid, *Aphis pomi* DeGeer, or the nearly identical spirea aphid, *A. spireacola* Patch. Apple/spirea aphid colonies were abundant on developing apple shoots all three years. Thrips (Thysanoptera) made up 5–11% of total prey in the samples from fruit trees but were more abundant in webs on weeds (22%). The western flower thrips, *Frankliniella occidentalis* (Pergande) is the only species listed by Beers et al. (1993) as a pest of tree fruit in Washington. A pale, yellowish insect, its host range includes several fruit trees, alfalfa, potatoes, and numerous species of weeds (Beers et al. 1993). Thrips were not identified to species due to small size, entanglement in webbing, and poor preservation. The vast majority, however, were pale, yellowish insects, in general resembling *F. occidentalis.* White apple leafhopper adults, *Typhlocyba pomaria* McAtee, were most abundant

Table 2. Total number of prey items in each taxon found in *Dictyna coloradensis* webs from apples, pears, and weeds.

Prey taxa	Apples	Pears	Weeds
Neutral impact taxa			
Chironomidae	195	163	745
Sciaridae	760	238	112
Bibionidae	25	0	94
Psychodidae	6	2	1
Scatopsidae	1	4	1
Simuliidae	1	3	0
Tipulidae	1	1	0
Nematocera–unidentified	2873	1022	590
Stratiomyidae	1	0	0
Therevidae	4	0	0
Bombyliidae	2	0	3
Drosophilidae	175	78	28
Phoridae	38	29	8
Conopidae	0	0	1
Small muscoid flies	375	100	87
Medium muscoid flies	30	26	10
Diptera—unidentified	0	0	5
Halictidae	12	7	0
Chrysididae	1	0	0
Tenthredinidae	0	0	1
Scarabaeidae	2	0	2
Coleoptera—unidentified	6	1	6
Aleyrodidae	1	0	0
Fulgoroidea	0	0	1
Lygaeidae	6	0	17
Hemiptera—unidentified	2	1	3
Psocoptera	42	18	9
Ephemeroptera	1	1	0
Pest taxa			
Aphididae—alate	1549	1011	431
Aphididae—apterous	230	67	5
Typhlocyba pomaria	289	5	2
Other Cicadellidae	18	1	2
Cacopsylla pyricola—adults	3	165	1
Cacopsylla pyricola—nymphs	0	50	0
Phyllonorycter elmaella	193	37	3
Lepidoptera—unidentified	3	0	3
Caterpillar	0	2	0
Miridae—*Lygus* sp.	2	0	3
Miridae—*Campylomma* sp.[a]	12	1	1
Thysanoptera	687	281	777
Acari	3	5	0
Predator and parasitoid taxa			
Cecidomyiidae	6	5	4
Empididae	387	132	6
Dolichopodidae	11	4	0
Pipunculidae	25	9	3
Tachinidae	6	6	1
Syrphidae	2	0	0
Braconidae	349	56	81
Ichneumonidae	76	16	18

Table 2. Continued.

Prey taxa	Apples	Pears	Weeds
Pnigalio flavipes	177	63	3
Trechnites insidiosus	0	50	0
Mymaridae	641	17	20
Encyrtidae	0	0	1
Chalcidoidea—unidentified	713	373	106
Platygastridae	40	16	21
Scelionidae	25	14	5
Ceraphronidae	73	14	16
Megaspilidae	2	2	1
Proctotrupidae	3	4	1
Dryinidae	1	1	2
Bethylidae	3	0	6
Diapriidae	1	0	3
Cynipoidea	12	3	1
Parasitoids—unidentified[b]	249	94	123
Sphecidae	8	8	0
Formicidae	15	7	133
Vespidae	1	1	0
Staphylinidae	39	4	35
Carabidae	2	0	3
Coccinellidae	2	1	0
Hemerobiidae	6	2	0
Chrysopidae	2	0	0
Anthocoridae—*Orius*	27	5	7
Nabidae—*Nabis*	0	0	1
Lygaeidae—*Geocoris*	0	0	5
Miridae—*Deraeocoris*	2	2	0
Salticidae	7	1	1
Linyphiidae—*Erigone*	13	2	2
Linyphiidae	10	9	17
Thomisidae	2	0	0
Oxyopidae	6	1	0
Araneae—unidentified	0	2	0
Prey totals	10,493	4243	3578

[a] *Campylomma* also act as predators by feeding on such pests as aphids and mites.
[b] Category includes only hymenopteran parasitoids.

in webs from "Fuji" apples during 1998 when they comprised nearly 5% of all prey. *Typhlocyba* comprised less than 2% of total prey in the other samples, and nymphs were rarely captured. Adult, western tentiform leafminer, *Phyllonorycter elmaella* Doglanar and Mutuura, made up 1–2% of the prey in each tree fruit sample, but only three of 3578 prey in webs from weeds. Pear psylla, *Cacopsylla pyricola* (Foerster), a serious pest of pear in the Pacific Northwest, made up 5.5% of the prey in *D. coloradensis* webs from pear during 1997, just under 1% in 1998, and 8% in 1999. Psylla populations at the research farm were low during 1998, probably accounting for their rarity as prey despite the greater number of webs examined compared to 1997. Psylla numbers were higher during 1999 when leaves and shoots were often sticky with honeydew, and this was reflected in the number captured in *D. coloradensis* webs. Most captured *C. pyricola* were adults, although a substantial number of nymphs fell victim in 1999 (50 nymphs, 134 adults). However, it was difficult, at times, to distinguish psylla nymphs from their cast skins.

Small, hymenopterous parasitoids were the most abundant predatory and parasitoid insects trapped in *D. coloradensis* webs. They comprised 12% to 28.6% of total prey in yearly samples from each of the plants. Hosts of many of the parasitoids were not determined or are unknown, some are probably hyperparasitoids, and some probably occurred only incidentally in the fruit trees. Known parasitoids of apple and pear pests were, however, captured. *Pnigalio flavipes* (Ashmead) (Eulophidae), the most common parasitoid of the western tentiform leafminer in the Pacific Northwest (Beers et al. 1993), made up 1%–2% of total prey in samples from fruit trees. It was rarely found in webs on weeds. Mymaridae (fairyflies) were captured in substantial numbers in webs on "Fuji" (449 = 11.9%) and "Golden Delicious" (132 = 6.6%) during 1998. Both represented large increases over numbers found in 1997. Mymarids in the genus *Anagrus* are important egg parasitoids of the white apple leafhopper and parasitism rates of up to 70% have been reported in unsprayed orchards (Beers et al. 1993). Many mymarids found in webs on apple may have been leafhopper egg parasitoids. Two percent of the insects in webs from pear during 1999 were *Trechnites insidiosus* (Crawford) (Encyrtidae), the most important parasitoid of pear psylla in western North America (Beers et al. 1993).

Other taxa of insect predators and parasitoids rarely comprised more than 1% of the total prey in webs from a given plant type (Table 2). Empididae, however, made up 7.5% (233 flies) of the prey found in webs on "Fuji" apple in 1997. Spiders also were infrequently snared in *D. coloradensis* webs (< 1% of prey in samples from any of the plant types) and were small, either immatures or taxa of small body size.

DISCUSSION

The diversity of prey captured by *D. coloradensis* is in agreement with the idea of spiders as generalist predators (Wise 1993). Individual species, however, utilize a restricted range of available prey depending on factors such as spider size, hunting strategy, and web size and placement (Marc & Canard 1997). Spiders generally feed on prey smaller than themselves (Jackson 1977, Nyffeler et al. 1994). This was true of *D. coloradensis,* the vast majority of whose prey consisted of insects less than 5 mm in length. The predominant use of small prey has also been noted in *D. segregata* (Nyffeler et al. 1988), *D. arundinacea* (Heidger & Nentwig 1985), and 11 species, including *D. coloradensis,* studied by Jackson (1977). Large and dangerous prey were, however, captured occasionally. Two worker yellow-jackets (*Vespula* sp.) were found in 1997 webs and on 26 Apr 2000 a recently captured worker honeybee, *Apis mellifera* L., was noted in the web of a female on a dead weed. The spider was feeding on the bee at the time. Overall, however, few prey larger than a housefly were found in the webs. No codling moth, *Cydia pomonella* (L.) or leafrollers, *Pandemis pyrusana* Kearfott, were captured. Both are important apple pests in Washington (*C. pomonella* was very abundant at the farm in 1997–1998), but at adult lengths of 12 mm or more, they may be too large to be readily subdued by *D. coloradensis* webs.

A given species of spider may not utilize all stages in a prey species' life cycle to equal degrees (Marc and Canard 1997). This was true for several prey species of *D. coloradensis,* most or all of whose life cycles are spent on the fruit trees. Adult white apple leafhopper, adult pear psylla, and alate aphids were common prey but immature leafhoppers and psylla and apterous aphids fell victim less frequently. This is probably related to the relative mobility of different stages of the prey and their locations on the plant. White apple leafhopper and pear psylla adults are mobile and fly readily when disturbed. They would appear much more likely to blunder into webs than the more sedentary nymphs. Also, white apple leafhopper nymphs generally feed on the lower surface of the leaf (Beers et al. 1993) whereas *D. coloradensis* webs are constructed almost exclusively on the upper surface. Psylla nymphs, with their flattened body form and leaf-surface hugging habits were often found alive beneath *D. coloradensis* webs—apparently able to avoid entanglement in the silk. Alate aphids, although not strong fliers, are more mobile than the apterous forms and again must be more likely to come into contact with webs. Green apple aphid colonies generally develop on succulent, young tissue and are found on growing shoot tips, shoot stems, and the undersides of leaves (Beers et al. 1993). Thus the sedentary, apterous forms are less likely to come into contact with *D. coloradensis* webs.

Dictyna coloradensis webs trapped many small (1–3 mm), hymenopterous parasitoids (19.1% of all prey). Some parasitoids were observed crawling over leaf surfaces, which must often bring them into contact with webbing. This is true of *P. flavipes* and *T. insidiosus* females, both of which search leaf surfaces for hosts (Beers et al. 1993), and many became entangled in the webs. Nearly the same number of male *P. flavipes* (122) were captured as females (118). *T. insidiosus* is thelytokous in the western states (Unruh et al. 1995) and males were not found in the webs. Thirteen percent of the prey of *D. arundinacea* (L.) consisted of small parasitoid wasps (Heidger & Nentwig 1985).

Predatory insects, and parasitoids other than Hymenoptera, were infrequently found in *D. coloradensis* webs. *Deraeocoris* spp. (Miridae), for example, are important predators of pear psylla (Beers et al. 1993) and were abundant on the pears during 1999. Yet *Deraeocoris* accounted for only 0.09% of the prey in webs on pear during 1999. Aphid predators such as Coccinellidae and Chrysopidae, often abundant in unsprayed orchards with high aphid populations, made up similarly low percentages of prey in all samples. Such insects, perhaps because of size, behavior, and distribution on the plants may not be very vulnerable to entanglement in *D. coloradensis* webs.

Other spiders were infrequent prey in *D. coloradensis* webs. The low number taken (0.4% of total prey) is in accord with Nyffeler's (1999) findings that web building spiders are 99% insectivorous whereas hunting types take a higher proportion of other spiders. Jackson (1977), for example, found that 27% of the prey of *Phidippus johnsoni* (Peckham and Peckham) (Salticidae) was other spiders.

Capture of beneficial insects and spiders by *D. coloradensis* (intraguild predation in a broad sense) was substantial in terms of the overall numbers captured. However, the hosts of many of the parasitoids may not be orchard pests and their capture may have little negative impact on orchard ecology from a pest management standpoint. Greenstone (1999) noted that the net effect of intraguild predation can only be determined by examining the system in the presence and absence of the predator. Although intraguild predation and competitive interactions among predators may in some cases disturb natural pest control, in others they may promote greater spider biodiversity and allow spiders to survive periods of low prey density (Sunderland 1999).

Several studies have shown that small Diptera are important components in the diet of *Dictyna* spiders. Several families of small flies made up 50% of the prey captured by *D. arundinacea* in a meadow in Germany (Heidger & Nentwig 1985) and small Diptera dominated the prey of each of 11 *Dictyna* species studied by Jackson (1977). Chironomidae comprised 70.7% of the total prey of *D. annulipes* in an apple orchard in Ontario, Canada (Hagley & Allen 1989), and a diverse array of small Diptera were important components in the diet of *D. coloradensis* in Washington. The abundance of these small flies was likely important in supporting the high population of *D. coloradensis* observed during this study. Also, their presence during much of the season may help fill in gaps in availability of other types of prey, as noted by Sunderland (1999) with respect to intraguild predation.

Clearly, *D. coloradensis* is a polyphagous predator that includes a wide range of insects in its diet. Prey selectivity is based primarily on size and activity level—small, active insects are most heavily utilized. Small, active pests of apple and pear are taken in substantial numbers, but unfortunately, from a pest management standpoint, known parasitoids of some pests are also trapped, sometimes in considerable numbers.

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Literature Cited

Beers, E. H., J. F. Brunner, M. J. Willett & G. M. Warner. (eds.). 1993. Orchard pest management: A Resource book for the Pacific Northwest. Published by Good Fruit Grower, Yakima, Washington.

Borror, D. J., D. M. DeLong & C. A. Triplehorn. 1976. An introduction to the study of insects (4th ed.) Holt, Rinehart, and Winston, New York.

Chamberlin, R. V. & W. J. Gertsch. 1958. The spider family Dictynidae in America north of Mexico. Bull. Am. Mus. Nat. Hist., 116: 1–152.

Dondale, C. D. 1956. Annotated list of spiders (Araneae) from apple trees in Nova Scotia. Can. Entomol., 88: 697–700.

Greenstone, M. H. 1999. Spider predation: how and why we study it. J. Arachnol., 27: 333–342.

Goulet, H. & J. T. Huber (eds.). 1993. Hymenoptera of the world: An identification guide to families. Research Branch, Agriculture Canada. Publication 1894/E.

Hagley, E. A. C. & W. R. Allen. 1989. Prey of the cribellate spider, *Dictyna annulipes* (Araneae, Dictynidae), on apple tree foliage. J. Arachnol., 17: 366–367.

Heidger, C. & W. Nentwig. 1985. The prey of *Dictyna arundinacea* (Araneae: Dictynidae). Zool. Beitr. N. F. 29: 185–192.

Jackson, R. R. 1977a. Comparative studies of *Dictyna* and *Mallos* (Araneae, Dictynidae): III. Prey and predatory behavior. Psyche, 83: 267–280.

Jackson, R. R. 1977b. Prey of the jumping spider *Phidippus johnsoni* (Araneae: Salticidae). J. Arachnol., 5: 145–149.

Marc, P. & A. Canard. 1997. Maintaining spider biodiversity in agroecosystems as a tool in pest control. Agric. Ecosyst. Environ., 62: 229–235.

Muma, M. H. 1975. Spiders in Florida citrus groves. Fla. Entomol., 58: 83–90.

Nyffeler, M. 1999. Prey selection of spiders in the field. J. Arachnol., 27: 317–324.

Nyffeler, M., D. A. Dean & W. L. Sterling. 1988. Prey records of the web-building spiders *Dictyna segregata,* (Dictynidae), *Theridion australe* (Theridiidae), *Tidarren haemorrhoidale* (Theridiidae), and *Frontinella pyramitela* (Linyphiidae) in a cotton agroecosystem. Southwestern Nat., 33: 215–218.

Nyffeler, M., W. L. Sterling & D. A. Dean. 1994. How spiders make a living. Environ. Entomol., 23: 1357–1367.

Putman, W. L. 1967. Prevalence of spiders and their importance as predators in Ontario peach orchards. Can. Entomol., 99: 160–170.

Roth, V. D. 1993. Spider genera of North America with keys to families and genera and a guide to literature (3rd ed.). (Distributed by American Arachnological Society). U. of Florida, Gainesville.

Sunderland, K. 1999. Mechanisms underlying the effects of spiders on pest populations. J. Arachnol., 27: 308–316.

Unruh, T. R., P. H. Westigard & K. S. Hagen. 1995. Pear psylla. Chapter 19. pp. 95–100. *In* Nechols, J. R., L. A. Andres, J. W. Beardsley, R. D. Goeden, & C. G. Jackson. 1995. Biological control in the western United States. Accomplishments and benefits of regional research project W-84, 1964–1989. Univ. Calif. Div. Agric. Nat. Res. Publ. 3361.

Wise, D. H. 1993. Spiders in ecological webs. Cambridge University Press, Cambridge, U.K.

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OVERWINTERING POTENTIAL IN CALIFORNIA OF TWO RUSSIAN WHEAT APHID PARASITOIDS (HYMENOPTERA: APHELINIDAE ET APHIDIIDAE) IMPORTED FROM CENTRAL ASIA

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Abstract.—*Aphelinus albipodus* Hayat and Fatima and *Diaeretiella rapae* (M'Intosh) (Hymenoptera: Aphelinidae and Aphidiidae) were imported to the USA for biological control of Russian wheat aphid (*Diuraphis noxia* Mordwilko) in 1992. Early laboratory studies identified potential limitations for their successful establishment in northern California where these parasitoids were extensively colonized and evaluated against Russian wheat aphid. Specifically, those studies showed that *A. albipodus* was particularly susceptible to moderately low temperatures (10° C). These results for *A. albipodus* were in contradiction with seasonal field temperatures prevalent in its collection site (Tahcheng, People's Republic of China) where field temperatures are below freezing for several months each year. This study sought to reconcile these apparently contradictory results. We examined whether short daylength-induced diapause, i.e. winter diapause, occurs in *A. albipodus* and *D. rapae,* and thus could be used as an overwintering strategy by these parasitoids. Under laboratory conditions, > ⅔ of *A. albipodus* individuals entered diapause when daylength was reduced from 14 h to 12 h. In contrast, diapause was not detected in *D. rapae* under the same conditions. However, we suggested that diapause may occur in *D. rapae* under shorter daylengths because (i) this parasitoid's development and survivorship are not affected by temperatures associated with 12 h daylengths at its collection site (Wuqia, PRC), and (ii) other studies have demonstrated diapause in this parasitoid at daylengths < 12 h. We discuss our results in light of *A. albipodus*' rapid establishment in northern California, and the use of our analytical procedure as a component of a process for screening natural enemies in importation biological control programs.

Key Words.—Insecta, *Aphelinus albipodus, Diaeretiella rapae,* diapause, biological control, *Diuraphis noxia,* establishment, importation.

Numerous biological control campaigns involving exotic natural enemies have been successful since the introduction of the vedalia beetle to California more than 100 years ago (DeBach & Rosen 1991; Greathead & Greathead 1992). Experience gained during that time and theoretical analyses have led to the identification of traits that presumably make natural enemies effective biological control agents (Huffaker et al. 1974, 1977; Beddington et al. 1978; Murdoch et al. 1985; Luck 1990; Murdoch & Briggs 1996). However, at this time it is uncertain whether these traits are useful or efficient for identifying the most promising natural enemies among a suite of available natural enemies (Luck 1990; González & Gilstrap 1992). In contrast, identifying natural enemies that offer promise for successful establishment in a new area seems a more tenable goal. Characterizing an exotic natural enemy's potential for establishment is important because lack of successful establishment precludes its eventual success in suppressing a pest population.

Climate (excessively cold, hot, or dry seasonal weather) is the single most

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frequently cited reason for natural enemy failure in biological control campaigns (Stiling 1993). Climate can early on limit a natural enemy's potential for success by impeding its permanent establishment following colonization. Close matching between the climates of collection and colonization areas of natural enemies used in classical biological control campaigns, i.e., *climate-matching,* is a long-standing conceptual "rule of thumb" for improving the chances of successful establishment of exotic natural enemies (Flanders 1940; Messenger 1959, 1971). It is unclear, however, how much emphasis is commonly placed on climate-matching in the planning phase of foreign exploration efforts. A comparatively information-intensive approach to climate-matching has been used successfully for forecasting range expansions of exotic pests (Messenger & Flitters 1954; Meats 1989; Hughes & Maywald 1990).

Shortly after the discovery of the Russian wheat aphid, *Diuraphis noxia* Mordwilko (Homoptera: Aphididae), in the USA in 1986, a biological control campaign involving several state, federal, and university agencies was organized against this pest. Numerous Russian wheat aphid natural enemies were imported to the USA as a result of this combined effort (Gilstrap et al. 1994). Based on information available from their collection areas, a limited suite of parasitoids was selected from among these natural enemies for evaluation in California (González et al., unpublished data). Among these parasitoids were *Aphelinus albipodus* Hayat and Fatima and *Diaeretiella rapae* (M'Intosh) (Hymenoptera: Aphelinidae and Aphidiidae, respectively). A series of studies identified potential limitations for successful establishment of these parasitoids in California (Bernal & González 1995, 1996, 1997; Bernal et al. 1997). In general, those studies suggested that *A. albipodus* was less tolerant of low temperatures than *D. rapae,* but the reverse was true at high temperatures. The implications of these results were that establishment in California of *A. albipodus* could be restricted by winter temperatures, but establishment of *D. rapae* could be restricted by summer temperatures. However, these results and their implications were in disagreement with available information concerning the climate of each of these parasitoid's collection areas (extremely cold and long winters, and moderate summers; see below). This was particularly true with regard to *A. albipodus*' susceptibility to low temperatures in the laboratory (Bernal & González 1996; Bernal et al. 1997), and its rapid establishment in northern California (González et al., unpublished data).

Based on these observations, we examined whether *A. albipodus* and *D. rapae* enter diapause in response to a short daylength, i.e., winter diapause. Entry into diapause under short daylength conditions would explain how these parasitoids survive the low temperatures prevalent during the late fall through early spring in their collection areas, and would influence their performance against Russian wheat aphid in California. Based on the results of this and previous studies we suggest that *A. albipodus* and *D. rapae* are able to survive the severe winters prevalent in their collection areas by entering a short daylength-induced diapause. In addition, we discuss how diapause and temperature-related developmental restrictions can affect the potential for successful establishment and the population dynamics of these parasitoids under California conditions.

MATERIAL AND METHODS

Parasitoid and Host Cultures.—Aphelinus albipodus and *D. rapae* were collected, respectively, near Tahcheng (46°42′ N, 83°00′ E, ca. 500 m elevation) and

Wuqia (Ulugqat) (39°05′ N, 74°02′ E, ca. 3000 m elevation), Peoples Republic of China, by D. González in 1992. The procedures for rearing Russian wheat aphid and both species of parasitoids were described earlier (Bernal & González 1993).

Experiments.—Two sets of trials were conducted for each of *A. albipodus* and *D. rapae.* The first set was designed to provide baseline information concerning emergence rates from mummies, and the maximum egg to adult developmental times in each of the parasitoids. The second set was designed to detect diapause if it occurred in either parasitoid species. The methodology for both sets of trials, and for both parasitoids, was similar, except that the daylength used in the second set of trials was shorter than in the first set of trials.

Previous studies showed that emergence rates from mummies at 21° C, 50–70% R. H., and 14 h daylengths were high (≥ 90%) in both *A. albipodus* and *D. rapae.* Thus, these environmental conditions (hereafter "non-diapause conditions") were used to obtain baseline information concerning emergence rates and developmental times in the first set of trials. Small pots of wheat, cv MIT, each covered with a small cage and containing ca. 40 Russian wheat aphids of instars III-adult (Bernal & González 1997) were exposed to 20 previously mated and fed, 1–2 day old female *A. albipodus* or *D. rapae.* The aphids were exposed to the female parasitoids for 24 h, after which the parasitoids were removed and the aphids were incubated under the non-diapause conditions described above. When aphid mummies formed, they were transferred each to a gelatin capsule (size #0) and further incubated under non-diapause conditions to allow emergence of adult parasitoids. The mummies were monitored daily for emergence of adult parasitoids, and the number of days from oviposition to emergence of individual adult parasitoids, the number of mummies formed, and the number of mummies yielding adult parasitoids from each pot were recorded. Fifteen pots with Russian wheat aphid were prepared for each of *A. albipodus* and *D. rapae.*

The second set of trials was similar to the first, except that the daylength was 12 h (hereafter "diapause conditions") rather than 14 h. In this case, 20 pots with Russian wheat aphid were used for *A. albipodus* and 15 pots for *D. rapae.* The results of the first set of trials showed that under non-diapause conditions, maximum egg to adult developmental times were 28 days in *A. albipodus* ($n = 344$), and 23 days in *D. rapae* ($n = 291$). Thus, for the second set of trials, mummies of each species not yielding adults within their corresponding maximum egg to adult times were tentatively considered to be in diapause. Emergence rates from mummies under diapause versus non-diapause conditions were compared via log-likelihood ratios for 2 × 2 contingency tables, with Yate's correction for continuity, for each of *A. albipodus* and *D. rapae* (Zar 1996).

Mummies under diapause conditions yielded fewer adult parasitoids than mummies under non-diapause conditions in *A. albipodus* but not in *D. rapae* (see *Results*). Whether the *A. albipodus* mummies that did not yield adult parasitoids under diapause conditions indeed contained diapausing individuals was determined via dissections. These mummies ($n = 242$) were divided into 2 groups of equal size at 28 days; one group was maintained under diapause conditions (i.e., 12 h daylength), the other was transferred to non-diapause conditions (i.e., 14 h daylength). Subsamples of mummies from each group were dissected at 48, 55, and 80 day from oviposition. Mummies containing live last instar parasitoid larvae or pupae were considered to be in diapause. Both groups of mummies were further incubated if diapausing individuals were detected in the subsamples. The days to emergence, and the numbers of any parasitoids emerging from both groups of mummies were recorded.

Finally, the mean monthly temperatures and daylengths of each of the parasitoid's collection sites were compared versus a representative site from northern California, Tulelake (41°58′ N, 121°28′ W), where *A. albipodus* and *D. rapae* were colonized. Data for these comparisons were obtained from Walter & Lieth (1967), Pearce & Smith (1990), and Anonymous (1993).

RESULTS

The emergence rate of adult *A. albipodus* from mummies was significantly lower ($P \ll 0.001$) under the 12 h daylength relative to the 14 h daylength (Fig. 1). Less than ⅓ the proportion of *A. albipodus* adults emerging from mummies under the 14 h daylength emerged under the 12 h daylength. In contrast, emergence rates of *D. rapae* adults were similarly high and not significantly different ($P = 0.439$) under both daylengths (Fig. 1).

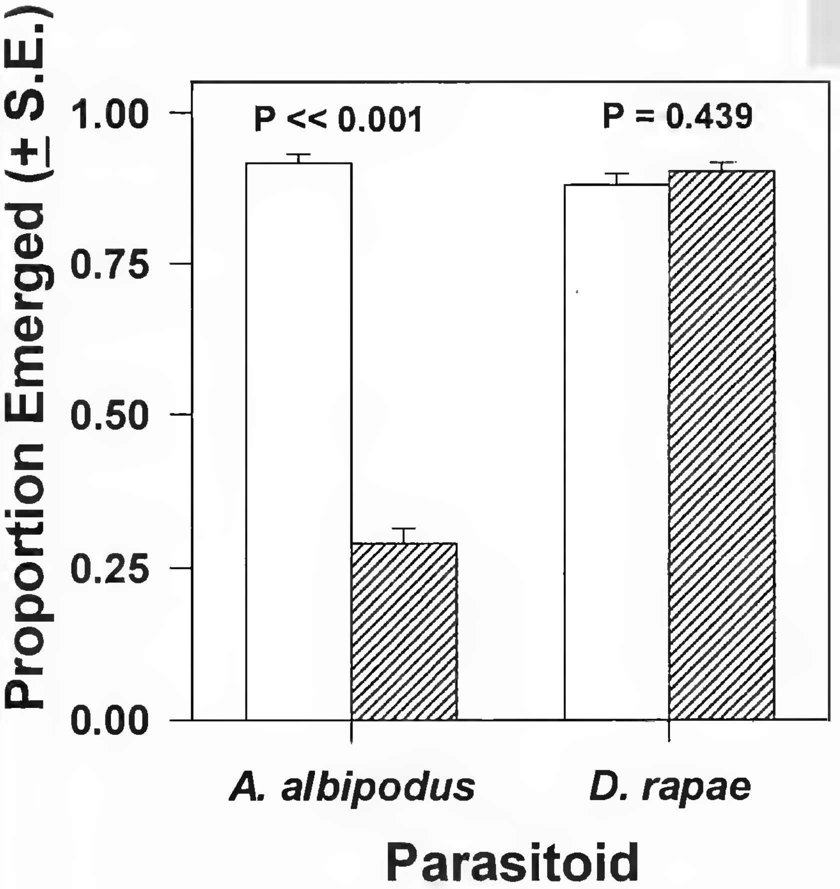
None of 121 mummies that were maintained at 12 h daylength for up to 84 days from the egg stage yielded *A. albipodus* adults. Dissection of these mummies revealed that they contained live last-instar larvae throughout this sampling period; 98% contained live last-instar larvae at 48 days from the egg stage ($n = 65$ mummies), 89% at 55 days ($n = 28$ mummies), and 93% at 80 days ($n = 28$ mummies). In contrast, ca. 12% of 121 mummies transferred from 12 h daylength to 14 h daylength at 28 days from the egg stage yielded *A. albipodus* adults within 47–75 days.

Dissection of five of the mummies transferred to 14 h daylength at each of 48, 55, and 80 days from the egg stage indicated that the remaining mummies contained living last-instar larvae (15/15 total mummies dissected contained live last-instar larvae). Although additional adult emergence from the mummies transferred to 14 h daylength was plausible given the prevalence of live last instar larvae inside these mummies after 80 days, these were accidentally destroyed at 84 days when a mechanical failure caused a sudden increase in the ambient temperature to >40° C for ca. 20 h.

DISCUSSION

Our results showed that *A. albipodus* entered diapause when it developed under a 12 h daylength. The incidence of diapause in *A. albipodus* at this daylength, discounting for mummy stage mortality evident under the 14 h daylength (ca. 8%), was ca. 68%, and it occurred in the last larval instar. In addition, our results showed that diapause could be broken in some *A. albipodus* individuals by exposing diapausing mummies to a 14 h daylength. In contrast to *A. albipodus, D. rapae* did not enter diapause when it developed under a 12 h daylength.

Our findings concerning *A. albipodus* were not unexpected, whereas those concerning *D. rapae* were initially puzzling given the climatic conditions prevalent in their areas of origin (Fig. 2). Mean monthly temperatures at Tahcheng, *A. albipodus*' collection site, vary from −16° C in January to 22° C in July, and daylengths vary from 8.5 h in December to 15.9 h in June. Temperature conditions in Wuqia, *D. rapae*'s collection site, are less extreme than in Tahcheng, ranging



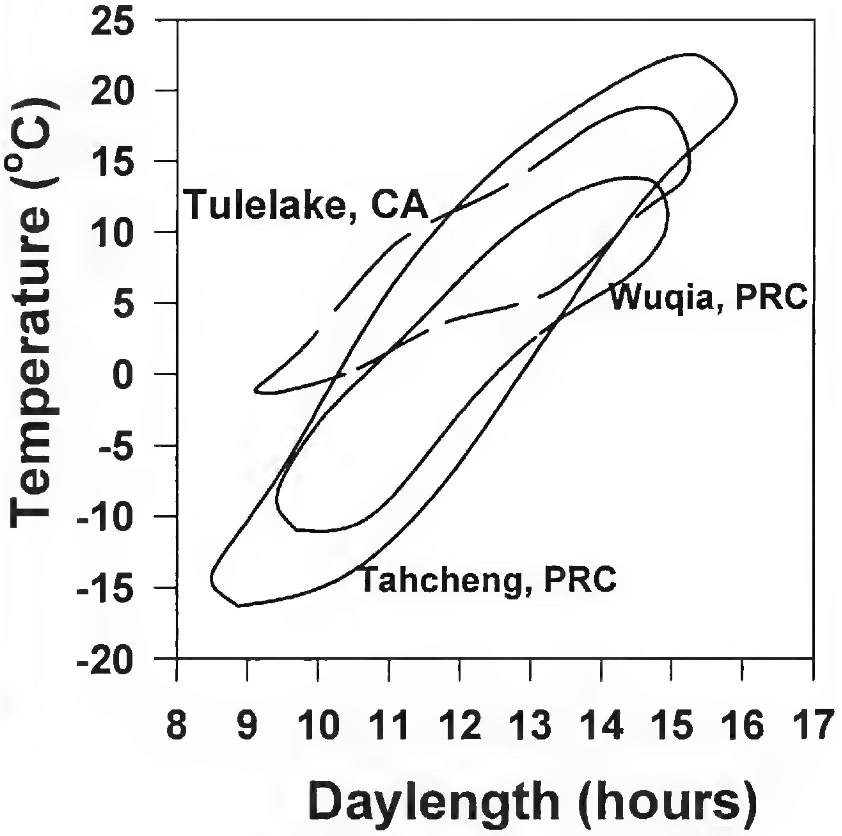


Figure 1. Emergence rates of *Aphelinus albipodus* and *Diaeretiella rapae* under two daylengths (21° C, 50–70% R.H.); hollow columns = 14 h daylength, stippled columns = 12 h daylength. Numbers above column pairs indicate significance of difference in emergence rates between 14 h and 12 h daylengths: *A. albipodus*, $G = 306.470$, 1 df, $n = 685$; *D. rapae*, $G = 0.666$, 1 df, $n = 719$.

Figure 2. Daylength (on the 15th of each month) and mean monthly temperature variation in: Tahcheng, People's Republic of China, *Aphelinus albipodus*' collection site; Wuqia, PRC, *Diaeretiella rapae*'s collection site, and; Tulelake, California, a representative northern California colonization site for *A. albipodus* and *D. rapae*.

from −11° C in January to 13.5° C in July, while daylengths are similar, 9.4 h in December to 14.9 h in June. Despite differences in temperature, winter conditions in both Tahcheng and Wuqia would require a mechanism by which *A. albipodus* and *D. rapae* could survive during 5 months of subfreezing mean monthly temperatures.

Diapause provides a mechanism for winter survival in *A. albipodus.* Mean monthly temperatures and average daylengths in Tahcheng closely match temperature- and daylength-related developmental restrictions in *A. albipodus* that are evident from this and other studies (Bernal & González 1996; Bernal et al. 1997). Those studies showed that *A. albipodus:* (i) enters diapause at 12 h daylengths, and; (ii) cannot develop to adulthood if temperatures are 10° C or below. *Aphelinus albipodus* mortality at 10° C is >80% during egg to mummy development, and adults do not emerge from mummies that develop at this temperature (Bernal & González 1996; Bernal et al. 1997). Mean temperatures in Tahcheng decrease to 10° C and below in the fall, and are associated with 12 h and shorter daylengths. Mean temperatures then increase to 10° C and above in the spring and are associated with 14 h and longer daylengths. Thus, *A. albipodus* may avoid fatally low temperatures by entering diapause when daylengths decrease to 12 h in the fall, then resuming development when daylengths increase to 14 h in the spring.

In contrast to *A. albipodus,* diapause was not detected in *D. rapae* at 12 h daylength. Based on our results, however, we cannot discount the possibility of diapause in this parasitoid. *Diaeretiella rapae* populations in the Netherlands enter diapause during the winter (Hafez 1961). Moreover, diapause in these *D. rapae* populations peaks in late October (Hafez 1961) when daylengths are between 10.7 and 8.8 h. Thus, diapause may be induced at daylengths shorter than 12 h in the Wuqia *D. rapae* population. Average daylengths in Wuqia decrease to 12 h in the early fall and are associated with mean temperatures of ca. 7° C. Later in the fall, mean temperatures decrease to subfreezing levels, but daylengths by then decrease to 10.5 h and shorter. Previous studies show that developmental mortality in *D. rapae* is low at 10° C, and that its lower developmental threshold is in the range 2.5–3.9° C (Bernal & González 1995, 1997). Thus, diapause at 12 h daylength in the Wuqia *D. rapae* population may not be necessary given the associated mean field temperatures (ca. 7° C) in the area. Hence, based on the results of previous studies (Hafez 1961; Bernal & González 1995, 1997) and on the lengthy and severe winters prevalent in Wuqia, a likely scenario is that diapause in *D. rapae* is induced by daylengths shorter than 12 h, which are associated with near- or sub-freezing temperatures.

Our results concerning *A. albipodus* are consistent with previous reports of diapause in closely related *Aphelinus* spp. Yu (1992) found that >50% and >95% of *A.* nr. *varipes* (= *A. varipes,* see Bernal et al. 1997; J. B. Woolley, personal communication) collected in southern Alberta (Canada) entered diapause when they developed under 14 h and 12 h daylengths, respectively. The corresponding rates for *A. varipes* collected in Kazakhstan (= *A. albipodus,* see Bernal et al. 1997; J. B. Woolley, personnel communication) were 0% and >90%. Diapause was induced by short daylengths both in Yu's and this study. Short daylengths in these cases are associated with low winter temperatures that may be particularly detrimental to *Aphelinus* species. Developmental thresholds and high mortality at temperatures between 5 and 10° C are common in *Aphelinus* spp. (e.g., Force &

Messenger 1964; Walker et al. 1988; Trimble et al. 1990; Asante & Danthanarayan 1992; Lajeunesse & Johnson 1992; Yu 1992; Bernal & González 1993, 1996; Bernal et al. 1997; Lee & Elliot 1998a, b). Thus, *Aphelinus* spp. appear to be highly susceptible to low temperatures and to employ diapause as an overwintering strategy (Trimble et al. 1990; Yu 1992; this study).

Both *A. albipodus* and *D. rapae* were imported to California for release against Russian wheat aphid (González et al., unpublished data). Both were extensively released in northern California and *A. albipodus* rapidly became established. It is unclear at present whether *D. rapae* became established because this species already occurred in the area. In either case, it is evident that the climate in northern California is milder during the winter relative to the collection areas of both parasitoids, and daylength variation during the year is similar between these areas, or less in the case of *D. rapae* (Fig. 2). Thus, although diapause may be induced by short winter daylengths in northern California, it may not be required for winter survival of *A. albipodus* and *D. rapae.* Summer, rather than winter, temperatures may represent an obstacle for establishment of *D. rapae,* in particular, in northern California. Earlier studies showed that *D. rapae* is more susceptible to high temperatures than *A. albipodus* (Bernal & González 1995, 1996). This is suggested also by the seasonal variation in mean temperatures in each of these parasitoid's collection sites. Thus, winter diapause and summer survival are two important factors that may affect the population dynamics of *A. albipodus* and *D. rapae* and their impact on Russian wheat aphid populations in California. Moreover, the timing of emergence of diapausing parasitoids in the spring will likely influence their impact on Russian wheat aphid populations. Previously it was suggested that in annual agroecosystems, early-appearing natural enemies are likely to have a greater impact on pest populations than those emerging later in the season (Bernal & González 1993; Gilstrap 1997). Our results, and previous studies (Bernal & González 1995, 1996), suggest that *A. albipodus* is likely to emerge later in the season than *D. rapae.*

Differences in climate between collection and colonization areas of exotic natural areas are reported to contribute substantially to reducing the success rate of classical biological control (Stiling 1993). Specifically, they hamper biological control efforts early on in their development by precluding the successful establishment of exotic natural enemies. A practice that could contribute substantially to reducing the number of biological control efforts that fail during the colonization phase is to emphasize closer climate-matching during the planning phase of foreign exploration efforts. An approach similar to that taken to forecast potential range expansions of pest species (Meats 1989; Hughes & Maywald 1990) would be desirable, but may seldom be possible with exotic natural enemies. Unlike pest species, usually little or no information is available concerning an exotic natural enemy's response to temperature and other biological parameters necessary for such an approach. Many times exotic natural enemies are undescribed species and biological information can only be inferred from related species; other times, the available information is limited to a taxonomic description. In both cases, pertinent biological information becomes available only after a series of studies are conducted. We believe that the analyses presented here, including the results from previous studies (Bernal & González 1995, 1996, 1997; Bernal et al. 1997), provide an initial model for assessing the potential for successful establishment of exotic natural enemies early in the development of a biological control campaign, and a means for improving the success rate of classical biological control. Ultimately, the success of a classical biological control campaign is contingent upon the successful establishment of exotic natural enemies.

ACKNOWLEDGMENT

We are grateful to Dr. Bob Wharton and Janet Griset (both at Texas A&M University) for critically reviewing the manuscript and for suggestions for its improvement. Marcella Waggoner and her team provided the aphids and parasitoids used in the experiments. Our Chinese collaborators, G. Zhang, J. Zhang, W. Zhang, Y. Min, R. Wang, Du Bing Ren, Wei Zhengming, Geng Shouguang, J. Wen, X. Liu, and Y. Zhong are gratefully acknowledged for their skilled assistance during foreign exploration in China.

LITERATURE CITED

Anonymous. 1993. Daily average temperatures and precipitation in California. Statewide IPM Project, University of California, Davis.

Asante, S. K. & W. Danthanarayana. 1992. Development of *Aphelinus mali* an endoparasitoid of wooly apple aphid *Eriosoma lanigerum* at different temperatures. Entomol. Exp. Appl., 65: 31–37.

Beddington, J. R., C. A. Free & J. H. Lawton. 1978. Characteristics of successful natural enemies in models of biological control of insect pests. Nature, 273: 513–519.

Bernal, J. S. & D. González. 1993. Temperature requirements of four parasites of the Russian wheat aphid *Diuraphis noxia*. Entomol. Exp. Appl., 69: 173–182.

Bernal, J. S. & D. González. 1995. Thermal requirements of *Diaeretiella rapae* (M'Intosh) on Russian wheat aphid (*Diuraphis noxia* Mordwilko, Hom., Aphididae) hosts. J. Appl. Ent., 119: 273–277.

Bernal, J. S. & D. González. 1996. Thermal requirements of *Aphelinus albipodus* (Hayat and Fatima) (Hym., Aphelinidae) on *Diuraphis noxia* (Mordwilko) (Hom., Aphididae) hosts. J. Appl. Ent., 120: 631–638.

Bernal, J. S. & D. González. 1997. Reproduction of *Diaeretiella rapae* on Russian wheat aphid hosts at different temperatures. Entomol. Exp. Appl., 82: 159–166.

Bernal, J. S., M. Waggoner & D. González. 1997. Reproduction of *Aphelinus albipodus* (Hymenoptera: Aphelinidae) on Russian wheat aphid (Hemiptera: Aphididae) hosts. Eur. J. Entomol., 94: 83–96.

DeBach, P. & D. Rosen. 1991. Biological control by natural enemies (2nd ed.). Cambridge University Press, Cambridge.

Flanders, S. E. 1940. Environmental resistance to the establishment of parasitic Hymenoptera. Ann. Entomol. Soc. Amer., 33: 245–253.

Force, D. C. & P. S. Messenger. 1964. Duration of development, generation time, and longevity of three hymenopterous parasites of *Therioaphis maculata* reared at various constant temperatures. Ann. Entomol. Soc. Amer., 57: 405–413.

Gilstrap, F. E. 1997. Importation biological control in ephemeral crop habitats. Biol. Control, 10: 23–29.

Gilstrap, F. E., D. González & L. McKinnon. 1994. Biological control of Russian wheat aphid: a summary of 1998–1993. pp. 53–61. *In* Peairs, F. B., M. K. Kroening, & C. L. Simmon (comps.). Proceedings of the sixth Russian wheat aphid workshop. Fort Collins, January 23–25, 1994. Great Plains Agricultural Council, Fort Collins.

González, D. & F. E. Gilstrap. 1992. Foreign exploration: assessing and prioritizing natural enemies and consequences of preintroduction studies. pp. 53–70. *In* Kauffman, W. C. & J. E. Nechols (eds.). Selection criteria and ecological consequences of importing natural enemies. Entomol. Soc. Amer., Lanham.

Greathead, D. J. & A. H. Greathead. 1992. Biological control of insect pests by insect parasitoids and predators: the BIOCAT database. Biocontrol News Info., 13: 61N–68N.

Hafez, M. 1961. Seasonal fluctuations of population density of the cabbage aphid, *Brevicoryne brassicae* (L.) in The Netherlands, and the role of its parasite, *Aphidius* (*Diaeretiella*) *rapae* (Curtis). T. Pl.-ziekten, 67: 445–548.

Huffaker, C. B., F. J. Simmonds & J. E. Laing. 1974. The theoretical and empirical basis of biological control. pp. 41–78. *In* Huffaker, C. B. & P. S. Messenger (eds.). Theory and practice of biological control. Academic Press, New York.

Huffaker, C. B., R. F. Luck & P. S. Messenger. 1977. The ecological basis of biological control. pp. 560–586. *In* White, D. (ed.). Proceedings, XV International Congress of Entomology. Washington, D. C., 19–27 August. Entomol. Soc. Amer., College Park.

Hughes, R. D. & G. F. Maywald. 1990. Forecasting the favourableness of the Australian environment for the Russian wheat aphid, *Diuraphis noxia* (Homoptera: Aphididae), and its potential impact on Australian wheat yields. Bull. Entomol. Res., 80: 165–175.

Lajeunesse, S. E. & G. D. Johnson. 1992. Developmental time and host selection by the aphid parasitoid *Aphelinus* sp. nr. *varipes* (Foerster) (Hymenoptera: Aphelinidae). Can. Ent., 124: 565–575.

Lee, J. H. & N. C. Elliot. 1998a. Comparison of developmental responses to temperature in *Aphelinus asychis* (Walker) from two different geographic regions. Southwest. Entomol., 23: 77–82.

Lee, J. H. & N. C. Elliot. 1998b. Temperature effects on development in *Aphelinus albipodus* (Hymenoptera: Aphelinidae) from two geographic regions. Great Lakes Entomol., 31: 173–179.

Luck, R. F. 1990. Evaluation of natural enemies for biological control: a behavioral approach. Trends Ecol. Evol., 5: 196–199.

Meats, A. 1989. Bioclimatic potential. pp. 241–252. *In* Robinson A. S. & G. Hooper (eds.). Fruit flies: their biology, natural enemies and control. Volume 3B. Elsevier, Amsterdam.

Messenger, P. S. 1959. Bioclimatic studies with insects. Ann. Rev. Entomol., 4: 183–206.

Messenger, P. S. 1971. Climatic limitations to biological control. Proc. Tall Timbers Conf. Ecol. Animal Control Habitat Mgmt., 3: 97–114.

Messenger, P. S. & N. E. Flitters. 1954. Bioclimatic studies of three species of fruit flies in Hawaii. J. Econ. Entomol., 47: 756–765.

Murdoch, W. W. & C. J. Briggs. 1996. Theory for biological control: recent developments. Ecology, 77: 2001–2013.

Murdoch, W. W., J. Chesson & P. L. Chesson. 1985. Biological control in theory and practice. Am. Nat., 125: 344–366.

Pearce, E. A. & G. Smith. 1990. The *Times* books world weather guide. Times Books-Random House, New York.

Stiling, P. 1993. Why do natural enemies fail in classical biological control programs? Amer. Entomol., 39: 31–37.

Trimble, R. M., L. R. H. Blommers & H. H. M. Helsen. 1990. Diapause termination and thermal requirements for postdiapause development in *Aphelinus mali* at constant and fluctuating temperatures. Entomol. Exp. Appl., 56: 61–69.

Walker, J. T. S., S. C. Hoyt, D. P. Carroll & G. V. Tangren. 1988. Influence of constant and alternating temperatures on wooly apple aphid (Homoptera: Eriosomatidae) and its parasitoid *Aphelinus mali* (Haldeman) (Hymenoptera: Aphelinidae). Melanderia, 46: 36–42.

Walter, H. & H. Lieth. 1967. Klimadiagram Weltatlas. VEB Gustav Fischer Verlag, Stuttgart.

Yu, D. S. 1992. Effects of photoperiod and temperature on diapause of two *Aphelinus* spp. (Hymenoptera: Aphelinidae) parasitizing the Russian wheat aphid. Can. Ent., 124: 853–860.

Zar, J. H. 1996. Biostatistical analysis. Prentice Hall, Englewood Cliffs.

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A NEW SPECIES OF *CORTICARINA* FROM ARIZONA (LATRIDIIDAE: CORTICARIINI)

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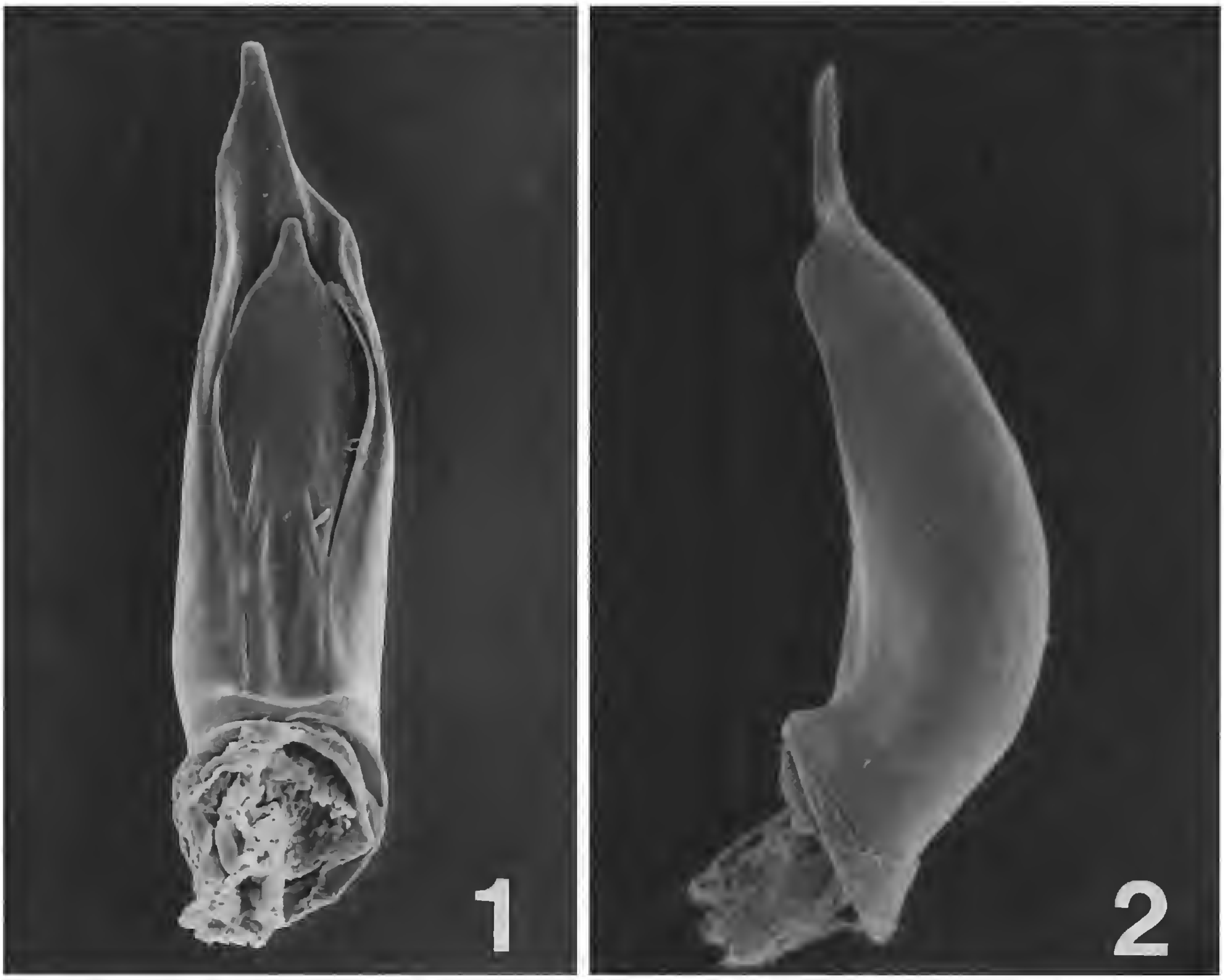
Abstract.—*Corticarina arizonensis* is described as new. It is compared to other North American species.

Key Words.—Insecta, Coleoptera, Latridiidae, *Corticarina,* Arizona.

In 1994 two specimens of *Corticarina* were swept from an oak tree at the base of a talus slope at approximately 9200 feet in the Barfoot campground in the Chiricahua mountains of Southeastern Arizona. Dissection of the lone male demonstrated a new species based on the unknown aedeagal shape. Recent collecting (1998) in the same spot yielded an additional twenty-one specimens. The same aedeagal shape was found when males from this collection were dissected. All specimens were collected within 100 feet of the original collection, but this time all were swept from conifers. Additional specimens were collected on Mt. Lemmon, Arizona at an elevation of 7500 feet from the flower heads of dead cow parsnip (*Heracleum lanatum* Michaux) in the company of numerous *Cortinicara gibbosa* Gyllenhal. Numerous collections of *Corticarina cavicollis* Mannerheim and *Corticarina fuscula* Gyllenhal have been made in the Chiricahua Mountains and Southeastern Arizona at lower elevations without evidence of this new species. It is likely that this species is restricted to the higher mountain elevations. *Corticarina arizonensis* can be differentiated from all other species of *Corticarina* by the shape of the male aedeagus (Figs. 1 and 2). *Corticarina arizonensis* is the only North American species in which both the dorsal and ventral lobes of the aedeagus are sharply pointed. The aedeagus of the other North American *Corticarina* are illustrated by Andrews (1985, 1992).

CORTICARINA ARIZONENSIS Andrews, NEW SPECIES

Description.—Length 1.33–1.59 mm. Width 0.63–0.74 mm. Pronotal length 0.30–0.37 mm. Pronotal width 0.37–0.44 mm. $n = 43$. Color dark brown to dark reddish brown; legs, antennal segments 2–6 lighter brown; surface shiny. Antennae 0.45–0.51 mm long, segment 8 longer than wide, segment 10 wider than long. Pronotum 1.11 to 1.47 times as wide as long; lateral margin slightly sigmoid in anterior one-half, widest in anterior one-half; postmedian depression weakly developed; lateral depression narrow, weakly developed, limited to posterior one-half; dorsally evenly rounded from side to side; lateral margins smoothly arcuate, minutely serrate. Pronotal surface distinctly punctured, punctures generally separated by approximately a puncture width. Elytra narrowly inflated, 1.13 to 1.75 times as long as wide. Elytral striae well defined; setae arranged in straight lines, each raised medially and generally terminating in next puncture; humeral callus distinct. Fully winged. Eyes fully developed, 77 facets in single eye examined. Male: protibia toothed on inner surface, tooth 45/100 from apex. Male genitalia as in Figs. 1 and 2.



Figures 1–2. Corticarina arizonensis aedeagus. Figure 1. Ventral view. Figure 2. Lateral view.

Types.—HOLOTYPE (Male): ARIZONA. Pima Co: Santa Catalina Mts., Mt. Lemon, Summerhaven, IX-17-1998, 32°26.26′ N, 110°45.52′ W, F. Andrews & T. Eichlin. Deposited in the collection of the California Academy of Sciences. PARATYPES (23). Same data as Holotype (11); ARIZONA. Cochise Co. Barfoot Park, VIII-2-1994, F. Andrews & T. Eichlin (2); 10.6 mi. NW Southwest Research Station, Barfoot Cpg., IX-14-1998, 31°55.11′ N, 109°16.47′ W, F. Andrews & T. Eichlin (10).

LITERATURE CITED

Andrews, F. G. 1985. *Corticarina scissa* (LeConte); a valid species (Coleoptera: Lathridiidae). Coleop. Bull. 39: 147–149.

Andrews, F. G. 1992. Two new species of *Corticarina* from coastal California (Coleoptera: Lathridiidae: Corticariini) with notes on J. L. LeConte types. the Coleop. Bull., 46: 274–280.

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MELANOTRICHUS BOYDI, A NEW SPECIES OF PLANT BUG (HETEROPTERA: MIRIDAE: ORTHOTYLINI) RESTRICTED TO THE NICKEL HYPERACCUMULATOR *STREPTANTHUS POLYGALOIDES* (BRASSICACEAE)

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Abstract.—*Melanotrichus boydi,* NEW SPECIES is described from the western foothills of the Sierra Nevada Mountains in California. The nickel hyperaccumulating species, *Streptanthus polygaloides* (Gray), Brassicaceae, an endemic to serpentine soils, is its only known host plant.

Key Words.—Insecta, Miridae, plant bugs, *Melanotrichus,* new species, nickel hyperaccumulators, serpentine soil.

As a consequence of its size, exceedingly diverse topography, climate, and geologic history, California supports a remarkably large and interesting flora (Munz & Keck 1973). Despite the pioneering work of E. P. Van Duzee and recent students of North American Miridae, the plant bug fauna of California is still poorly known. Current studies by the junior author in serpentine soil exposures of California have revealed a new species of plant bug restricted to a nickel hyperaccumulator species of crucifer. In this paper we describe *Melanotrichus boydi* Schwartz & Wall, NEW SPECIES, provide illustrations of the male genitalia, photomicrographs of the head, pretarsus, ostiolar peritreme, scalelike setae, a distribution map and discuss the first known example of bioaccumulation for a native herbivore on a metal hyperaccumulator. All measurements are based on ten specimens with the mean and range presented.

MELANOTRICHUS BOYDI Schwartz & Wall, New Species
(Figs. 1–14)

Types.—Holotype, male: U.S.A. CALIFORNIA. *ELDORADO Co.:* NE of Coloma, [900 m], 22 Jun 1998, M. A. Wall, ex *Streptanthus poly*[*galoides*]., M. Wall 98–105; deposited: California Academy of Sciences, San Francisco (CAS). Paratypes: 1♂, 1♀ same data as holotype except no host and M. Wall 1; *MARIPOSA Co.:* 1♂, 1♀ NW of Coulterville, [700 m], 23 Jun 1998, M. Wall (2); 3♂, 5♀ Lake McClure at hwy 49 [bridge], [900 m], 23 Jun 1998, M. Wall (9); 1♂, 5♀ NW of Mariposa, 29 Jun 1998, M. Wall (7); *PLACER Co.:* 1♂, 3♀ S of Sugar Pine Res[ervoir], [1270 m] 28 Jun 1998, M. A. Wall; *TUOLUMNE Co.:* 4♂, 4♀ S of Mocassin on hwy 49, [700 m], 11 Jun 1999, M. A. Wall; 4♂, 9♀ SW of Chinese Camp, Red Hills Rec Area, [470 m], 28 May 1999, M. A. Wall; 1♀ Chinese Camp, [470 m], 10 Jun 1997, M. A. Wall; 1♂ S of Chinese Camp in Red Hills Rec Area, [470 m], 9–13 Jun 1996, M. A. Wall. Paratypes deposited

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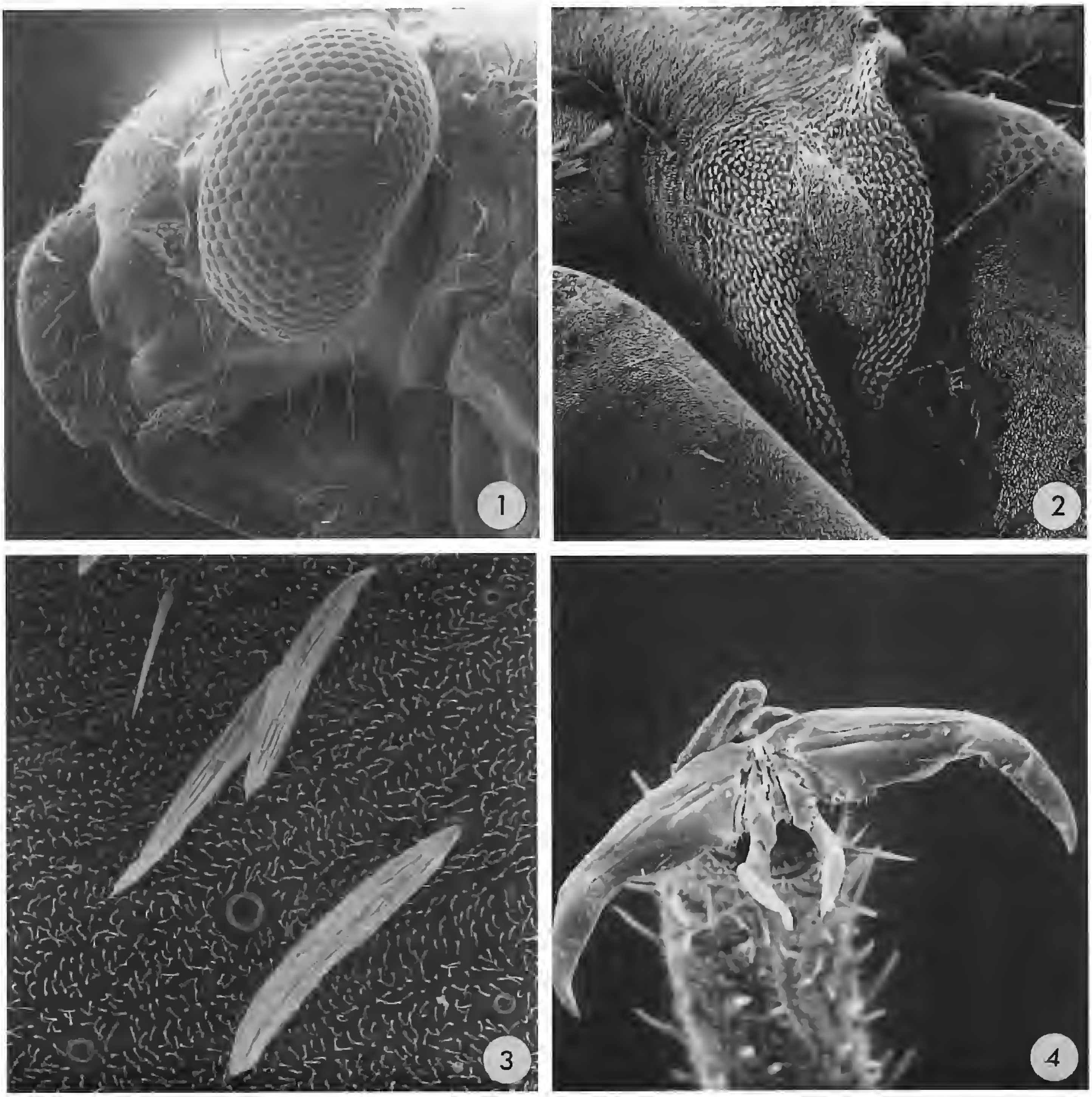
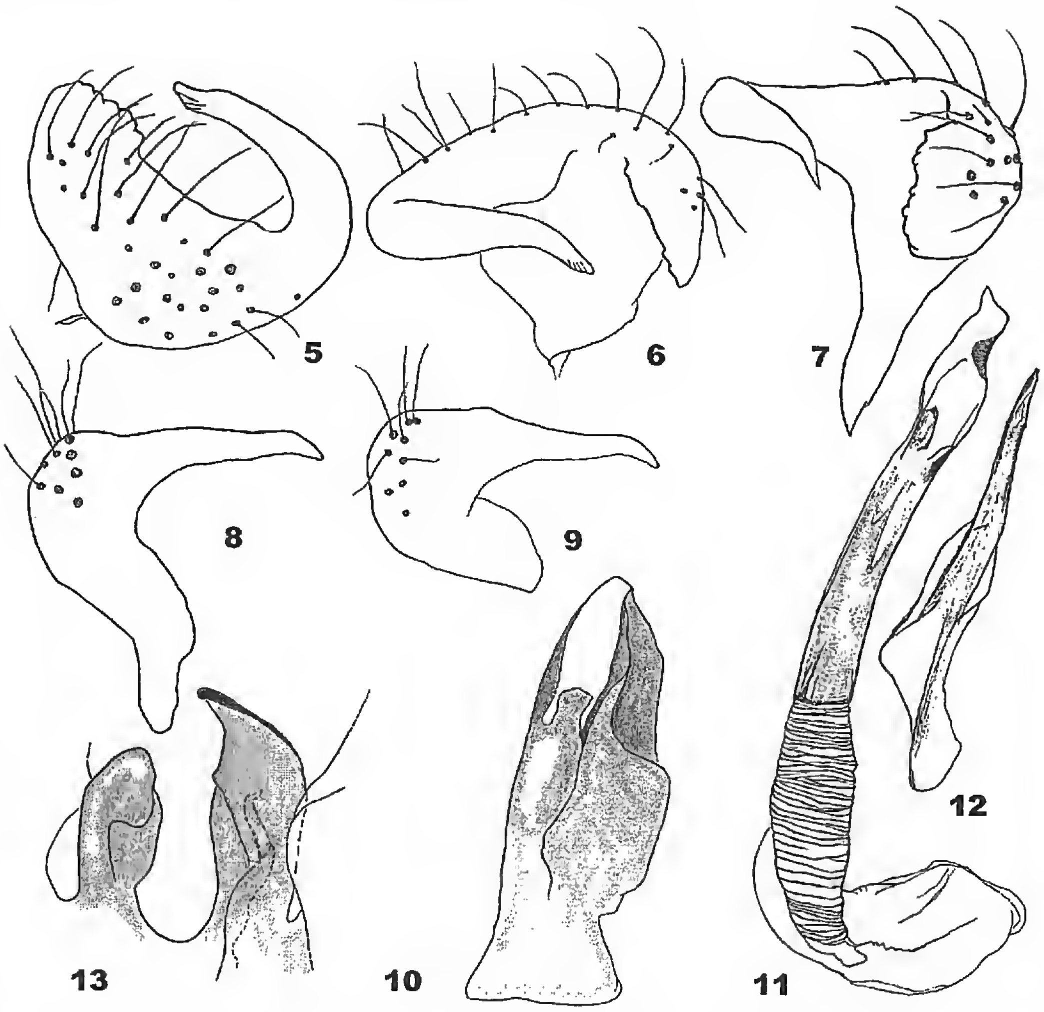


Figures 1–4. Scanning electron micrographs of *Melanotrichus boydi*. Figure 1. Head, lateral view. Figure 2. Ostiolar peritreme, lateral view. Figure 3. Scalelike setae on corium. Figure 4. Pretarsus, apical view.

at the American Museum of Natural History, New York, CAS, the Canadian National Collection of Insects, Ottawa and the National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Description of Males.—Orthotylinae: Orthotylini. Length from clypeus to apex of membrane 5.74 (5.20–6.15) mm, maximum width across hemelytra 1.88 (1.60–2.10) mm. *Head:* width 0.93 (0.88–0.99) mm, vertex width 0.39 (0.36–0.41) mm. *Labium:* length 1.14 (1.08–1.23) mm, reaching apex of mesosternum, sometimes just extending to slightly beyond middle of mesosternum, but labrum usually reaching apex of mesosternum. *Antenna:* segment 1, length, 0.55 (0.50–0.60) mm; 2, 1.86 (1.73–2.15) mm; 3, 1.60 (1.45–1.83) mm; 4, 0.47 (0.45–0.49) mm. *Pronotum:* length 0.70 (0.63–0.79) mm, basal width 1.34 (1.23–1.45) mm.

Generally green with greenish-yellow to orange-yellow on embolium, cuneus, mesoscutum, sometimes scutellum, pronotum on calli and anterior of calli, head, antennal segment 1, extreme base of antennal segment 2, legs, and venter; black on antennal segments 2–4, apex of labial segment 4, tarsus, pretarsus; membrane of hemelytra infuscate with greenish-yellow veins; dorsum with inter-



Figures 5–13. Male genitalia of *Melanotrichus boydi*. Figures 5–7. Left paramere. Figure 5. Apex of shaft, apical view. Figure 6. Sensory lobe, apical view. Figure 7. Sensory lobe, lateral view. Figures 8 and 9. Right paramere. Figure 8. Dorsal view. Figure 9. Lateral view. Figure 10. Phallotheca, dorsal view. Figure 11. Detail of ductus seminis & secondary gonopore, lateral view. Figure 12. Detail of spiculum, lateral view. Figure 13. Ventral processes of genital segment, apical view.

mixed vestiture of moderately distributed, shining white, reclining simple setae and head, anterior of pronotum and hemelytra with scattered shining, silvery, sericeous scalelike, setae (Fig. 3).

Head broadly subtriangular; clypeus moderately produced and slightly rounded in dorsal aspect, anteriorly flattened with slightly rounded ventral margin in lateral aspect (Fig. 1); posterior margin of head wider than, and slightly removed from, anterior margin of pronotum; basal carina broad, gently rounded; eyes large, height greater than head height in lateral aspect; posterior margin gently curved anteriorly in dorsal aspect; vertex width equal to 1.5× width of eye. Antennal segment 1 with moderately distributed, reclining, black simple setae and two subapical black bristles; diameter about 1.5× as wide as segment 2; segment 3 & 4 slightly thinner than segment 2. Pronotum trapeziform, calli slightly swollen. Mesoscutum moderately broadly exposed. Hemelytra subparallel-sided, widest at apex of embolium; length of cuneus about 3× width. Venter unmarked; ostiolar peritreme (Fig. 2). Legs long; tibia with dark brown to black bristles, unmarked at base; claw (Fig. 4) gently curved with minute pulvillus and apically converging parempodium.

Genitalia: Left paramere (Figs. 5–7) broad, C-shaped, sensory lobe with truncate, broadly serrate apex; shaft broadly curved, gradually attenuate. Right paramere (Figs. 8 and 9) L-shaped, broad basally, strongly attenuate distally. Phallotheca (Fig. 10) strongly sclerotized, convoluted, aperture on right aspect. Vesica with narrow elongate ductus seminis (Fig. 11) and one basally thickened, distally attenuate spiculum (Fig. 12); apex of spiculum subequal to apex of secondary gonopore (Figs. 11 and 12). Ventral processes of genital segment (Fig. 13); right process larger than left process, strongly sclerotized with flattened dorsal flange, which protrudes posteriorly beyond margin of genital aperture.

Description of Females.—Similar to males except, eye smaller, head and vertex wider, and hemelytral margin more rounded, length from clypeus to apex of membrane 5.86 (5.20–6.50) mm, maximum width across hemelytra 2.01 (1.80–2.29) mm. *Head:* width 1.01 (0.98–1.15) mm, vertex width 0.49 (0.45–0.53) mm. *Labium:* length 1.26 (1.20–1.38) mm, reaching apex of mesosternum, sometimes just extending to slightly beyond middle of mesosternum, but labrum usually reaching apex of me-

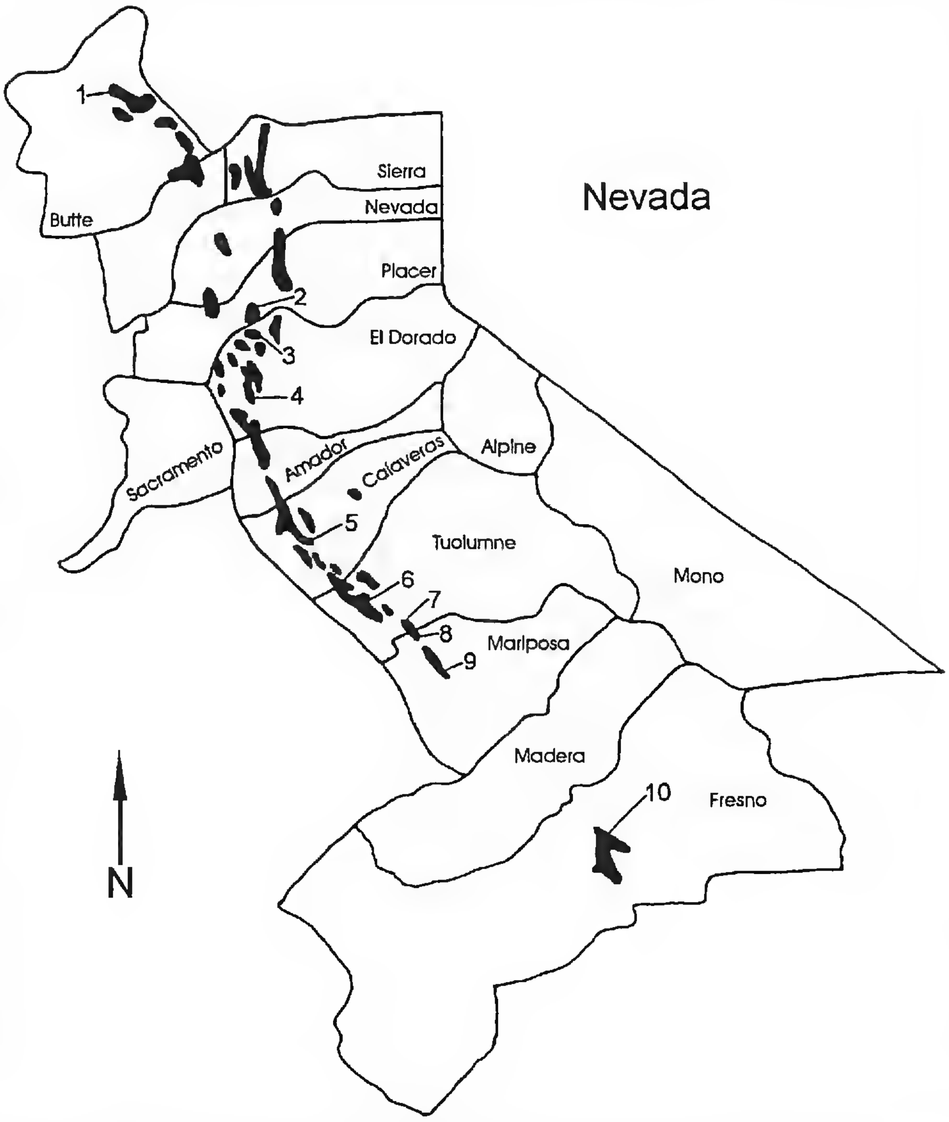


Figure 14. Distribution of *Melanotrichus boydi.* Areas filled in black represent distribution of serpentine soil within the foothills of the Sierra Nevada. *M. boydi* was either observed or collected at all numbered sites. Site numbers correspond with information presented in Table 1 (modified from Wall 1999).

sosternum. *Antenna:* segment 1, length, 0.58 (0.53–0.64) mm; 2, 1.85 (1.66–2.06) mm; 3, 1.49 (1.33–1.58) mm; 4, 0.46 (0.45–0.48) mm. *Pronotum:* length 0.81 (0.71–0.91) mm, basal width 1.58 (1.35–1.75) mm.

Diagnosis.—*Melanotrichus boydi* NEW SPECIES is most similar to *M. mistus* (Knight) and *M. stanleyaea* (Knight) in size (almost all other species of *Melanotrichus* are less than 5 mm in length) but is distinguished by the white simple setae on the dorsum, the black antennal segments 2–4, and the structure of male genitalia, especially the narrow apex of the right paramere and pointed vesical spiculum. *Melanotrichus mistus* has conspicuous black setae on the dorsum, yellow to orange antenna, and male genitalia with the apices of the right paramere and vesical spiculum blunt. *Melanotrichus stanleyaea* has similar pale vestiture to *M. boydi* but the antenna is pale, and the apex of the right paramere is longer and more acutely attenuated.

Taxonomy.—Schuh (1995) and Kerzhner and Josifov (1999) treat *Melanotrichus* Reuter as a subgenus of *Orthotylus* Fieber. However, given the absence of a phylogenetic analysis of the genus we choose to follow North American authors and describe our new species in the genus *Melanotrichus.* In Henry (1991: 455) *M. boydi* will key to *M. concolor* (Kirschbaum). In Knight (1968) this species will key to *M. stanleyaea* Knight, under *Dichaetocoris* Knight (cf., Knight 1968:

Table 1. Concentration of Ni found in sample of *M. boydi* collected at six sites throughout California (see Fig. 14). Concentrations represent values obtained from samples consisting of 15–20 individuals of *M. boydi* from each site analyzed via atomic absorption spectrophotometry.

Site location	Ni content in ppm on dry weight basis
Site 1	735
Site 3	751
Site 4	789
Site 6	777
Site 7	718
Site 10	751

114) or as *M. wileyae* Knight (cf. Knight 1968: 117). The black antennal segments 2–4, distribution, and host plant are sufficient to distinguish *M. boydi* from these species.

Hostplants.—Streptanthus polygaloides (Gray), Brassicaceae, a winter annual, endemic to serpentine soils from the foothills of the western slopes of the Sierra Nevada Mountains in California is the host of both immature and adult stages. Wall and Boyd (in press) provided evidence to indicate that *M. boydi* is probably monophagic. At ten localities where this species was collected on *S. polygaloides* they sampled other locally abundant plants—a conifer, three woody dicots, four herbaceous dicots, including other species of Brassicaceae and another species of *Streptanthus,* and a monocot—for the presence of *M. boydi* and did not collect any.

Distribution.—Figure 14. In addition to the localities listed under *Types, M. boydi* was also collected from the following sites in late-May to mid-July: *BUTTE Co.:* N of Magalia, 800 m; *CALAVERAS Co.:* N of San Andreas, 300 m; *FRESNO Co.:* NW of Pine Flat Lake, 400 m; *PLACER Co.:* S of Washington, 1330 m. In the western foothills of the Sierra Nevada *M. boydi* is associated throughout the range of *S. polygaloides* from Butte County in the north to Fresno County in the south encompassing a wide range of elevation (330 m to 1330 m) within the foothills woodland and the yellow pine forest plant communities.

Etymology.—Named to honor Dr. R. S. Boyd, Department of Botany and Microbiology, Auburn University, who provided insight and encouragement to the junior author during his Master's degree, and for his leadership in the study of hyperaccumulation ecology.

Discussion.—Melantrichus boydi is unique in several ways. Not only is it the only species of insect reported to specialize on a Ni hyperaccumulator, but it appears to accumulate Ni at levels one to two orders of magnitude higher than other insects found feeding on *S. polygaloides* (Wall 1999). This high level of Ni accumulation is concordant across the known range of *M. boydi* (Table 1). Botanists have long used a qualitative colorimetric test for identifying plants in the field that contain high levels of Ni. In this test, plant material is crushed onto filter paper permeated with the colorless chemical, dimethylglioxime, which reacts with the Ni in the plant and changes to a various shades of red (Reeves 1992). This same test consistently gives a positive result when *M. boydi* is crushed onto the filter paper. While perhaps only having novelty status, this colorimetric test adds another interesting element to the taxonomist's arsenal for identifying this species. At the very least, the presence of high levels of Ni in *M. boydi* is considered an autapomorphy for the species.

Including *M. boydi* n. sp., five North American mirids apparently specialize on brassicaceous hosts, all are members of the genus *Melanotrichus. Melanotrichus albocostatus* Knight is known from *Cardaria costatus, Descurainia sophia* (L.) Webb, and *Sisymbrium irio* L. Webb (Henry 1991), *M. leonardi* Kerzhner and Schuh is known from *D. sophia* (Kelton 1980), *M. stanleyaea* is known from *Stanleya pinnata* (Pursh) Britton (Knight 1968), and *M. whiteheadi* Henry is known from *D. pinnata pinnata* (Walt.) Britt. (Henry 1991). Interestingly, *S. pinnata* is a hyperaccumulator of Selenium (Brooks 1998). Determining whether or not host preference for Brassicaceae has evolved in multiple lineages, or if these five species represent a monophyletic group within *Melanotrichus* requires a detailed phylogenetic analysis, which is beyond the scope of this present study.

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LITERATURE CITED

Brooks, R. R. 1998. Geobotany and hyperaccumulators. Chapter 3. pp. 55–94. *In* Brooks, R. R. (ed.). Plants that Hyperaccumulate Heavy Metals. CAB International, Wallingford.

Henry, T. J. 1991. *Melanotrichus whiteheadi,* a new crucifer-feeding plant bug from the southeastern United States, with new records for the genus and key to the species of eastern North America (Heteroptera: Miridae: Orthotylinae). Proc. Entomol. Soc. Wash., 93: 449–456.

Kelton, L. A. 1980. Two new species of *Melanotrichus* Reuter from western Canada and a description of the male of *M. atriplicis* (Heteroptera: Miridae). Can. Entomol. 112: 337–339.

Kerzhner, I. M. & M. Josifov. 1999. Cimicomorpha II, Miridae. Volume 3. *In* Aukema, B & C. Rieger (eds.). Catalogue of the Heteroptera of the Palaearctic. The Netherlands Entomological Society, Wageningen.

Knight, H. H. 1968. Taxonomic review: Mirdae of the Nevada Test Site and the western United States. Brigham Young Univ. Sci. Bull., Biol. Ser., 9: 1–282.

Munz, P. A. & D. D. Keck. 1973. A California flora and supplement. University of California Press, Berkeley.

Schuh, R. T. 1995. Plant bugs of the world (Insecta: Heteroptera: Miridae). New York Entomol. Soc., New York.

Reeves, R. D. 1992. The hyperaccumulation of nickel by serpentine plants. pp. 253–277. *In* A. J. M. Baker, J. Proctor, and R. D. Reeves (eds.). The Ecology of Ultramafic (serpentine) Soils. Intercept, Andover.

Wall, M. A. 1999. Nickel accumulation in serpentine arthropods with emphasis on a species of *Melanotrichus* (Heteroptera: Miridae). M.S. Thesis, Auburn University, Alabama.

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Scientific Note

ALTITUDINAL DISTRIBUTION AND PHENOLOGY OF THREE SPECIES OF CARRION BEETLES (COLEOPTERA: SILPHIDAE) FROM NEVADO DE COLIMA, JALISCO, MÉXICO

The taxonomy of carrion beetles (Coleoptera: Silphidae) from México was revised by Peck, S. B. & R. S. Anderson (1985. Quaest. Ent., 21(3): 247–317) who recorded eleven species belonging to four genera. Other contributions, especially for Jalisco State include: Volcán de Tequila (Navarrete-Heredia, J. L. 1995. Dugesiana, 2(2): 11–26); Sierra de Manantlán (Rivera-Cervantes, L. E. & E. García-Real. 1998. Dugesiana, 5(1): 11–22), and La Primavera and Barranca del Río Santiago (Navarrete-Heredia, J. L. & H. E. Fierros-López. 1998. Dugesiana, 5(1): 49–50). This study was done in Jalisco by staff members from the Center for Zoological Research, University of Guadalajara to determine carrion beetle distribution. In this note, we describe our trapping results from the National Park Nevado de Colima, Jalisco, México.

Field work was done on the NW slope of the National Park Nevado de Colima, in the locality El Floripondio, Cerro Las Víboras, San Gabriel County, between 2200–3000 meters above sea level (m). We used carrion traps (model NTP-80) designed by Morón, M. A. & R. Terrón [1984. Acta Zool. Mex. n.s., (3): 1–47]. Six sites were selected: *Cupressus* forest (2300 m), oak-pine forest (2400 m), cloud forest (2600 m), *Abies* forest (2840 m), disturbed *Abies* forest (2920 m), and *Abies*-grass association (2950 m). One carrion trap was used for each site during one month, starting in April and ending in October 1998. Rotting squid was used as bait.

Three species of carrion beetles were collected: *Oxelytrum discicolle* (Brullé),

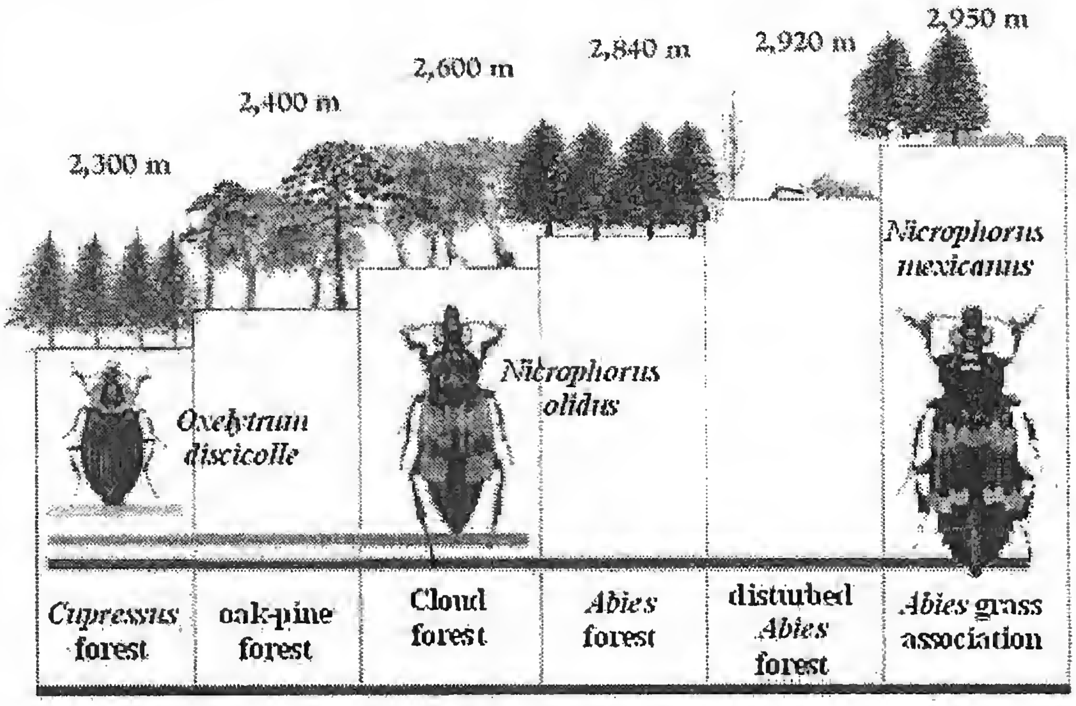

Figure 1. Altitudinal distribution of three Silphidae species from El Floripondio, Jalisco, collected with carrion traps.

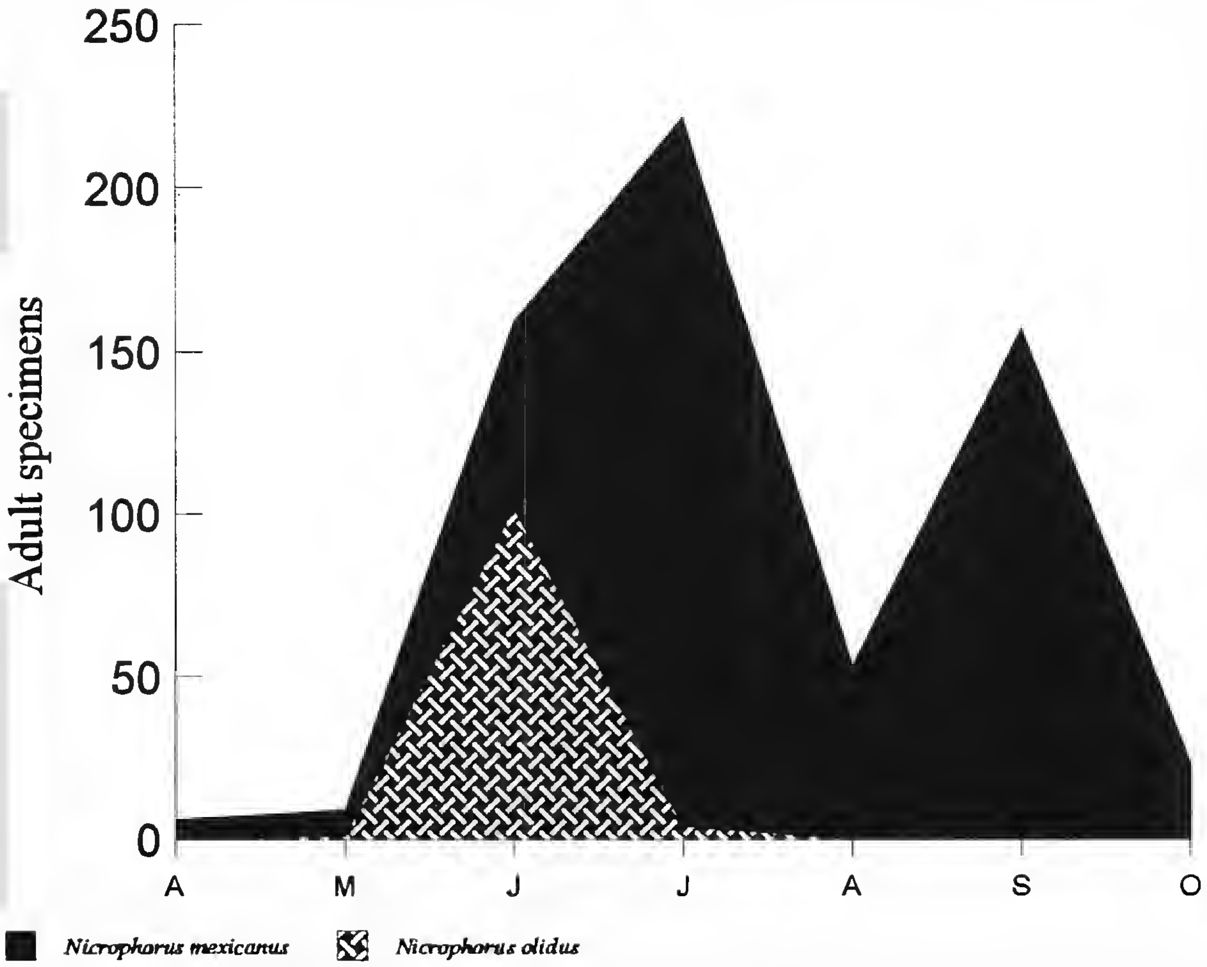

Figure 2. Abundance of *Nicrophorus mexicanus* and *N. olidus* from El Floripondio, Jalisco, collected with carrion traps between April and October, 1998.

Nicrophorus mexicanus (Matthews) and *Nicrophorus olidus* (Matthews). These species were represented by 743 specimens. *Nicrophorus mexicanus* was the commonest species (628 specimens), and was collected monthly and distributed between 2300–2950 m. *Nicrophorus olidus* was the second most common species, represented by 107 specimens, found between 2300–2600 m, but collected only during May–August (Fig. 1). Finally, only eight specimens of *O. discicolle* were collected in the *Cupressus* forest in June. Other Mexican localities demonstrating similar silphid abundance and distribution include: Volcán de Tequila, Jalisco (Navarrete-Heredia, 1995); Sierra de Manantlán (Rivera-Cervantes & García-Real, 1998) and Cofre de Perote, Veracruz (Arellano, L. 1998. Dugesiana, 5(2): 1–16). In all of them, *Nicrophorus* species are well represented, mostly at higher elevations, whereas *O. discicolle* is less abundant and restricted to lower places.

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FIRST RECORDS OF LEPTOPODIDAE IN WASHINGTON STATE (HEMIPTERA: HETEROPTERA) WITH NOTES ON HABITAT

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Abstract.—*Patapius spinosus* (Rossi) was found in several locations in Benton and Whitman Counties, Washington State. Adults were found from late January through late October with mating pairs and immatures being found only in the fall of the year. The bug was associated with cobblestone and basalt that was being used as roadgrade stabilization or in piles of such rock that had been left after construction activities.

Key Words.—Insecta, Leptopodidae, Hanford Site, *Patapius spinosus* (Rossi), Washington State.

Extant leptopodid bugs are primarily Old World in distribution with fossil evidence known from Mexico and Ecuador (Froeschner 1988). The first recording of a leptopodid from the United States was in California (Arbuckle, Colusa County) where a single individual was found during the examination of tree protectors used to trap peach twig borer larvae on almond trees (Usinger 1941). Subsequent to this first finding, the species in question, *Patapius spinosus* (Rossi) has been found in Nevada, and Idaho (Brothers 1979). *Patapius spinosus* is currently known from California, Nevada, and Idaho in the United States, the Canary Islands, Europe, North Africa, and has been introduced into Chile (Froeschner 1988). Both Brothers (1979) and Froeschner (1988) provide excellent illustrations of the bug. Our finding of this species at several widely separated locations in Washington State is a significant extension of its previously known range and may indicate that the species is relatively widespread in the western United States.

Patapius spinosus appears to be rather generalized in its habitat selection. Both Usinger (1941) and Brothers (1971) found the species in areas removed from water sources; Brothers (1971) found specimens on the undersides of cobblestone in a mine-tailings dump. The sites from which we obtained specimens are comparable to a mine tailings area except that our sites are located near water (which the tailings site may have been). Our first finding occurred at the Hanford Nuclear Site (Benton County) in southcentral Washington State. The Hanford Site is an area of native shrub-steppe vegetation with semi-arid climatic conditions that include hot and dry summers and cold winters. Annual precipitation is less than 12 cm. Temperatures range from an average of 3° C in Jan to 33° C in July; temperatures of 30° C or above occur an average of 56 days per year (ERDA 1975).

Specimens were found on the undersides of cobblestones that had been deposited along the margins of a built-up gravel road that ran parallel to an alkaline pond (West Lake—46°36.06′ N, 119°32.78′ W) located at 150 m in elevation. West Lake is the only naturally occurring pond on the Hanford Site. The pond is surrounded by an alkaline crust with no emergent macrovegetation along the shoreline. However, large areas of bullrush (*Scirpus* sp.) as well as various grasses and other vegetation occur in the area surrounding the pond. The size of the pond is a direct function of ground water elevation and fluctuates throughout long and short term periods depending on climate and seasonal weather conditions. On average, the pond encompasses 4 hectares. The first specimens were discovered while examining the undersides of the cobblestone on 15 Jan 1999. Subsequent to this finding, a more concerted effort was undertaken on 29 Jan during which several hundred rocks were turned and 30 adult specimens located. Again, on 12 Feb, several specimens were found; we continued to find specimens, sporadically, throughout the summer and into early September when the study, at this site, was discontinued. Only material from the first two collecting dates were taken and processed. Additionally, a single specimen was collected in a pitfall trap (14–26 Aug 1998) located in vegetation surrounding West Lake. Although no effort was made at these times to quantify our collections, we noticed that specimens were never found on the section of rock that was in contact with the soil (moist) and that there appeared to be a certain clumping phenomenon to their discovery. Although few rocks harbored specimens, multiple specimens were sometimes discovered under individual rocks. Specimens are deposited in the M. T. James Entomological Collection, Washington State University.

In an examination of the M. T. James Entomological Collection, Washington State University, we located two specimens that had been collected along the Snake River at the McCauley Ranch that was located (area since flooded) between Almota and Penwawa Canyons (Whitman County) on 20 Mar 1971. A descriptive label on these specimens stated that they had been collected under rocks, as had our Hanford Site specimens. We therefore expanded our survey activities to several, apparently likely sites adjacent to the Snake River. These sites were all located in Whitman County, along the Snake River: Wawawai River road, approximately 19 km SW of Pullman (46°36.91′ N, 117°22.51′ W); corner of Wawawai Grade road and Wawawai River road, approximately 17 km SW of Pullman (46°36.05′ N, 117°22.65′ W); Almota, (Fig. 1) approximately 24 km W of Pullman (46°42.22′ N, 117°27.98′ W) and; Boyer Park (Fig. 2) (at Lower Granite Dam) approximately 22 km WSW of Pullman (46°40.64′ N, 117°26.74′ W).

On 28 Feb 1999, sampling was conducted at the above-delineated Snake River sites. Records were kept of the number of rocks turned, the number of times leptopodids were found, and in what size "groups." A total of 1610 rocks were turned with 94 leptopodids found. Specimens were found singly and in groups of up to 10 on the underside of a single rock. While no samples were taken during the summer, on 21 Oct 1999 the Snake River sites were again surveyed. At this time, no count of bugs was maintained and only a small number were collected and processed. However, the number of leptopodid adults was high and, indeed, appeared higher than during our winter sampling periods. Additionally, this was the only time that we found mating pairs and immatures. Again, leptopodids were found in small piles of cobblestone and basalt rock that had been used as road-grade support or had been left in small piles (often of several hundred rocks) after completion of road or walking path construction. These latter piles were often scattered and had been overgrown with grasses (Fig. 2). It is interesting to note that not every pile of rock contained the bugs but, when they were found, numerous rocks within the pile harbored them.

Rocks with leptopodids underneath always contained some open space below and were almost never wet. In the few instances where rocks with leptopodids below were wet, all of the surrounding rocks in the pile were also wet. In most

Figure 1. Basalt rock used for roadside grading at Almota (Whitman County).

Figure 2. Pile of basalt rock at Boyer Park (Whitman County).

areas, when wet and dry rocks were adjacent, it appeared that the insects favored the dry rocks. Rocks with leptopodids on them varied extremely in color and arrangement. There was no apparent pattern in size or color of rock and the number of specimens occurring on the underside of the rock. Some piles of rocks were embedded in grasses; others were on bare dirt. In no cases were leptopodids found on the steep piles of basalt rubble adjacent to roadwork or railroads. When the insects were found near railways and road cuts, they were always on the undersides of rocks arranged in a flatter and less congested manner.

It is interesting to speculate on how *P. spinosus* was introduced into Washington. At both Hanford and the Snake River sites, the bugs were found under cobblestone, river rock that is used for stabilization of roadways. In all instances, the rock had been brought to the site from other areas that could not be discerned by us. However, at Hanford, the rock may have come from the adjacent Columbia River (approximately 3 km from West Lake) and, at the Whitman County sites, rock may have come from the adjacent Snake River. It may be that the bugs are associated with cobble habitat and are distributed as this rock is moved and used in construction efforts. Unfortunately, besides our minimal observations, we have no evidence of such movement.

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LITERATURE CITED

Brothers, D. R. 1979. First record of *Patapius spinosus* in Idaho and Nevada (Hemiptera: Leptopodidae). Great Basin Nat., 39: 195–196.

Energy Research and Development Administration (ERDA). 1975. Final Environmental Statement, Waste Management Operations. ERDA-1538. Volume 2. Energy Research Development Administration, Richland, Washington.

Froeschner, R. C. 1988. Family Leptopodidae Amyot and Serville, 1843. p. 166. *In* Henry, T. J. and R. C. Froeschner (eds.). Catalog of the Heteroptera, or True Bugs, of Canada and the Continental United States. E. J. Brill, Leiden.

Usinger, R. L. 1941. A remarkable immigrant leptopodid in California. Bull. Brooklyn Entomol. Soc., 36: 164–65.

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Scientific Note

ERNOBIUS MOLLIS (L.) (COLEOPTERA: ANOBIIDAE): AN EXOTIC BEETLE COLONIZES MONTEREY PINE, *PINUS RADIATA* D. DON, IN NORTHERN CALIFORNIA

In 1990, the first collection of the bark anobiid, *Ernobius mollis* (L.), west of Texas was made in Oakland, Alameda County, California from a living Norway spruce, *Picea abies* (L.) Karsten, planted as an ornamental tree (Seybold, S. J. & J. L. Tupy, 1993. Pan-Pacif. Entomol., 69: 36–40.). *Ernobius mollis* is native to northern Europe, but has been introduced into North America (Craighead, F. C. 1950. Insect Enemies of Eastern Forests, USDA For. Serv. Misc. Pub. 657.) and the southern hemisphere (Casimir, J. M. 1958. Div. Wood Tech., For. Comm. New South Wales Tech. Notes, 2: 24–27 [Australia, New Zealand, and South Africa]). Seybold and Tupy (1993) speculated that *E. mollis,* known to colonize Monterey pine, *Pinus radiata* D. Don, in the southern hemisphere, might soon colonize the abundant urban plantings of *P. radiata* in the San Francisco Bay Area.

On 20 Sep 1993, a homeowner in Albany, Alameda County, California (Talbot Street) reported that she had observed insect damage in a variety of wooden articles in her home. On examination of her residence, none of the wooden articles of concern to the homeowner appeared to harbor active infestations of wood-destroying insects. However, examination of several pieces of barked *P. radiata* firewood stacked within the structure indicated that the small branch sections were infested with a wood-boring insect. These *P. radiata* branches had emergence holes through the bark surface. Peeling the already loose bark from the xylem revealed live larvae and pelleted frass in the bark-xylem interface as well as larval insect galleries etched in the xylem surface. The homeowner reported that the *P. radiata* branches had been cut approximately six months earlier (i.e., Mar 1993) from a standing tree in Fremont, Alameda County, California on Bud Court near the Highway 880 Mowry Avenue Exit. The branches were placed in a laboratory cage at the University of California at Berkeley at ambient indoor temperature (16° C to 29° C) and larval and adult *E. mollis* were periodically collected from the logs from Sep 1993 to Jun 1996. By Jun 1996 the bark-xylem interface had been completely obliterated and the remaining paper thin bark formed an easily damaged shell over the xylem.

This collection documents the presence of *E. mollis* in urban plantings of *P. radiata* in the San Francisco Bay Area. Although this collection record was from cut branches, future northern California reports of infestations from moribund *P. radiata* and perhaps other ornamental conifers should be expected. Through its association with moribund tree tissue, *E. mollis* may also play a role in the dissemination of the pitch canker fungus, *Fusarium circinatum* Nirenberg & O'Donnell (Nirenberg, H. I. & K. O'Donnell. 1998. Mycologia, 90: 434–458.), a fairly recently introduced and fatal disease of *P. radiata* and other pines in coastal northern California (McCain, A. H., C. S. Koehler & S. A. Tjosvold. 1987. Calif. Agric., 41: 22–23.). In Europe, *E. mollis* is documented to infest cones of Douglas-fir, *Pseudotsuga menziesii* (Mirbel) Franco, and giant sequoia, *Sequoiadendron giganteum* (Lindley) J. Buchholz (Roques, A. 1983. Les insectes ravageurs des cônes et graines de conifères en France, Institut National De La Recherche Agronomique Publication.). A native species of *Ernobius* [*punctulatus* (LeConte)] is known to infest cones of *P. radiata* (White, R. E. 1982. A Catalog of the Coleoptera of America North of Mexico Family Anobiidae, USDA Agric. Handbook No. 529-70, Furniss, R. L. & V. M. Carolin 1992. Western Forest Insects, USDA For. Serv. Misc. Publ. No. 1339.) and to acquire the pitch canker fungus through its association in the *P. radiata* cone with other cone-infesting insects (Hoover, K., D. L. Wood J. W. Fox & W. E. Bros. 1995. Can. Entomol., 127: 79–91.). Therefore, association of *E. mollis* with moribund *P. radiata* cone tissue and the bark-xylem interface of branch and stem material appear to be a likely means for this introduced insect to disseminate pitch canker disease in northern California. As both the insect and the fungal pathogen have wider host ranges among conifers, *E. mollis* could play a role in transmission of the fungus to new hosts and to new regions such as the montane forests of the Sierra Nevada or the coastal forests of the Pacific Northwest.

Pinus radiata is frequently brought into coastal California homes as firewood, and this example illustrates how easily larval and adult *E. mollis* might enter homes. However, experiences from Europe, the southern hemisphere, and eastern North America suggest that because of its requirement for bark-covered sapwood, *E. mollis* will not be a pest in structures in northern California unless it encounters bark-covered timbers, or boards with unfinished edges or bark-occluded knots. This example also illustrates that although an active infestation of *E. mollis* may be present in firewood in a structure, if damage to other, unbarked wooden items in the structure clearly occurred prior to manufacture, any relationship between *E. mollis* and the damage can likely be discounted.

Finally, the original colony of *E. mollis* collected 22 Feb 1990 in Oakland was maintained until Aug 1996 in a laboratory cage at ambient indoor temperature on the original *P. abies* branch and stem material. On 12 Jul 1996, seven live male and twelve live female adults were recovered from the cage. One pair of these adults was observed *in copulo* and live larvae were also present. On 6 Aug 1996, one live male, four live females, and two live larvae were also recovered from the cage before the logs were frozen and disposed of. Thus, multiple, consecutive generations of *E. mollis* successfully re-infested the same dry substrate for more than 6.5 years.

Record.—USA. CALIFORNIA. ALAMEDA CO.: 1.5 km SE Albany Hill, Talbot Street, Albany, 20 Sep 1993, S. J. Seybold, *Pinus radiata.*

Acknowledgment.—I thank R. Kohl for bringing this occurrence of *E. mollis* to my attention; A. J. Blomquist (University of Nevada, Reno) for helping to process the specimens; D. L. Wood (University of California at Berkeley) and B. J. Cabrera (University of Minnesota) for critical reviews of earlier drafts of this report; and N. G. Rappaport (USDA Forest Service, Albany, California) for translation of French literature. This work was supported by a cooperative research agreement (PSW-92-0014CA) between DLW and the Chemical Ecology of Forest Insects Project, Pacific Southwest Research Station, U.S. Department of Agriculture, Forest Service, Albany, California. Specimens of *E. mollis* recovered from *P. radiata* were deposited in the California Academy of Sciences Entomology Collection, Golden Gate Park, San Francisco, California 94118.

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Scientific Note

RANGE EXTENSION OF *PSENEO PUNCTATUS* FOX AND NOTES ON PREDATION OF AN INTRODUCED SHARPSHOOTER, *HOMALODISCA COAGULATA* (SAY)

The tribe Psenini Bohart & Menke (Hymenoptera: Sphecidae: Pemphredoninae) was described in 1976 (Bohart, R. M. & S. Menke 1976. Sphecid wasps of the world, a generic revision, University of California Press, Berkeley, California, USA). It is a poorly understood group, and basic biologies are unknown. Psenini are small, slender, delicately constructed wasps that most commonly occur in association with damp shady situations. Some genera and species within the tribe are located in southern California (R. M. Bohart, personal communication). However, only one species of *Pseneo* has been recorded in California, *Pseneo longiventris* (Cameron) (van Lith, J. P. 1975. Neotropical species of *Psen* and *Pseneo* [Hymenoptera: Sphecidae: Psenini]. Tijdeschrift voor Entomologie. 118: 1–41).

We became aware of a large aggregate of digging wasps on the grounds of the University of California Riverside in August 1998. Many of the nests seemed to be completed, closed, nests, but the majority had entrances open with provisioning occurring. Many nests were so close together that the mounds at the entrances were overlapping. The wasps appeared to have little difficulty finding their own nests, and no aggressiveness was observed between neighboring females. We counted 181 nesting sites within 30 plant propagation trays (45 × 45 × 10 cm) filled with U. C. mix #3 (Matkin, O. A. & P. A. Chandler. 1957. The UC soil type mixes. U. C. Berkeley, California Agriculture Experiment Station, Manual 23) to a depth of 6 cm. All trays were located within a 10 m^2 area in an open lathhouse on raised benches. The soil-filled trays were being temporarily stored prior to being used for seedling establishment in unrelated experiments. Nesting wasps were observed wherever the soil was exposed in any of the trays. We observed wasps active in 53 (29%) of the observed 181 nesting sites.

Specimens were collected and identified as *P. punctatus* Fox, a species found from North Dakota to southern Mexico. Features of the male, including the species-specific details of the antenna and genital capsule, clearly match those of typical *P. punctatus.* However, the Riverside wasps have extensive reddish coloration on the legs in both sexes; in van Lith's (1975) key they run to *P. carolina,* a southeastern U.S. species described exclusively from females (also originally described as a subspecies of *P. punctatus*). Specimens of putative male *P. carolina* from Texas raise questions as to the validity of the taxon, as they are nearly identical to the California specimens of *punctatus* (A. Finnamore, personal communication), and the resultant distribution of "*carolina*" would apparently bisect the known distribution of *punctatus.* Our suspicion is that *P. punctatus* is a species with a large distribution and substantial geographic variation, which has not yet been sampled adequately to resolve the limits of the various forms, including *P. carolina,* which was probably inappropriately elevated to species status by van Lith. *Pseneo punctatus* represents the second *Pseneo* species collected in California (Bohart, personal communication; Krombein, K. V. 1979. Superfamily

Sphecoidea. pp. 1573–1740. *In* Krombein, K. V., P. D. Hurd, Jr., D. R. Smith & B. D. Burks [eds.]. Catalogue of Hymenoptera of America North of Mexico. 2: 1119–2209. Smithsonian Institution Press, Washington, D.C., USA). Voucher specimens are located at the University of California Riverside, Entomology Research Museum.

During our observations of *P. punctatus* over a period of several days we noted the following behaviors. Nest excavation was observed only in the afternoon. Nests were excavated with the mandibles and front legs. Soil was loosened by the mandibles, formed into a small uneven clump, and pushed backward beneath the body with the front legs. Usually the clumps of soil are thrown clear of the body by the initial thrust of the front legs. If not, the soil clumps are thrown clear of the body with the assistance of the middle and hind legs. The female typically digs the burrow vertically straight down. As the wasp digs deeper, small clumps of soil clog the nest entrance and hide the digging female. Occasionally, as soil accumulates near the nest entrance, the wasp would back up and clear the entrance hole. During mound building, most wasps would occasionally tamp the soil down with their abdomens, presumably to prevent the nest entrance from becoming obstructed with excavated soil. Nest entrances were 6.50 ± 2.35 mm (mean ± SD, $n = 16$, range 5–12 mm) in diameter, and were sometimes hidden under fallen leaves or other debris.

Over a period of hours to days, females repeatedly provisioned their nests with large Homopteran sharpshooters (Cicadellidae). When the nest was fully provisioned, the female would repeatedly emerge and re-enter the nest entrance dragging clumps of soil with her forelegs back into the hole each time she entered. When the upper portion of the burrow was filled with soil, the female would walk over the top of the mound repeatedly scraping the surface with her forelegs and tapping it with her abdomen. At this point, it was no longer possible to discern that a burrow was present.

What was of particular interest to us was that *P. punctatus* was using both the native smoketree sharpshooter, *Homalodisca lacerta* (Fowler) (Homoptera: Cicadellidae), and the introduced glassywinged sharpshooter, *Homalodisca coagulata* (Say), as prey. *Homalodisca coagulata* became established in California during 1989–1990 (Sorenson, J. T. & R. J. Gill. 1990. Pan-Pacific Entomol., 72: 160–161). It has now been established in 11 counties and on numerous host plants including citrus, grapes, oleander and a wide variety of ornamental landscape and native plants. Currently, *H. coagulata* is the principle vector of Pierce's disease of grapevines in the southern portion of California (Costa, H. S., M. J. Blua, J. A. Bethke, & R. A. Redak. 2000. [In press]. HortScience University of California, Office of the President. 2000. Report of the Pierce's Disease Research and Emergency Task Force). The vast majority of prey we observed were *H. coagulata* adults. *Pseneo punctatus*' natural prey most likely is *H. lacerta,* and we believe it has expanded its usable hosts to include the recently introduced sharpshooter.

When several of the nests were excavated, we usually observed three cells per nest, but it was difficult at times to accurately determine how many cells each nest contained. Many cells contained sharpshooters that were old, decayed and untouched. We could not determine if they were abandoned or if they were part of the normal provisioning of the nest and simply unused. Although the number of sharpshooters per cell varied, they commonly contained about 4 adults. In some cells, we observed eggs deposited between the front pair of coxae on the venter of a single sharpshooter. They were oblong, white, and slender, and on average they were 2.29 ± 0.35 mm long (mean ± SD, $n = 5$, range 3.0–4.6).

Wasp cocoons were also observed. On average cocoons were ellipsoidal, 14.50 ± 1.34 mm in length, and 5.79 ± 0.70 mm in width (mean ± SD, $n = 14$, range 13–17, and 5–7 respectively). Cocoons were covered with small pieces of plant material and sharpshooter fragments (mostly head capsules and wings).

Occasionally, we observed wasps emerging from the soil as adults. Emergence holes were a mean of 3.64 ± 0.50 mm in diameter (mean ± SD, $n = 11$, range 3–4) and unlike active nest entrances, they were not marked by any debris or mounds of dirt.

Specimens Examined.—CALIFORNIA. *RIVERSIDE Co.:* Riverside, University of California campus, lath house, 21 Aug 1998, Kathleen A. Campbell, swept, 2 females, deposited: University of California, Riverside, Entomology Research Museum; same loc., 25 Aug 1998, reared from larva, 1 female, reared from pupae, (6 males, 2 females), deposited: University of California, Riverside, Entomology Research Museum; same loc., 27 Aug 1998, reared from larva, 1 female, deposited: University of California, Riverside, Entomology Research Museum; Riverside, University of California campus, undeveloped area 2 meters west of the lath house, 11 Sept 1998, James A. Bethke, swept from eucalyptus, (1 male, 3 females), deposited: University of California, Riverside, Entomology Research Museum; Riverside, University of California campus, solid bin adjacent to Entomology Annex I, swept, 1 female, deposited: University of California, Riverside, Entomology Research Museum.

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Scientific Note

MONODONTOMERUS ARGENTINUS BRETHES (HYMENOPTERA: TORYMIDAE): A PARASITOID OF *EUGLOSSA NIGROPILOSA* MOURE (HYMENOPTERA: APIDAE: EUGLOSSINAE)

Euglossine bees are the only group in the subfamily Apidoideae that do not have eusocial behavior. Euglossines display a broad spectrum of social interactions, from solitary to presocial, and are thus an important group for studying the evolution of eusociability in bees (Garófalo, C. A. 1985. Entomol. Gener., 11: 77–83). An important factor involved in the origin of social behavior is the effect of parasites and parasitoids on survival and reproduction (Roubik, D. W. 1989. Ecology and natural history of tropical bees [1st ed.]. Cambridge University Press. New York).

Although it is known that microhymenoptera are parasitoids of *Euglossa* (Zucchi, R., S. F. Sakagami & J. M. F. de Camargo. 1969. J. Fac. Sci. Hokkaido Univ., Series VI, Zool., 17: 271–380), little is known about their relationship with their hosts (Dressler, R. L. 1982. Ann. Rev. Ecol. Syst., 13: 373–394). Here I present data on the parasitic behavior of the microhymenopteran *Monodontomerus argentinus* Brethes (Torymidae) and discuss its effect on the social structure of *E. nigropilosa.* I compared the percentage parasitism of *M. argentinus* on both an attended and an unattended nest of *E. nigropilosa.* This study was carried out between August 1994 and April 1995.

Euglossa nigropilosa is a communal bee of NW South America, the colonies of which have active bees all year. It is distributed between 700 and 1400 m in the Andes of Colombia and Ecuador. This species builds nests with an envelope, a resinous cover that protects the cells. Cells are of 10 × 6 mm, with soft resinous walls. I found several nests of *E. nigropilosa* in wood cavities of timber buildings at the Reserva Natural La Planada (RNLP), Colombia (77°24′ W, 1°5′ N). The nests contained colonies of up to 22 females (Otero, J. T. 1996. Bol. Mus. Ent. Univ. Valle. 4: 1–19).

Nests of *E. nigropilosa* were parasitized by *M. argentinus,* an ectoparasitic wasp that is known to attack the solitary bee *Eufriesea nigrescens* Friese, another euglossine, in the eastern part of the Andes in Colombia (Sakagami, S. F. & Strum. 1965. Insecta Matsumurana, 28: 83–97). This is the first record of a different host for *M. argentinus.* Samples of both species were deposited in the Museo de Entomología of Departamento de Biología de la Universidad del Valle (Cali, Colombia).

With the objective to study bee behavior inside the nest, on 20 Sept. 1994 I placed a nest with four adult bees and 18 cells of *E. nigropilosa* in a wooden box 30 × 15 × 10 cm, with a glass plate covering the upper surface and a wood cover which remained in place during non-observation hours. The bees had free access through a one cm diameter hole. However, the adult bees abandoned the box nest. This undefended nest was compared to a nearby undisturbed nest, in which adult bees were still present, for levels of cell parasitism by *M. argentinus.*

This second nest provided a control for the degree to which adult bees can protect their nest from parasitism. On 11 Nov. 1994 I opened all the cells of the abandoned box nest to check the level of parasitism of *M. argentinus.* For comparison, I opened 20 randomly chosen cells from the undisturbed nest to determine whether or not they were parasitized.

Comparison between the nests with and without females revealed that parasitism dropped significantly ($\chi^2 = 12.73$, $P = 0.0004$) with the presence of adults in the nest. The percentage of parasitism on the 18 cells in the box nest with female bees absent was 72%. However, the percentage for the control nest, which had between eight and 14 female bees, was only 15%, based on the sampled cells. In the box nest cells there was an average of 13.69 (± 9.04 SD, $n = 13$) wasp offspring per cell. Individual wasps were found at all developmental stages: young larvae, mature larvae, prepupae (pupae without pigmentation); and pupae (black pupae).

I observed the behavior of 38 *M. argentinus* wasps inside the defended *E. nigropilosa* nest. *Monodontomerus argentinus* arrived at the nest entrance after a zigzag flight. The wasp flew around the entrance for up to five min, before landing at the entrance hole. Parasitoid wasps entered the nest slowly, using the same entrance hole that the bees used. Upon landing, the wasps drummed on the surface of the nest with their antennae, moving them fast and harmoniously. The wasps alternated each antenna in this process. The wasps advanced slowly and continued drumming until they arrived at the entrance hole. Once inside the nest, the wasps drummed with their antennae on the surface of a cell for up to five min. without moving any other part of the body. When a wasp found an appropriate cell, it continued drumming for several minutes before ovipositing. Oviposition lasted for up to two min. For this process the wasp raised her abdomen, exerted her ovipositor and put it in contact with the resin wall of the cell. Occasionally the parasitoids withdrew their abdomen and continued drumming on the next cell.

Euglossa nigropilosa appeared to recognize *M. argentinus* as a natural enemy. These interactions were very strong. For example, a parasitoid, recently killed in a cyanide bottle, was left exposed in the nest. This body was torn apart by a resident bee. On first detecting the dead wasp, the bee became excited and circled around it, touching it with her antennae. It then bit the wasp in the abdomen and pushed it five cm away from the cell. The bee again found the dead wasp on the ground and bit it repeatedly for more than a minute. Following this attack the parasitoid lost two legs and had its wing and crushed abdomen nearly destroyed.

This strong reaction may, however, have been a response to the odor of the cyanide, and not the presence of the parasitoid body. During observations of attempts to parasitize a cell, I never observed the bees to perceive the wasp's presence. The wasps proved very adept at escaping from the bees notice in the nest. When a parasitoid was approached by a bee, the wasp jumped to the ground, so evading detection, and remained there for several minutes before attempting to oviposit again.

Sakagami and Strum (1965) found an aggregation of nests of the solitary bee *Euplusia longipennis* in Colombia in 1956 (*Eufriesea nigrescens* sensu Kimsey, L. S. 1982. Systematics of bees of the genus *Eufriesea.* University of California press). These nests had 81 highly elaborate resinous cells of approximately 19 × 9 mm, two of which were parasitized by *M. argentinus* (2.5% parasitism). Each

Table 1. Length of bees and cells, and number of broods per cell of the parasitic wasp *Monodontomerus argentinus* in two different euglossine bees in Colombia.

	Euglossa nigropilosa	*Eufriesea nigrescens*
Bee length (mm)	12	16
Cell length (mm)	10	19
Cell diameter (mm)	6	8
Number of broods by cell	13.7 (SD = 9.4; n = 13)	33.5 (SD = 2.1; n = 2)

parasitized cell had an average of 33.5 (SD ± 2.1, $n = 2$) parasites. *Eufriesea nigrescens* and *Euglossa nigropilosa* were attacked by the same parasitoid, *M. argentinus,* but the two host species have different defense strategies. The solitary species, *E. nigrescens,* provides cells with thick protective walls. In contrast *E. nigropilosa* build cells with a thin, vulnerable wall. However, adult bees of *E. nigropilosa* may protect the nest from *M. argentinus.* In addition, the presence of a resinous envelope enclosing the nest may restrict the wasp's entrance. These defenses of *E. nigropilosa,* however, appear to provide less effective protection from the parasitic wasps than the thick cell walls of *E. nigrescens.* Parasitism incidence was higher in *E. nigropilosa,* between 72% in box nest and 15% in the control nest, than in *E. nigrescens* (2.5%). There appears to be less parasitism when nests are protected by many active females. In this case, the parasitoids probably spent more time escaping from resident bees and were not able to oviposit in cells.

From these observations I suggest that the presence of active bees in the nest may affect the rate of *M. argentinus* parasitism of *E. nigropilosa.* Despite having vulnerable cell walls, *E. nigropilosa* has active bees throughout the year and the large colony size makes the presence of a female in the nest more likely, decreasing the risk of *M. argentinus* attack. In contrast, *E. nigrescens* is a seasonal bee with oviposition limited to only two months of the year. Females of *Eufriesea nigrescens* die after oviposition and they can not protect the cells. Thus an intrinsic protective mechanism is needed, in this case a thick resinous cell wall that is difficult for the parasitoid to penetrate.

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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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INVERSE DENSITY-DEPENDENT PARASITISM OF *OPSIUS STACTOGALUS* FIEBER (HOMOPTERA: CICADELLIDAE) BY *GONATOPUS* SP. (HYMENOPTERA: DRYINIDAE)

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Abstract.—The relationship between *Opsius stactogalus* Fieber leafhopper density (abundance per plant-sample mass) and parasitism by the dryinid wasp *Gonatopus* sp. was examined. Branches cut from *Tamarix ramosissima* Ledebour shrubs, sustained by treated wastewater, were weighed and sampled for parasitized and unparasitized leafhoppers. Leafhopper abundance increased linearly as branch mass increased exponentially ($\text{mass}^{0.64}$), in agreement with isometric scaling laws relating leaf abundance to branch mass. The proportion of leafhopper nymphs parasitized (18%) was greater than the proportion of adults parasitized (2.9%). Branches were more likely to contain one or more parasitized nymphs, signifying exploitation of the branch by *Gonatopus*, as nymph density increased. On branches containing at least one parasitized nymph, increasing nymph density was related to an increase in the number of parasitized nymphs but to a decrease in parasitism rate. Parasitism of *O. stactogalus* nymphs on branches exploited by *Gonatopus* was inverse density dependent. *Gonatopus* appears not to regulate populations of *O. stactogalus* or limit the leafhopper's damage to *T. ramosissima.*

Key Words.—Insecta, Cicadellidae, *Opsius stactogalus*, Dryinidae, *Gonatopus*, *Tamarix*, parasitism.

The tamarix leafhopper, *Opsius stactogalus* Fieber, is a small, cryptic insect primarily found on tamarisk, *Tamarix* spp. (Tamaricaceae) (Harding 1930, Liesner 1971). Tamarisk is a halophytic shrub or tree facultatively-dependent on shallow groundwater (Brock 1994, Di Tomaso 1998). Species of *Tamarix* are native to the Old World, occurring from the Mediterranean across southern Russia to eastern Asia, and were imported to the USA in the early 1800s for use as ornamentals (Robinson 1965). Tamarisk since has spread beyond cultivation with the most-recent survey estimating the plant's extent to exceed 350,000 ha in the western USA (Robinson 1965). Tamarisk's invasiveness, water uptake, and low diversity of dependent wildlife has made it the target of classical biological control (Fornasari 1997). The taxonomy of New World *Tamarix* is unclear (Brock 1994, Di Tomaso 1998); eight species occur in North America (Baum 1967) with five species, four deciduous and one evergreen, currently recognized in California (Wilken 1993).

Opsius stactogalus is the most abundant insect on tamarisk (Harding 1930, Hopkins & Carruth 1954, Liesner 1971). The insect's green color and size (length 0.81 mm for first-instar nymphs, 4.5 mm for adult females, Harding 1930) make it difficult to distinguish from tamarisk's sessile, scalelike leaves (1.5 to 3.5 mm-long in *Tamarix ramosissima* Ledebour, Wilken 1993). The life cycle of *O. stactogalus* is comprised of five nymphal instars, adults, and eggs inserted within stems (Harding 1930). Generations per year number three in Kansas (Harding 1930) and four in New Mexico (Liesner 1971). Like many other Cicadellidae, *O. stactogalus* is a fluid-feeder, and the aggregate feeding imposed by populations of the leafhopper can reduce tamarisk's growth (Liesner 1971). Although the leafhopper was described as a new species in 1907 from collections in Texas, a later comparison of Meditteranean and North American specimens and review of the systematic literature revealed the 1907 species description as synonymous with an original description in Europe during 1847 (Harding 1930). *Opsius stactogalus,* like its host tamarisk, is native to the Old World.

Opsius stactogalus nymphs and adults are parasitized by the dryinid wasp *Gonatopus* spp. (Harding 1930, Liesner 1971). Dryinidae occur worldwide and parasitize only the homopteran suborder Auchenorrhyncha (Olmi 1984). Dryinid larvae are individually enclosed in a sac of exuviae that protrudes between their host's thoracic or abdominal sclerites. Adult females of many Dryinidae species also are predaceous on their hosts (Olmi 1984). The only published records of *Gonatopus* parasitizing *O. stactogalus* in North America are of *Gonatopus caroli* Olmi and *Gonatopus curriei* Krombein (Guglielmino & Olmi 1997). One adult female *Gonatopus* reared from a parasitized *O. stactogalus* I collected at the present study's locality was identified as *G. caroli* (M. Olmi, personal communication).

The effect of parasitism by *Gonatopus* on the abundance of *O. stactogalus* is uncertain. Harding (1930) described parasitism rate by *Gonatopus* as low and unable to significantly affect rapid population increases of *O. stactogalus.* In contrast, Liesner (1971) described parasitism rates (30–44% of leafhoppers parasitized) high enough to hinder his collecting leafhoppers for experimental trials. Increasing parasitism rate with increasing *O. stactogalus* density (density dependence) may regulate leafhopper populations (Turchin 1995) and decrease their detrimental effect on tamarisk. Parasitism rate decreasing with increasing leafhopper density (inverse density dependence) or unrelated to leafhopper density (density independence) would not regulate populations of *O. stactogalus* and limit the insect's damage to tamarisk. A synopsis (Stiling 1987) of the relationships between insect-host density and parasitism rate (171 published accounts) found density independence most common (52%) followed by density dependence (25%) and inverse density dependence (23%). This study examines the relationship between density of *O. stactogalus* and parasitism rate by *Gonatopus.*

Materials and Methods

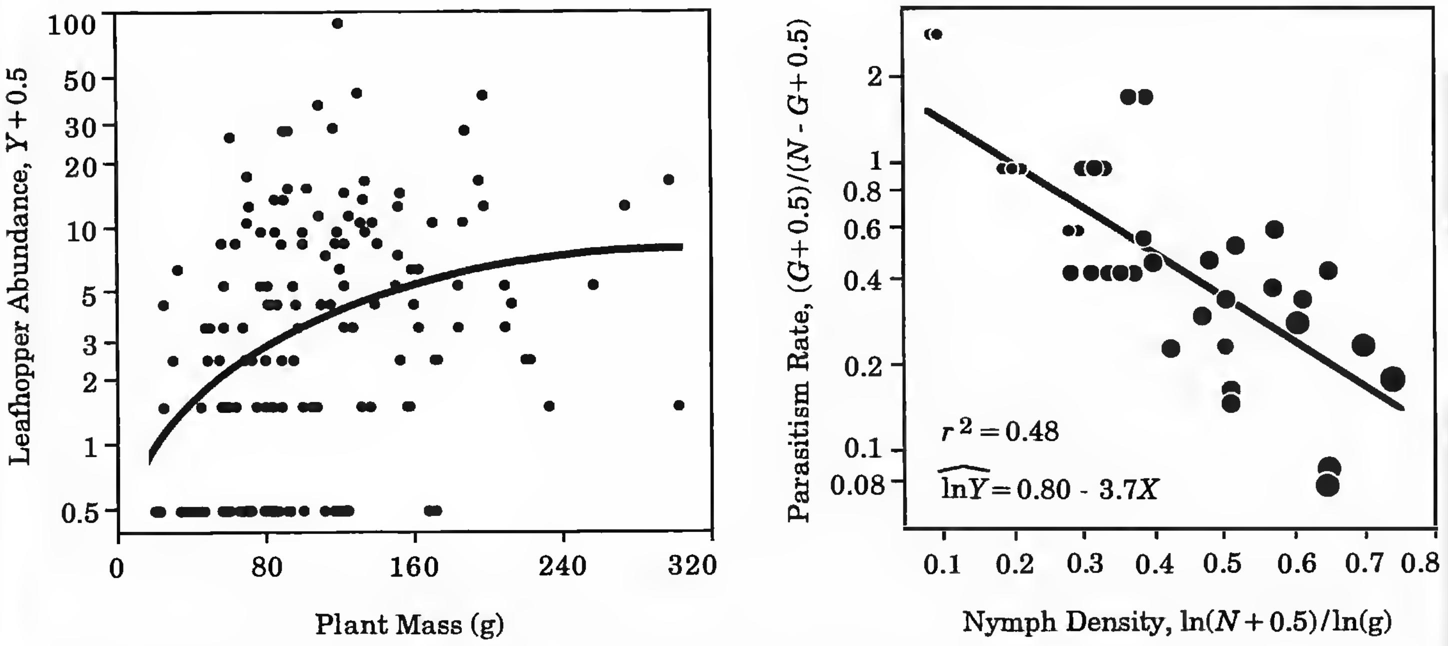
The study site was located at the effluent discharge of the City of Boulder City, Clark County, Nevada, wastewater treatment plant. The treatment plant discharges approximately 2000 m^3 of secondary-treated municipal effluent per day equally into two parallel unlined southward-flowing channels approximately 0.1 km apart. Effluent discharged to each channel maintains a 2-m wide surface flow extending approximately 3 km downstream. Sustained by the effluent, and bordering both channels, are dense, linear stands of the deciduous tamarisk *T. ramosissima* alternating with clumps of cat-tail, *Typhus latifolia* L. (Typhaceae). The site lies at an elevation of 610 m within the Mojave Desert; creosote bush, *Larrea tridentata* (Sessé & Mocino ex Candolle) Coville (Zygophyllaceae), and bursage, *Ambrosia dumosa* (Gray) Payne (Asteraceae), are the dominant plant species surrounding the effluent-supported vegetation.

Leafhoppers on tamarisk were sampled at 12 points along the west edge of the east channel. Sampling points were located every 80 m along the channel beginning 80 m downstream of the effluent discharge. Three samples were taken at each point during the morning on 17–18 Jul, 16–17 Aug, 16–17 Sep, and 20–21 Oct 1999. Each leafhopper sample was taken by bagging a 1-m long tamarisk branch within a plastic trash bag (159 liter, 84 cm × 1.2 m, 76 μm thick) held open with a 52-cm diameter metal hoop. The bag was quickly swept over the branch and slipped off the hoop to constrict the bag around the proximal-end of the branch. The branch then was cut at the top of the bag, pushed into the bag, and the bag closed. Enclosed leafhoppers were killed with an aerosol insecticide (Raid® Concentrated Deep Reach Fogger, S.C. Johnson & Son, Racine, Wisconsin) containing 14 g of 1.7% cypermethrin. Approximately 10 min after treatment, the bag was held upright and the branch shaken for 30 sec. Dead leafhoppers shaken from the branch were collected into a 3-dram (15-mm diameter × 65-mm long) patent-lip glass vial. Plant mass supporting the collected leafhoppers was measured (± 2 g) by removing the branch from the bag and weighing it with a 300-g capacity spring scale. Vial contents were examined with a microscope, and collected leafhoppers were sorted from plant debris and stored in 70% ethanol. Leafhoppers were examined at 30× and the number of parasitized and unparasitized nymphs and adults counted. Parasitized and unparasitized *O. stactogalus* in ethanol were deposited as vouchers at the University of California, Riverside, Entomology Museum.

Opsius stactogalus density was estimated by first determining the relationship between leafhopper abundance and plant mass. Leafhopper abundance (transformed $\ln[Y + 0.5]$) was regressed (SPSS version 6.1, Chicago, Illinois) against plant mass and life stage, nymph or adult coded as an indicator variable. Two regressions were performed with plant mass in grams and with plant mass transformed ln(grams). Plant mass transformed ln(grams) was selected, due to its greater partial r^2, as the better linear predictor of leafhopper abundance and used to calculate leafhopper density. The interaction life stage × plant mass was added to the regression to test if the trends in abundance across transformed plant mass differed between nymphs and adults. For graphing, abundances of nymphs and adults in each sample were summed, transformed $\ln(Y + 0.5)$, and regressed against transformed plant mass.

Parasitism of *O. stactogalus* was examined by first comparing (χ^2 test) the proportions of parasitized nymphs and adults. Parasitism of nymphs was further examined at two spatial scales, the tamarisk branch and the individual leafhopper. To evaluate exploitation of tamarisk branches by ovipositing *Gonatopus,* the influence of nymph density ($\ln[N + 0.5]/\ln[g]$; N = number of nymphs, g = grams plant mass) on the probability of a leafhopper sample containing at least one parasitized nymph was determined with logistic regression (Neter et al. 1996). A predicted change and 95% confidence interval in the odds of a *Gonatopus* exploiting versus not exploiting a branch as nymph density increased was calculated from the regression coefficient and its standard error.

To evaluate parasitism of individual leafhoppers on branches exploited by *Gonatopus,* the number of parasitized nymphs (G) in leafhopper samples with at least one parasitized nymph was transformed $\ln(G + 0.5)$ and regressed against nymph density. One outlier leafhopper sample, collected on 17 Aug 1999, containing 35 unparasitized nymphs and 41 parasitized nymphs was excluded from the regression due to its extreme influence (standardized residual = 3.4) on the fitted function. Parasitism rate (R) on branches exploited by *Gonatopus* was quantified as



Figures 1–2. Fig. 1 (left). *Opsius stactogalus* abundance (nymphs + adults) plotted on a logarithmic scale against *Tamarix*-branch mass. Curve was fit by linear regression with plant mass transformed ln(g). Fig. 2 (right). Parasitism rate of *O. stactogalus* nymphs versus nymph density (N = nymph abundance) on exploited branches containing ≥ 1 parasitized nymph. Parasitism rate is the ratio of parasitized nymphs (G) to unparasitized nymphs plotted on a logarithmic scale. The size of each data point represents its final weight determined from iteratively reweighted least squares regressions.

the ratio of the number of parasitized nymphs to the number of unparasitized nymphs ($N - G$), transformed as an empirical logit (Agresti 1990), $R = \ln[(G + 0.5)/(N - G + 0.5)]$ in each leafhopper sample. Iteratively reweighted least squares regressions (see logistic regression with repeat observations, Neter et al. 1996) of parasitism rate against nymph density were performed to produce a maximum likelihood estimate of the regression coefficient. The regression was unweighted in the first iteration, and the resulting predicted parasitism rates ($\hat{R}$) were used to calculate predicted probabilities of parasitism, $\pi = [\exp(\hat{R})]/[1 + \exp(\hat{R})]$. A weighted regression then was performed with leafhopper-sample weights calculated with $N(\pi)(1 - \pi)$. Predicted probabilities of parasitism from the weighted regression were used to recalculate weights, and the process was repeated (3 iterations) until the regression coefficient stabilized. Weights determined in the final iteration were adjusted downward (multiplied by 34/51) to restore the unweighted error degrees of freedom. The leafhopper sample identified above as an outlier again was excluded (standardized residual = 3.2) from the analysis. A predicted change in the odds ratio of parasitized nymphs (+ 0.5) to unparasitized nymphs (+ 0.5) as nymph density increased was calculated from the regression coefficient.

RESULTS

Abundance of *O. stactogalus* was more linearly related to plant mass transformed ln(grams) (partial $r^2 = 0.092$; $F = 29.8$; df = 1,285; $P < 0.001$) (Fig. 1) than to plant mass in grams (partial $r^2 = 0.065$; $F = 20.5$; df = 1,285; $P < 0.001$) and was greater ($F = 9.1$; df = 1,285; $P = 0.003$) in nymphs (634 leafhoppers) than in adults (309 leafhoppers). The partial regression coefficient (0.64 ± 0.12 [SE]) for transformed plant mass therefore equaled the exponent of the power function, leafhopper abundance $= f$ (plant mass$^{0.64}$). Trends in abundance across transformed plant mass did not differ ($F = 0.47$; df = 1,284; $P = 0.5$) between nymphs and adults.

The proportion of *O. stactogalus* nymphs parasitized (18.0%) by *Gonatopus* was greater ($\chi^2 = 41.6$; df = 1; $P < 0.001$) than the proportion of adults parasitized (2.9%). Tamarisk branches supporting nymphs (99 of 144 total samples) were more likely ($\chi^2 = 41.4$; df = 1; $P < 0.001$) to be exploited by *Gonatopus* as nymph density increased. The odds of an ovipositing *Gonatopus* exploiting versus not exploiting a tamarisk branch increased 2.3-fold (95% confidence interval = 1.8 to 3.0) for a 2-fold increase, from 2 to 4 nymphs on a 100 g branch, in nymph density. The increase in the odds of *Gonatopus* exploiting a branch therefore was approximately proportional to the increase in nymph density.

On branches supporting at least one parasitized nymph (36 samples excluding outlier), increasing nymph density was related to an increase in the number of parasitized nymphs ($F = 15.6$; df = 1,34; $P = 0.004$) but to a decrease in the parasitism rate of nymphs ($F = 30.9$; df = 1,34; $P < 0.001$) (Fig. 2). The odds of a nymph being parasitized versus unparasitized decreased 38% with a 2-fold increase, from 2 to 4 nymphs on a 100 g branch, in nymph density. Parasitism of *O. stactogalus* nymphs on branches exploited by *Gonatopus* therefore was inverse density dependent.

DISCUSSION

A diminishing rate of increase in *O. stactogalus* abundance, as the mass of the tamarisk branch supporting the population increased, is predicted by the scaling laws of isometric growth (Schmidt-Nielsen 1984). Tamarisk branches cut for leafhopper samples were composed of a central, non-photosynthetic stem supporting smaller, branching stems covered with sessile leaves. The central stem contained vascular tissue transporting xylem and phloem to and from the leaves, the portion of the branch supporting *O. stactogalus.* The capacity for this transport, limiting the abundance of leaves (and leafhoppers) supported by the stem, would have been proportional to the area of the stem's cross-section. The mass of the stem, however, would have been proportional to its volume. As the stem grew, its cross-sectional area (A) would have increased more slowly than its mass (M) according to the equation $A = M^{2/3}$ or $A = M^{0.67}$. This function approximates the observed relationship between *O. stactogalus* abundance and tamarisk-branch mass.

Greater parasitism of nymphs compared to adults, as observed in *O. stactogalus,* also has been reported in other leafhopper species. Dryinids parasitizing eight species of leafhoppers inhabiting forage grass generally were found to attack nymphs more than adults (Buntin 1989). In contrast, Liesner (1971) observed higher rates of parasitism by *Gonatopus* in *O. stactogalus* adults (14–100%) than in nymphs (5–54%). Greater parasitism of *O. stactogalus* nymphs compared to adults is not due to different durations, and therefore exposure times, of the two life stages; both first through fifth instar nymphs and adults live an average of 1 month (Harding 1930). *Gonatopus* parasitizing *O. stactogalus* preferred nymphs over adults for hosts.

Increasing *O. stactogalus* nymph density was associated with increasing probability of a branch being exploited by *Gonatopus* and with increasing abundance of parasitized nymphs. *Gonatopus* therefore appears to be attracted to, or arrested by (Vinson 1984), populations of *O. stactogalus.* The increase in abundance of parasitized nymphs, however, did not keep pace with the increase in nymph abundance, resulting in a parasitism rate that decreased as nymph density increased. Reproductive rates of parasitoids can lag behind those of their hosts due to lower fecundities or long host-handling times (Stiling 1987).

Inverse density-dependent parasitism of *O. stactogalus* by *Gonatopus* is contrary to most insect host-parasite systems that have been studied (Stiling 1987). Decreasing parasitism rate with increasing host density may be common in Dryinidae, however, as it also has been observed in several dryinid species parasitizing grassland leafhoppers (Waloff 1975). The only other insect known to parasitize *O. stactogalus* in North America is the egg parasite *Polynema saga* (Girault) (Hymenoptera: Mymaridae) (Lawson 1929). Harding (1930) found approximately 25% of *O. stactogalus* eggs in Kansas parasitized by *P. saga,* and Liesner (1971) dissected *P.* (*Barypolynema*) *saga* from the leafhopper's eggs in New Mexico. *Opsius stactogalus* therefore supports two parasite species separately attacking nymphs and adults or attacking eggs. In comparison, 34 of 50 cicadellid species collected in Kansas grasslands supported two or more species of parasites infecting nymphs and adults (Baldridge & Blocker 1980), and eggs of the leafhopper *Circulifer tenellus* (Baker) in Iran were found to harbor seven species of parasites (Walker et al. 1997). Although caged *O. stactogalus* were eaten by Chrysopidae larvae (Harding 1930) and spiders (Liesner 1971), and leafhoppers may be eaten by adult female *Gonatopus,* the contribution of predation to *O. stactogalus* mortality in nature is unknown. Inverse density-dependent parasitism of *O. stactogalus* by *Gonatopus* may not only be due to intrinsic differences between the two species, such as fecundity rate, but also to interactions across several trophic levels (Hare 1992). The leafhopper's abundant, predictable food source and low diversity of natural enemies may combine to increase its reproductive rate beyond that of its parasite.

Populations of *O. stactogalus* are not regulated (Turchin 1995) by the inverse density-dependent parasitism imposed by populations of *Gonatopus.* Unconstrained population increase by *O. stactogalus* agrees with descriptions (Harding 1930, Hopkins & Carruth 1954, Liesner 1971) of the leafhopper occurring on tamarisk in high densities. Liesner (1971) also suggested populations of *O. stactogalus* can be high enough to reduce tamarisk growth. Reduced growth expectedly would result from the photosynthate drain imposed on the plant by high densities of the fluid-feeding leafhopper. Lack of population regulation by *Gonatopus* permits unhindered herbivory by *O. stactogalus,* considered beneficial when viewed in the context of biological control against tamarisk. Populations of *O. stactogalus* and herbivory by the leafhopper may be limited only by temperature. Insect development and photosynthate extraction would slow during the fall as temperatures decline and would cease when *T. ramosissima* and other deciduous *Tamarix* drop their leaves and force *O. stactogalus* to overwinter in the egg stage within stems.

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LITERATURE CITED

Agresti, A. 1990. Categorical data analysis. John Wiley & Sons, New York.

Baldridge, R. S. & H. D. Blocker. 1980. Parasites of leafhoppers (Homoptera: Cicadellidae) from Kansas grasslands. J. Kansas Entomol. Soc., 53: 441–447.

Baum, B. R. 1967. Introduced and naturalized tamarisks in the United States and Canada (Tamaricaceae). Baileya, 15: 19–25.

Brock, J. H. 1994. *Tamarix* spp. (salt cedar), an invasive exotic woody plant in arid and semi-arid riparian habitats of western USA. Chapter 4. pp. 27–44. *In* deWaal, L. C., L. E. Child, P. M. Wade, & J. H. Brock (eds.). 1994. Ecology and management of invasive riverside plants. John Wiley & Sons, New York.

Buntin, G. D. 1989. Dryinid (Hymenoptera: Dryinidae) parasites of leafhoppers and planthoppers (Homoptera) in forage-type bermudagrass. J. Kansas Entomol. Soc., 62: 602–606.

Di Tomaso, J. M. 1998. Impact, biology, and ecology of saltcedar (*Tamarix* spp.) in the southwestern United States. Weed Technology, 12: 326–336.

Fornasari, L. 1997. Host specificity of *Coniatus tamarisci* (Coleoptera: Curculionidae) from France: potential biological control agent of *Tamarix* spp. in the United States. Environ. Entomol., 26: 349–356.

Guglielmino, A. & M. Olmi. 1997. A host-parasite catalog of world Dryinidae (Hymenoptera: Chrysidoidea). Cont. Entomol. Int., 2: 165–298.

Harding, L. 1930. The biology of *Opsius stactogalus* Fieber (Homoptera, Cicadellidae). J. Kansas Entomol. Soc., 3: 7–22.

Hare, J. D. 1992. Effects of plant variation on herbivore-natural enemy interactions. Chapter 12. pp. 278–298. *In* Fritz, R. S. & E. L. Simms (eds.). 1992. Plant resistance to herbivores and pathogens: ecology, evolution, and genetics. Univ. Chicago Press, Chicago, Illinois.

Hopkins, L. & L. A. Carruth. 1954. Insects associated with salt cedar in southern Arizona. J. Econ. Entomol., 47: 1126–1129.

Lawson, P. B. 1929. A leafhopper parasite—*Polynema saga* (Girault) (Hymenoptera, Mymaridae). Ann. Entomol. Soc. Am., 22: 130.

Liesner, D. R. 1971. Phytophagous insects of *Tamarix* spp. in New Mexico. M.S. Thesis, New Mexico State University, Las Cruces.

Neter, J., M. H. Kutner, C. J. Nachtsheim, & W. Wasserman. 1996. Applied linear statistical models (4th ed.). McGraw-Hill, Boston, Massachusetts.

Olmi, M. 1984. A revision of the Dryinidae (Hymenoptera). Mem. Amer. Entomol. Inst., no. 37.

Robinson, T. W. 1965. Introduction, spread, and areal extent of saltcedar (*Tamarix*) in the western States. U.S. Dept. Int., Geol. Surv. Professional Paper, 491-A.

Schmidt-Nielsen, K. 1984. Scaling: why is animal size so important? Cambridge University Press, Cambridge.

Stiling, P. D. 1987. The frequency of density dependence in insect host-parasitoid systems. Ecology, 68: 844–856.

Turchin, P. 1995. Population regulation: old arguments and a new synthesis. Chapter 2. pp. 19–40. *In* Cappuccino, N. & P. W. Price (eds.). 1995. Population dynamics: new approaches and synthesis. Academic Press, New York.

Vinson, S. B. 1984. Parasitoid-host relationship. Chapter 8. pp. 205–233. *In* Bell, W. J. & R. T. Cardé (eds.). 1984. Chemical ecology of insects. Chapman & Hall, London.

Walker, G. P., N. Zareh, I. M. Bayoun, & S. V. Triapitsyn. 1997. Introduction of western Asian egg parasitoids into California for biological control of beet leafhopper, *Circulifer tenellus*. Pan-Pacific Entomol., 73: 236–242.

Waloff, N. 1975. The parasitoids of the nymphal and adult stages of leafhoppers (Auchenorryhncha: Homoptera) of acidic grassland. Trans. R. Entomol. Soc. London, 126: 637–686.

Wilken, D. H. 1993. Tamaricaceae: tamarisk family. p. 1080. *In* Hickman, J. C. (ed.). 1993. The Jepson manual: higher plants of California. Univ. Calif. Press, Berkeley.

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TAENIOGONALOS RAYMENTI CARMEAN & KIMSEY (HYMENOPTERA: TRIGONALIDAE) REARED AS A HYPERPARASITE OF *STURMIA CONVERGENS* (WEIDEMANN) (DIPTERA: TACHINIDAE), A PRIMARY PARASITE OF *DANAUS PLEXIPPUS* (L.) (LEPIDOPTERA: NYMPHALIDAE)

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Abstract.—*Taeniogonalos raymenti* is confirmed as a hyperparasitoid of the tachinid *Sturmia convergens* which parasitises larval *Danaus plexippus*. Trigonalids are indirect parasitoids and in this case we have direct evidence that wasp eggs must have been laid on the caterpillar's host plant, *Asclepias fruticosa,* before the secondary host, but not necessarily before the primary tachinid host, was present. Levels of hyperparasitism during our sampling period were very low at less than two percent.

Key Words.—Insecta, *Sturmia,* Tachinidae, *Asclepias.*

Trigonalid wasps are unique among the parasitic Hymenoptera as they oviposit onto foliage and the eggs are subsequently injested, along with the foliage, by larval sawflies or herbivorous caterpillars. The host relationships of larval trigonalids are poorly known, but most appear to be either primary parasitoids of larval sawflies, or hyperparasitoids of hymenopteran and tachinid parasitoids (Weinstein & Austin 1991). The family has a cosmopolitan distribution, but is quite small with only 100 known species. The biology, host relationships and systematics of trigonalids are reviewed by Weinstein & Austin (1991) and Carmean & Kimsey (1998). One of the major messages in both those reviews is that trigonalids remain a very poorly known group, with little or no biological information for most species. This note supplies a new host record for a trigonalid species from South-east Queensland.

Materials and Methods

Collection and Rearing.—As part of wider study, 222 wild, 5th instar *Danaus plexippus* (L.) caterpillars were collected from four sites in South-east Queensland from February to November 1998. Collections were made at Mt Crosby (27°32′ S, 152°49′ E), The University of Queensland Veterinary Research Farm Pinjarra Hills (= Moggill Farm) (27°35′ S, 152°53′ E), Dunn's Creek via Beenleigh (27°43′ S, 153°09′ E) and Pine River via Boondal (27°17′ S, 152°55′ E).

Caterpillars were collected from either *Asclepias fruticosa* L. or *A. curassavica* L., returned to the laboratory and reared individually on cut foliage of the host species they were collected on until they pupated. A further 33 caterpillars were obtained by placing *D. plexippus* eggs onto *A. fruticosa* plants, which did not carry existing *D. plexippus* eggs or larvae, at Moggill Farm and then immediately

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Table 1. Fate of fifth instar *Danaus plexippus* (L.) larvae collected from sites in South-east Queensland. (*P.l.* = *Paradrino laevicula* Mesnil, *S.c.* = *Sturmia convergens* (Weidemann), *W.s.* = *Winthemia sumatrana* (Townsend).

Collection site	Date	No. of larvae collected	No. of larvae parasitised	No. of adult tachinids emerging (*P.l./S.c./W.s.*)	No. of trigonalids reared
Wild collections					
Mt Crosby	Feb 98	21	18	31 (25/1/5)	0
Dunn's Ck	Apr 98	31	18	25 (21/4/0)	0
Pine River	May 98	27	12	19 (16/3/0)	0
Pine River	June 98	6	3	0	0
Dunn's Ck	June 98	22	19	36 (32/4/0)	0
Dunn's Ck	June 98	21	15	21 (21/0/0)	0
Dunn's Ck	June 98	40	20	24 (22/1/1)	0
Dunn's Ck	Nov 98	23	22	30 (17/13/0)	0
Moggill Farm	Nov 98	21	19	40 (10/26/4)	1
Mt Crosby	Nov 98	10	5	11 (6/5/0)	0
"Bag" reared					
Moggill Farm	Nov 98	33	33	48 (0/48/0)	6

bagging the plants with insect proof gauze. Caterpillars were harvested as 5th instars and then reared as above.

Identification and Voucher Material.—Trigonalids were identified by J. C. Cardale, Australian National Insect Collection, CSIRO Entomology, Canberra. Voucher material has been deposited with the University of Queensland Insect Collection. Tachinids were identified by B. Cantrell, Queensland Department of Primary Industries, Brisbane. Two species of tachinid were routinely reared from monarch butterfly caterpillars during our research. We were able to determine which tachinid was the trigonalid host from the remnant pupal cases, which are noticeably different between the two tachinid species.

RESULTS

Danaus plexippus caterpillars were found to be heavily parasitised by tachinids, most commonly *Sturmia convergens* (Weidemann) and *Paradrino laevicula* Mesnil. Both have been previously recorded at primary parasites of *D. plexippus* in South-east Queensland (Zalucki 1981). As we will be reporting on primary parasitism elsewhere, we will not here discuss it further.

Seven trigonalid wasps emerged from seven tachinid pupal cases which had emerged from seven individual caterpillars. These were identified as individuals of *Taeniogonalos raymenti* Carmean & Kimsey (previously *T. tricolor* Rayment, see Carmean & Kimsey 1998). All but one of these specimens were reared from a single collection of caterpillars made from plants which had been bagged immediately after placing butterfly eggs upon them (Table 1). In all cases the tachinid host, based on pupal case identification, was *S. convergens*. Because plants had been bagged immediately following artificial butterfly egg placement, it confirms that both *S. convergens* and *T. tricolor* placed their eggs on the host plant (*A. fruticosa*) prior to the presence of the primary host insect. The identity of the tachinid from which the seventh wasp was reared was not recorded, but the host plant was again *A. fruticosa*.

Overall hyperparasitism rate was only 1.8% (*n* = 397 tachinids reared), but for the case where 6 wasps were reared from a single collection, the hyperparasitism rate was 13% (*n* = 46 tachinids reared).

Discussion

Taeniogonalos is the most widely distributed genus of the Trigonalidae and species in the genus have been reared previously as primary parasitoids of sawflies, or a hyperparasitoids of tachinid and ichneumonid parasitoids of lepidoptera (Carmean & Kimsey 1998). This is the first rearing and oviposition substrate record for *T. raymenti,* but it is not the first time the genus *Sturmia* or the subfamily Danainae have been associated as primary and secondary hosts of this genus. Hirai & Ishi (1995) recorded *T. fasciata* (Strand) (previously *Poecilogonalos fasciata*) as hyperparasitising *Sturmia bella* (Meigen), a parasite of *Parantia sita* (Moore) (the tiger chestnut butterfly), in Japan.

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Literature Cited

Carmean, D. & L. Kimsey 1998. Phylogenetic revision of the parasitoid wasp family Trigonalidae (Hymenoptera). System. Entomol., 23: 35–76.

Hirai, N. & M. Ishi 1995. Host relationships of the tachinid fly, *Sturmia bella* (Diptera: Tachinidae), and the trigonalid wasp, *Poecilogonalos fasciata* (Hymenoptera: Trigonalyidae), parasitizing the Chestnut Tiger butterfly, *Parantica sita* (Lepidoptera: Danaidae). Appl. Entomol. Zool., 30: 241–244.

Weinstein, P. & A. D. Austin 1991. The host relationships of trigonalyid wasps (Hymenoptera: Trigonalyidae), with a review of their biology and catalogue to world species. J. Nat. Hist., 25: 399–433.

Zalucki, M. P. 1981. Temporal and spatial variation of mortality in *Danaus plexippus* L. Aust. Entomol. Mag., 8: 3–8.

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NEW SPECIES OF *CERACLEA* (TRICHOPTERA: LEPTOCERIDAE: ATHRIPSODINI) AND A FIRST RECORD OF *ADICELLA* (TRICHOPTERA: LEPTOCERIDAE: TRIAENODINI) FROM FAR EASTERN RUSSIA

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Abstract.—Three new species of the genus *Ceraclea,* belonging to the subgenus *Athripsodina: C.* (*A.*) *affinis, C.* (*A.*) *bilobulata* and *C.* (*A.*) *breviramosa* from the southern Far East of Russia are described and illustrated. The genus *Adicella,* represented by a new species, is newly recorded for the Russian fauna.

Key Words.—Trichoptera, Leptoceridae, *Ceraclea, Adicella,* new species, new record, Far Eastern Russia.

Until now, 9 genera and 59 species of the family Leptoceridae are known from the Russian Far East (Arefina 1997; Vshivkova et al. 1997; J. C. Morse, L. Yang, and I. M. Levanidova, unpublished data). During a survey of the caddisflies (Trichoptera) of the Ussuri River Basin, three *Ceraclea* species were collected that are new to science. Furthermore, a representative of the genus *Adicella,* which has not been previously known in Russia, was found.

The types of the new species are preserved in alcohol and held in the collections of the Institute of Biology and Soil Sciences, Russian Academy of Sciences, Vladivostok. In the present work, the terminology generally follows that in the revision by Yang & Morse (1988).

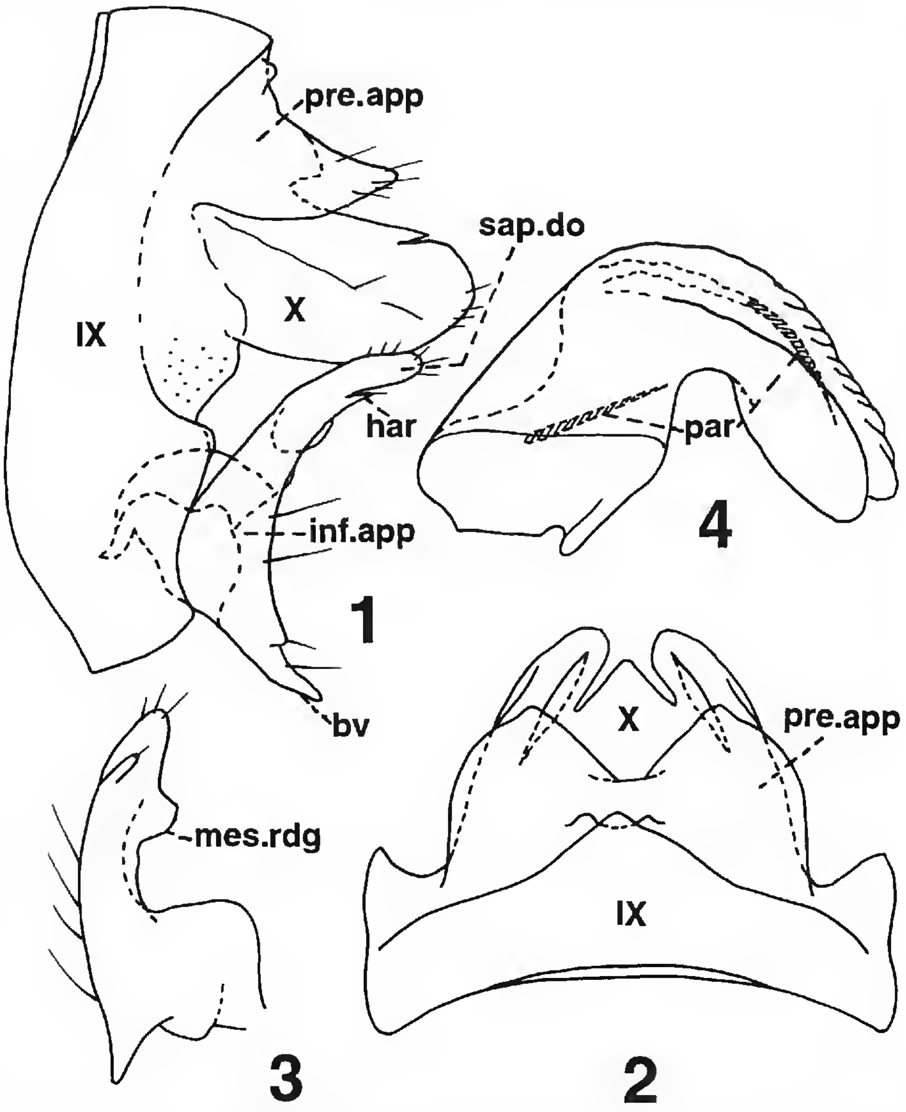
CERACLEA (*ATHRIPSODINA*) *DILUTA* Group

Ceraclea (*Athripsodina*) *affinis,* NEW SPECIES
(Figs. 1–7)

Types.—Holotype male: KHABAROVSK TERRITORY (RUSSIA), Birushka River, Ussuri River Basin, 23 Jul 1996, T. Arefina. Paratype: 1 female, same data as holotype.

Description.—Length of forewing: male—7.9 mm, female—8.1 mm. Head and body with white and brown hairs mixed. Vertex of head, thorax and coxae brown, abdomen and legs lighter. Wings yellowish brown with setae darker.

Male Genitalia (Figs. 1–4).—Tergum IX (IX) with pair of small papillae near poster meson. Preanal appendages (pre. app) subtriangular, fused basally, each with acute apex. Tergum X (X) composed of triangular median lobe and pair of lateral lobes, each with blunt apex in dorsal and lateral views, lateral lobes extending slightly beyond median lobe. Main body of each inferior appendage (inf. app) straight in lateral view with subapicodorsal lobe (sap. do) bent caudad; basoventral lobe (bv) of each inferior appendage nearly half as long as main body, obtusely angled about 110° from main body, stout at basal half then abruptly tapering to digitate apex; harpago (har) tiny; mesal ridge of inferior appendage (mes.rdg) produced in small, nearly trapezoidal process located slightly lower than harpago. Phallus strongly curved ventrad and constricted ventrally two-thirds distance from base; both paramere spines (par) seta-like with right spine positioned near apex, left spine almost straight and situated in anterior half of phallus.

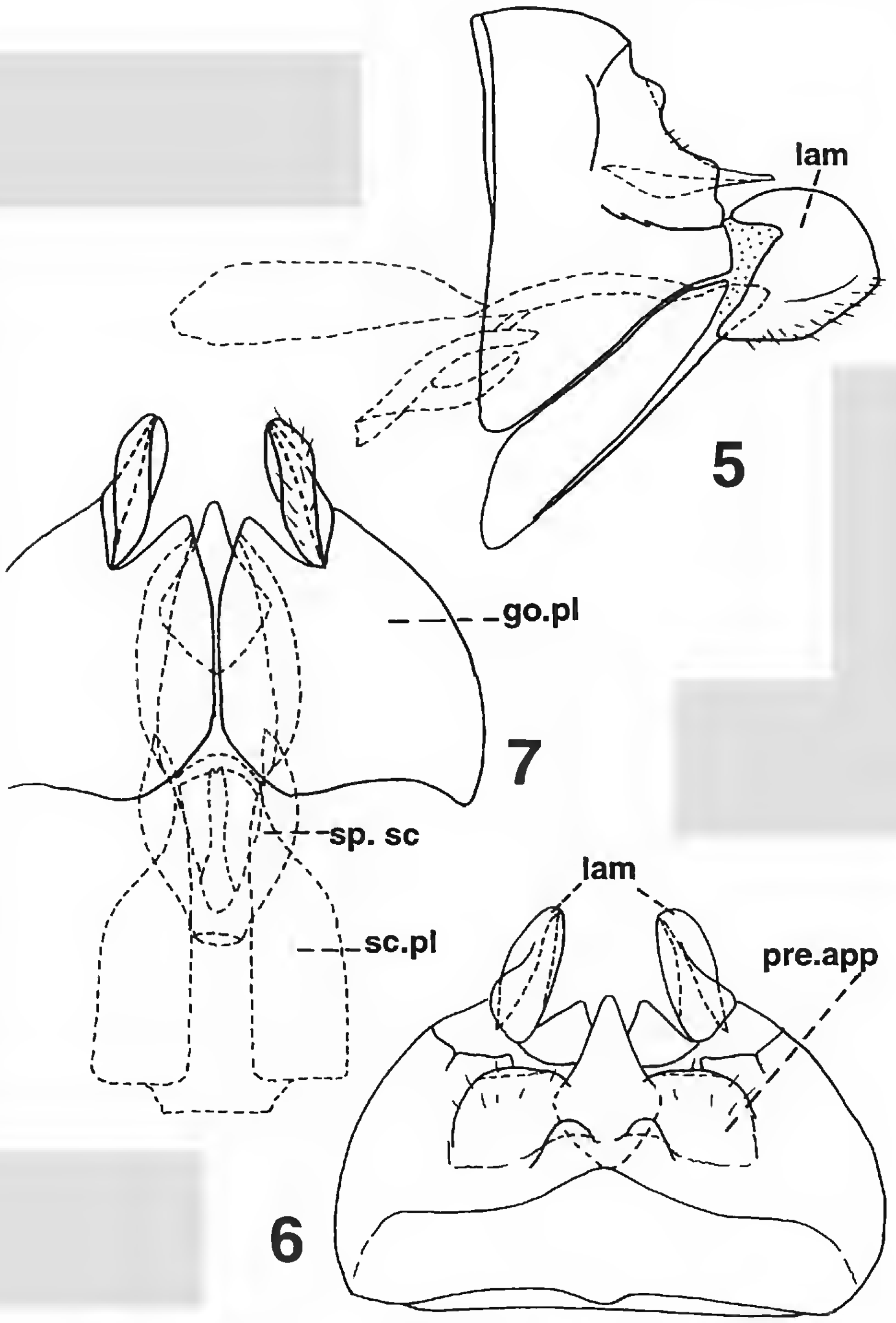


Figures 1–4. Male genitalia of *Ceraclea* (*A.*) *affinis* NEW SPECIES in lateral (1) and dorsal (2) views; left inferior appendage (3) in caudal view; phallus (4) in lateral view. Abbreviations: bv = basoventral lobe of an inferior appendage; har = harpago; inf.app = inferior appendage; mes.rdg = mesal ridge of an inferior appendage; par = paramere spines; pre.app = preanal appendage; sap.do = subapicodorsal lobe of an inferior appendage; IX, X = abdominal segments IX and X.

Female Genitalia (Figs. 5–7).—Tergum IX rounded apically, with pair of small subdorsal processes. Preanal appendages (pre.app) short, as long as broad, covered with short setae. Lamellae (lam) parallel-sided in dorsal and ventral views, semicircular in lateral view, setose ventrally. Each gonopod plate (go.pl; e.gon.IX of Nielsen 1980) with triangular caudal projection, plates approximate for most of their length, with triangular excisions between their caudal projections; gonopod plates slightly concave in middle with prominent mesal and lateral edges. Spermathecal sclerite (sp.sc) long, V-shaped, with lateral arms curved mesad near caudal end. Pair of broad sclerotized plates (sc.pl) suspended above spermathecal sclerite and extending cephalad nearly to two-thirds length of segment VIII.

Immature Stages.—Unknown.

Diagnosis.—*Ceraclea affinis* belongs to the *C.* (*A.*) *diluta* Group, which presently includes *C. diluta* (Hagen), *C. perplexa* (McLachlan) and *C. trilobulata* Morse, Yang, and Levanidova. Male genitalia of the new species most closely resemble those of *C. trilobulata* in the trilobate tergum X, in the shape of its inferior appendages, and in the presence of a ventral constriction of the phallus. It differs from *C. trilobulata* in the much longer base of the phallus, with the position of the ventral constriction nearly two-thirds of the distance from the based of the phallus; in the apparently longer middle lobe of tergum X; and in the thicker base of each inferior appendage. Because the females of *C. perplexa* and *C. trilobulata* are unknown, it is not possible to separate them from the female



Figures 5–7. Female genitalia of *Ceraclea* (*A.*) *affinis* NEW SPECIES (holotype) in lateral (5), dorsal (6) and ventral (7) views. Abbreviations: go.pl = gonopod plate of gonopod IX; lam = lamella; pre.app = preanal appendage; sc.pl = sclerotized plate of spermathecal sclerite; sp.sc = spermathecal sclerite.

of the new species; however, the apicolateral lamellae of *C. affinis* are shorter than those of *C. diluta.*

Distribution.—Known only from the type locality in Khabarovsk Territory (Russia).

Etymology.—Latin, "similar," with reference to the resemblance of the new species with *C. trilobulata.*

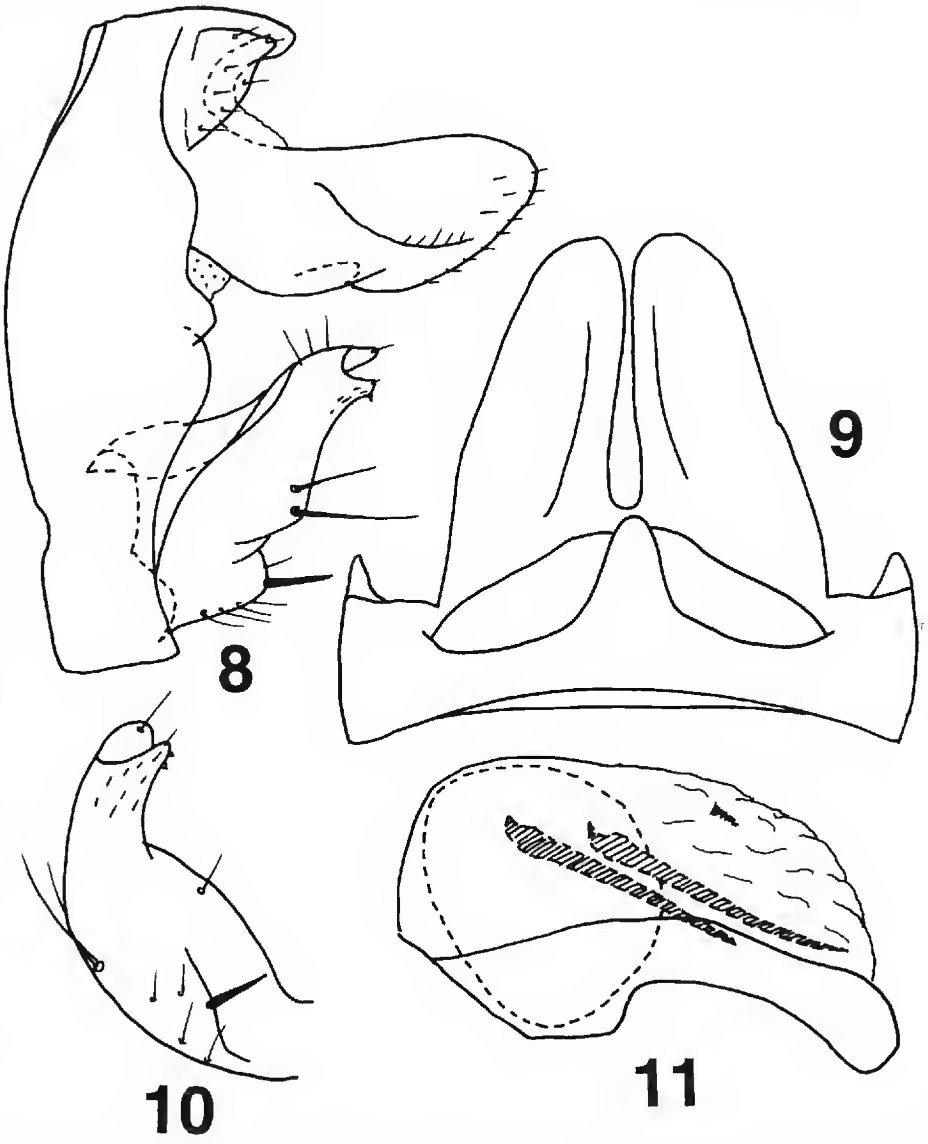
CERACLEA (*ATHRIPSODINA*) *ANNULICORNIS* Group

Ceraclea (*Athripsodina*) *bilobulata,* NEW SPECIES

(Figs. 8–15)

Types.—Holotype male: KHABAROVSK TERRITORY (RUSSIA). Ussuri River near Zabaikalskoe Village, 23 Jul 1996, T. Arefina. Paratypes: 7 males, same data as holotype.

Description.—Length of forewing: male—5.5–6.2 mm, female—5.3–5.9 mm. Head with mostly



Figures 8–11. Male genitalia of *Ceraclea* (*A.*) *bilobulata* NEW SPECIES (paratype) in lateral (8) and dorsal (9) views; left inferior appendage (10) in caudal view; phallus (11) in lateral view.

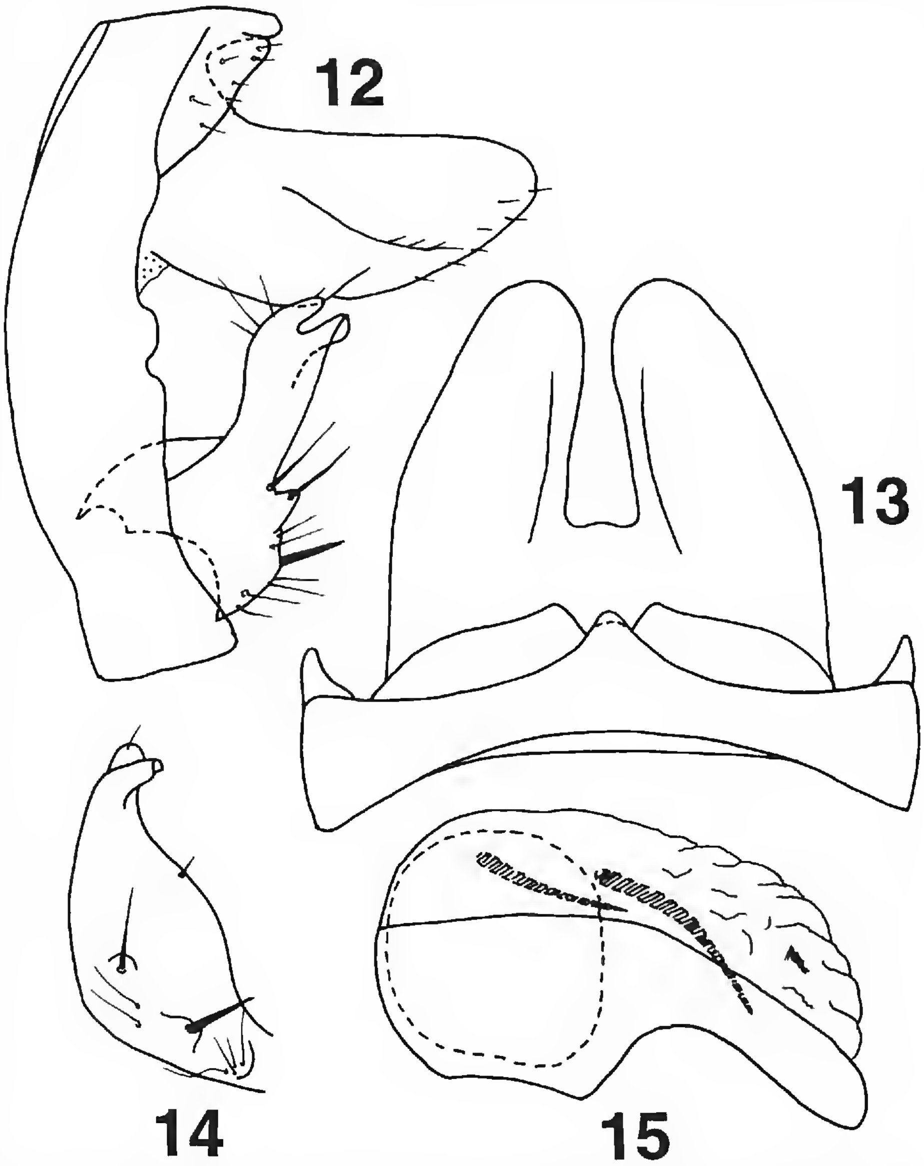
white hairs. Vertex of head and thorax yellow-brown, abdomen lighter, nearly white ventrally. Wings straw yellow with yellow-brown setae.

Male Genitalia (Figs. 8–15).—Tergum IX protruding at apical center. Preanal appendages very short and broad in dorsal view, separated basally, slightly shorter then tergum IX to slightly longer. Tergum X extending far beyond preanal appendages, broad basally, divided into two lobes nearly to base, each lobe with rounded apex; dorsal edge of tergum straight in lateral view, ventral edge of tergum upturned from middle, apex rounded. Main body of each inferior appendage slender, both harpago and subapicodorsal lobe short; harpago nearly as long as semimembranous subapicodorsal lobe to slightly longer; basoventral lobe of each inferior appendage vestigial, very short, with single spine directed somewhat mesad; mesal ridge without project and bearing only one normal seta; main body with variable caudolateral lobe bearing two large setae. Phallus curved ventrad, with sclerotization extended full length ventrally; anterior portion shorter and broader than posterior portion; two paramere spines present, left paramere spine about same size as right, but retracted somewhat more cephalad.

Remarks.—Different individuals of the species vary in the shape of the preanal and inferior appendages and in size and location of the paramere spines of the phallus. In spite of the variability of these characters, the available specimens generally agree with the foregoing description.

Female and Immature Stages.—Unknown.

Diagnosis.—The male of this species resembles those of *C. sibirica* (Ulmer) and *C. hastata* (Botosaneanu) in the presence of a spine at the basoventral position of the inferior appendages; in the mesal ridge of each inferior appendage without



Figures 12–15. Male genitalia of *Ceraclea* (*A.*) *bilobulata* NEW SPECIES (paratype) in lateral (12) and dorsal (13) views; left inferior appendage (14) in caudal view; phallus (15) in lateral views.

any projection; in tergum X lacking lateral processes; and in the sclerotization extending the full length of the phallus ventrally. However, tergum X is divided into two lobes in the new species whereas *C. sibirica* and *C. hastata* have no excision on tergum X. *Ceraclea bilobulata* differs from both *C. sibirica* and *C. hastata* and other known males of the *C.* (*A.*) *annulicornis* Group in the short and basally separated preanal appendages, in the very short basoventral lobe of each inferior appendage, in the mesal ridge of the inferior appendages having only one seta, and in possessing two phallic paramere spines nearly equal in length.

Distribution.—Known only from the type locality in Khabarovsk Territory (Russia).

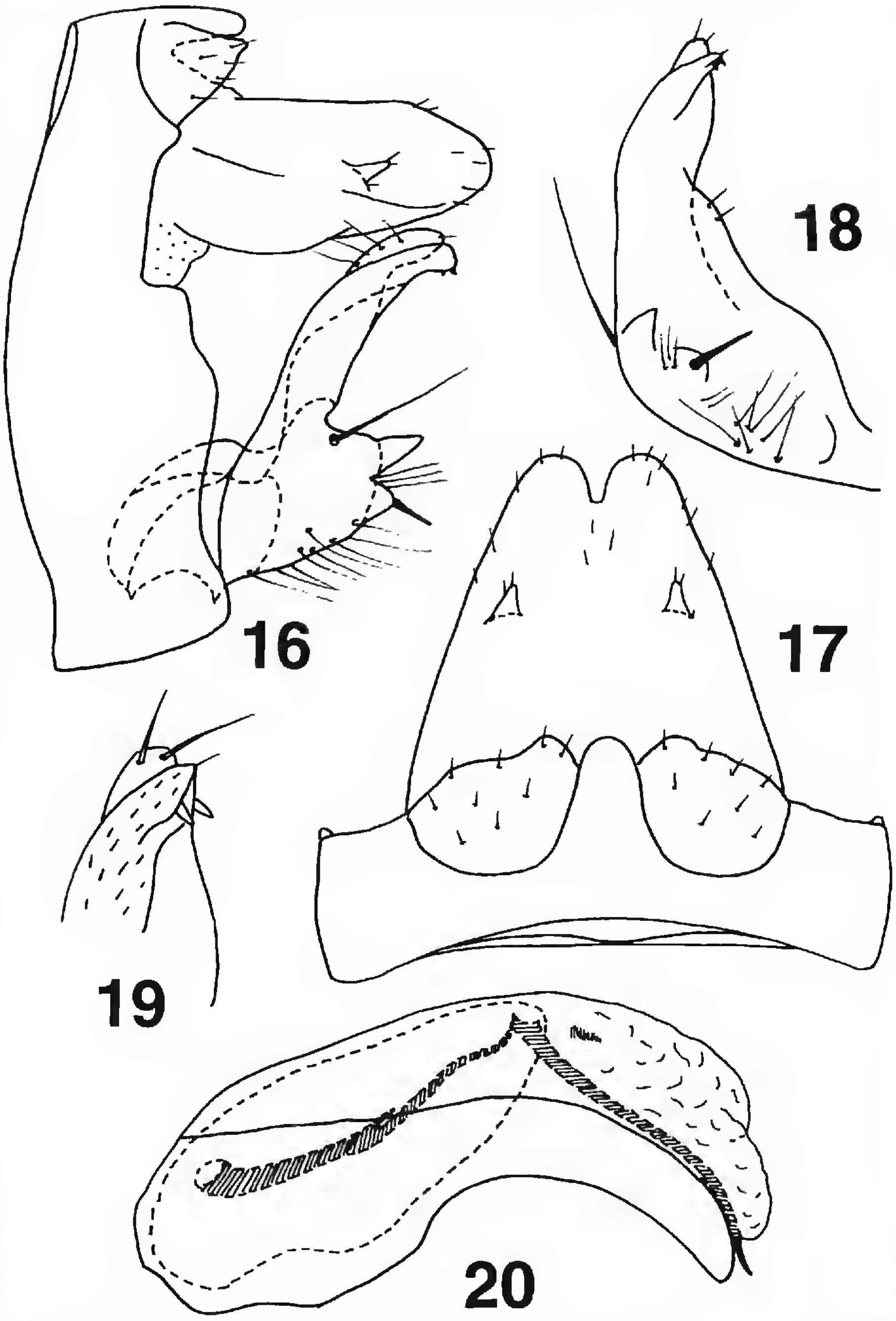
Etymology.—Latin, "two-lobed," with reference to the shape of tergum X in the male genitalia.

CERACLEA (*ATHRIPSODINA*) *RIPARIA* Group

Ceraclea (*Athripsodina*) *breviramosa*, NEW SPECIES

(Figs. 16–23)

Types.—Holotype male: KHABAROVSK TERRITORY (RUSSIA). Ussuri River near Zabaikalskoe Village, 23 Jul 1996, T. Arefina. Paratypes: 24 females, same data as holotype; Khabarovsk Territory (Russia), Kiya River, Ussuri River Basin, Ekaterinoslavka Village vicinity, 26 Jul 1996, T. Arefina, 4 females; Pri-

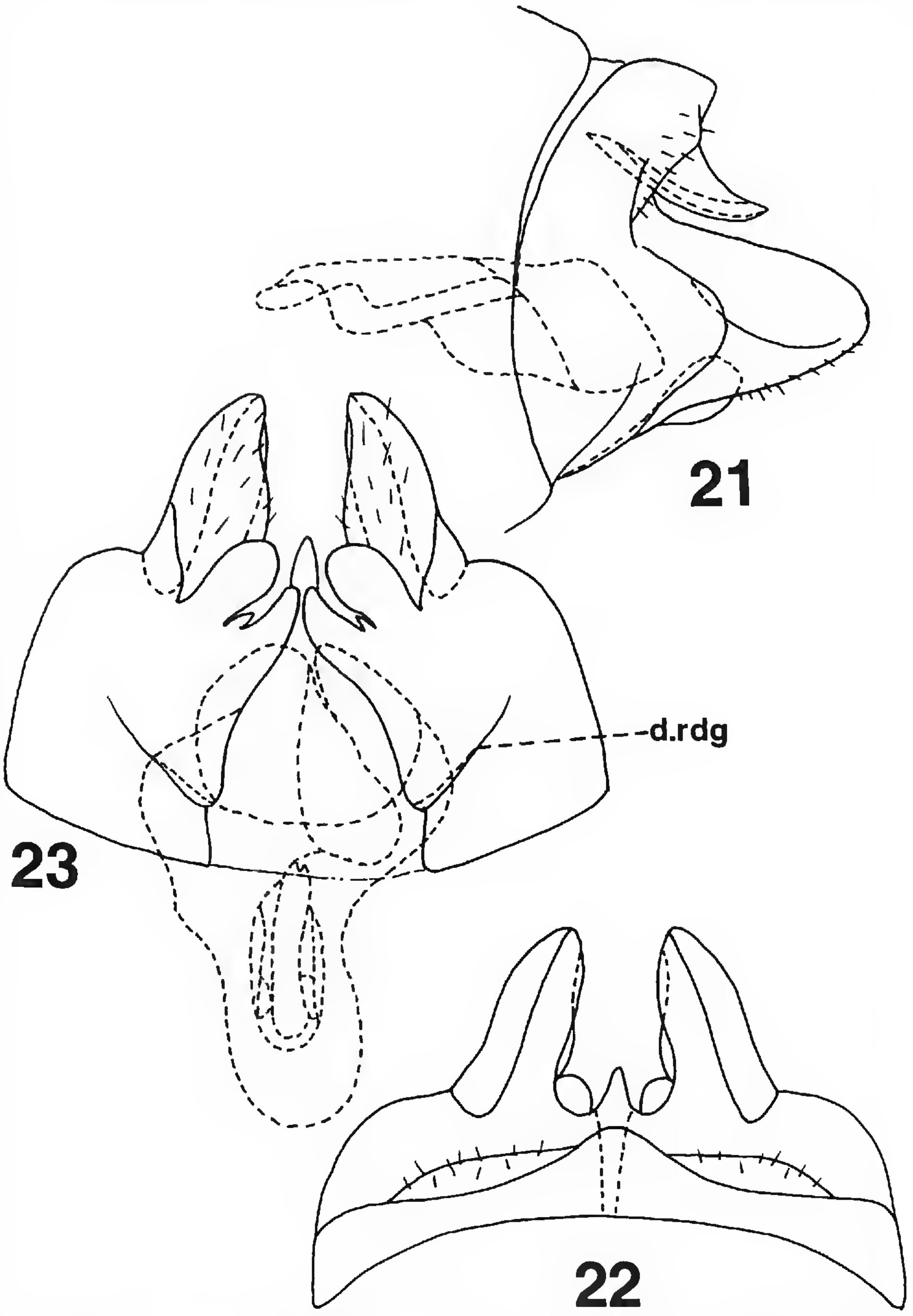


Figures 16–20. Male genitalia of *Ceraclea* (*A.*) *breviramosa* NEW SPECIES (holotype) in lateral (16) and dorsal (17) views; left inferior appendage (18) in caudal view; harpago and subapicodorsal lobe of left inferior appendage (19) in caudal view; phallus (20) in lateral view.

morye Region (Russia), Kabarga River, Ussuri River Basin, 28 Jul 1998, T. Tiunova, 2 females.

Description.—Length of forewing: male—5.8 mm, female—5.5–6.0 mm. Head with white hairs on middle of front and vertex, side hairs brownish. Head and thorax yellow-brown, abdomen whitish, abdominal dorsum pale brown. Wings straw yellow with yellow-brown setae.

Male Genitalia (Figs. 16–20).—Tergum IX protruding at apical center. Preanal appendages nearly as long as broad, separated basally, about as long as tergum IX, obliquely truncate apically. Tergum X about 2.5× as long as preanal appendages, broad at base, tapering to blunt apex, with V-shaped cleft apically one-eighth of its length; tergum X with pair of smaller papillae near middle of tergum. Basoventral lobe of each inferior appendage shorter than main body of appendage, directed somewhat mesad, bearing single spine subbasally; triangular projection above basoventral lobe, nearly as long as spine in lateral view. Main body of appendage slender; harpago slightly longer than subapicodorsal lobe, each harpago setose, with two small spines at apex; each subapicodorsal lobe with several long setae along dorsal surface and membranous apex bearing two setae. Mesal ridge of each inferior appendage with two normal setae. Phallus strongly curved ventrad about half distance from base, with sclerotization extended full length ventrally; anterior portion of phallobase slightly broader and longer than posterior portion in lateral view. Paramere spines aligned, with apex of left spine slightly inserted in elliptical opening of base of right spine, as typical for Group; left spine with short and straight



Figures 21–23. Female genitalia of *Ceraclea* (*A.*) *breviramosa* NEW SPECIES (paratype from Ussuri River near Zabaikalskoe Village) in lateral (21), dorsal (22) and ventral (23) views. Abbreviation: d.rdg = diagonal ridge of a gonopod plate.

dorsomedial projection; apical half of left spine sinuous, with upturned tip; right spine straight, curved ventrad at three-quarters distance from base, with tip turned slightly outwards, to right.

Female Genitalia (Figs. 21–23).—Preanal appendages broad but very short, as typical for Group. Lamellae setose ventrally, each with broadly rounded apex in lateral view. Gonopod plates widely separated anteriorly, not concave, each with well-sclerotized diagonal ridge (d. rdg); each plate with two caudal projections: mesal projection narrow and elongate, lateral projection rather large, oval in lateral and ventral views. Anterior part of the spermathecal sclerite narrow, broadens in middle, convex laterally in posterior part.

Immature Stages.—Unknown.

Diagnosis.—The male genitalia of this species resemble those of most species of the *C.* (*A.*) *riparia* Group in possessing two phallic paramere spines which are aligned, with the apex of the left spine inserted in an opening of the base of the right spine, but in this new species the left spine has a dorsomedial projection and an upturned tip. This is the only species with the *C.* (*A.*) *riparia* Group whose male: (1) lacks a pair slender lateral processes of tergum X; (2) has the inferior appendages each with such a short basoventral lobe; and (3) has the mesal ridge of each inferior appendage bearing only two setae. The female of this species resembles those of *C. riparia* (Albarda), *C. yangi* (Mosely) and *C. nankingensis* (Hwang) in the shape of the caudal projections of the gonopod plates and of the spermathecal sclerite, but it differs from all known species of the *C.* (*A.*) *riparia* Group in possessing a diagonal ridge of each gonopod plate.

Distribution.—Known only from the type localities in Khabarovsk Territory and the Primorye Region (Russia).

Etymology.—Latin, "short-branched," with reference to the short basoventral lobe of each inferior appendage in the male genitalia.

NEW RECORD

Adicella sp. n. (Yang and Morse, unpublished data)

Material Examined.—KHABAROVSK TERRITORY (RUSSIA). Kiya River, Ussuri River Basin, Yekaterinoslavka Village vicinity, 26 Jul 1996, T. Arefina, 2 males.

Distribution.—Khabarovsk Territory (Russia), China.

ACKNOWLEDGMENT

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LITERATURE CITED

Arefina, T. I. 1997. Three new to the Russia species of the caddisflies (Trichoptera: Leptoceridae). Far Eastern Entomol., 47: 18.

Nielsen, A. 1980. A comparative study of the genital segments and genital chamber in the female Trichoptera. Det Kongelige Dansk Videnskabernes Selskab Biologiske Skrifter, 23: 1–200.

Vshivkova, T. S., J. C. Morse & L. Yang. 1997. Fam. Leptoceridae. pp. 154–202. *In* Lehr, P. A. (ed.). Key to the insects of Russian Far East V. Trichoptera and Lepidoptera Pt. 1, Vladivostok.

Yang, L. & J. C. Morse. 1988. *Ceraclea* of the People's Republic of China (Trichoptera: Leptoceridae). Contr. Amer. Entomol. Inst., 23: 1–69.

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A FURTHER CONTRIBUTION TO THE AUSTRALIAN SYSTEMATICS OF THE TRIBE COLPURINI (HEMIPTERA: HETEROPTERA: COREIDAE: COREINAE)

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Abstract.—One new genus (*Weirhygia*) and four new species (*Weirhygia faceta, Grosshygia formosa, Grosshygia lepida,* and *Grosshygia pisina*) from Australia are described in the tribe Colpurini (Coreidae). A revised key to all known genera and species is included. Dorsal habitus illustrations and drawings of male genital capsule and female genital plates are provided.

Key Words.—Insecta, Hemiptera, Heteroptera, Coreidae, Colpurini, new genus, new species, Australia.

The Australian species of the tribe Colpurini have recently been reviewed by Brailovsky (1993), Brailovsky & Barrera (1996) and Steinbauer & Clarke (1996). During a visit to Queensland Museum, Brisbane, Australia, I found, a series of specimens of Colpurini that I first thought to be a previous known species of *Grosshygia* Brailovsky and *Grosshygioides* Brailovsky. A preliminary check of the head, pronotum, development of the hemelytra, general shape of the male genital capsule and abdominal sternite VII of the female revealed a new genus, and species and three new species of *Grosshygia.*

This additional information is made possible largely by the extensive collections of G. B. Monteith and his colleagues.

One of the most striking developments in australian colpurini systematics has been the discovery of an extensive fauna living on the ground of tropical rainforest at high and low elevations of northern and northeastern Queensland. They live associated with piles of freshly dead leaves from recently fallen trees.

Revised Key to Australian Colpurini

1. Each side of head immediately in front of eye with long pointed spine .... *Pachycolpura manca* Breddin
1′. Sides of head in front of eyes unarmed 2
2. Tylus projecting as single, large, acute spine 3
2′. Tylus globose, truncated or bifid 5
3. Femora unarmed; callar region of pronotum conspicuously convex; pronotal disc behind midline with transverse wrinkle; male genital capsule with small median projection .... *Acanthotyla fasciata* (Walker)
3′. Femora strongly armed with long, sharp ventral spines; callar region of pronotum weakly convex to flat; pronotal disc without transverse wrinkle; posteroventral edge of male genital capsule without median projection 4
4. Mandibular plate armed with short projection; posteroventral edge of male genital capsule convex, obtusely rounded ... *Agathyrna praecellens* Stal

4′. Mandibular plate unarmed; posteroventral edge of male genital capsule elongate and bifurcate ..... *Woodwardhygia bifida* Brailovsky (in part)

5. Antenniferous tubercles armed 6

5′. Antenniferous tubercles unarmed 14

6. Bucculae armed with obvious spine near middle third 7

6′. Bucculae uniformly rounded 8

7. Rostrum reaching middle third of abdominal sternite V; body robust, longer than 10.00 mm; frontal angles of pronotum conspicuously prominent; scutellum as wide or wider than long .... *Acantholybas kirkaldyi* Bergroth

7′. Rostrum reaching posterior margin of abdominal sternite IV; body shorter than 9.00 mm; frontal angles of pronotum scarcely exposed; scutellum clearly longer than wide .... *Acantholybas brunneus* Breddin

8. Micropterous, hemelytral membrane reduced to small flap; ocelli inconspicuous 9

8′. Macropterous to submacropterous, hemelytral membrane well developed; ocelli clearly developed .... *Pachycolpuroides monteithi* Brailovsky

9. Head dorsally flat; abdominal sternite VII of female without plica or fissura ... *Weirhygia faceta* Brailovsky NEW GENUS NEW SPECIES

9′. Head dorsally convex; abdominal sternite VII of female with plica and fissura 10

10. Apex of scutellum globose .... *Grosshygia nigra* Brailovsky

10′. Apex of scutellum subacute 11

11. Antenniferous tubercles each with external lobe arcuate, recurved, converging anteriorly, almost touching the basal joint of antennal segment I .... *Grosshygia lepida* Brailovsky NEW SPECIES

11′. Antenniferous tubercles each with external lobe obliquely projecting, diverging anteriorly 12

12. Head dorsally with vertex uniformly convex, without conical lobes; hemelytral membrane absent .... *Grosshygia pisina* Brailovsky NEW SPECIES

12′. Head dorsally with a transverse depression separated into two conical elevations; hemelytral membrane reduced to small flaps 13

13. Antenniferous tubercles each armed with long lobe; antennal segment II longer than 1.96 mm .... *Grosshygia lobatula* Brailovsky

13′. Antenniferous tubercles each armed with short lobe; antennal segment II shorter than 1.73 mm .... *Grosshygia monticeps* Brailovsky

14. Head dorsally convex; apex of scutellum globose .... *Grosshygia formosa* Brailovsky NEW SPECIES

14′. Head dorsally flat; apex of scutellum subacute 15

15. Abdominal sternite VII of female without plica or fissura; frontal angles of pronotum rounded, blunt, not produced 16

15′. Abdominal sternite VII of female with plica and fissura; frontal angles of pronotum produced forward as conical teeth 20

16. External edge of gonocoxa I in lateral view with upper half conspicuously exposed and lower half projected in a medium-sized convex lobe 17

16′. External edge of gonocoxa I in lateral view uniformly convex 18

17. Posteroventral edge of male genital capsule with small V-shaped concavity, laterally enclosed by two shorter arms; gonocoxa I in caudal view closed .... *Sciophyroides sortita* (Horvath)
17′. Posteroventral edge of male genital capsule with U-shaped concavity, enclosed by two lateral medium-sized robust arms; gonocoxa I in caudal view opened .... *Sciophyroides sulcicrus* (Breddin)
18. Body length longer than 10.30 mm; posteroventral edge of male genital capsule with large U-shaped concavity, laterally enclosed by two strong divergent arms .... *Sciophyrella australica* (Brailovsky)
18′. Body length shorter than 10.10 mm; posteroventral edge of male genital capsule not as above 19
19. Posteroventral edge of male genital capsule produced into medium-sized and robust lateral projections, enclosing deep U-shaped concavity; gonocoxa I in lateral view narrow .... *Sciophyrella diminuta* (Horvath)
19′. Posteroventral edge of male genital capsule with small V-concavity enclosed by two short globose arms; gonocoxa I in lateral view enlarged .... *Sciophyrella minuscula* Brailovsky & Barrera
20. Mandibular plate armed with large prominent tubercle; pronotal disc with deep longitudinal furrow along midline; hemelytra truncate, membrane absent .... *Grosshygioides mandibularis* Brailovsky
20′. Mandibular plate unarmed; pronotal disc flat, without midline furrow; macropterous; hemelytral membrane well developed 21
21. Femora armed with two rows of ventral spines: tylus apically bifid .... *Woodwardhygia bifida* Brailovsky (in part)
21′. Femora unarmed; tylus apically globose .... *Hygia (Australocolpura) sandaracine* Brailovsky

WEIRHYGIA BRAILOVSKY, NEW GENUS

Type species.—Weirhygia faceta Brailovsky, NEW SPECIES.

Description.—Head longer than wide (across eyes), pentagonal, nondeclivent, and dorsally flat; tylus unarmed, apically globose, extending anteriorly to and laterally higher than juga; juga unarmed, thickened, apically rounded, shorter than tylus; antenniferous tubercle armed with raised lobe, diverging anteriorly and rounded to quadrate apically; sides of head in front of eyes unarmed; genae and mandibular plates unarmed; antennal segment I robust, thickest, slightly curved outward; segments II and III cylindrical, and slender; segment IV fusiform; antennal segment II longest, I shortest and III longer than IV; ocelli not raised; preocellar pit obliquely deep; eyes small, globular; postocular tubercle protuberant, globose; buccula rectangular, short, elevated, not projecting beyond antenniferous tubercle, without teeth; rostrum long, reaching posterior margin of abdominal sternite VI or anterior margin of VII; rostral segment IV longest, I shortest, and II longer than III. Thorax. Pronotum: Wider than long, trapeziform, non declivent, and bilobate; anterior lobe longer than posterior lobe, each with anterolateral borders barely convex; collar wide; frontal angles projecting forward as conical teeth; humeral angles rounded, projected into rounded lobes, elevated, directed outward, higher than posterior pronotal disc; posterolateral and posterior borders almost straight; callar region weakly convex, separated medially by deep longitudinal furrow, which extends to posterior margin. Anterior lobe of metathoracic peritreme elevated, reniform, posterior lobe sharp, small. Legs: Unarmed; tibiae cylindrical, with longitudinal sulcus indistinct. Scutellum: Triangular, flat, wider than long, with apex subacute. Hemelytra: Coleopteroid; clavus and corium fused into coriaceous pad, wings meeting each other along midline; hemelytral membrane reduced to small flap, reaching middle third of abdominal tergite III, thus leaving the abdominal terga exposed. Abdomen: Connexival segments practically at same level as abdominal segments; posterior angle of connexivum extending into short and robust spine; abdominal sterna with medial furrow extending to posterior border of sternite VI. Integument: Body surface dull; ventral face of head, posterior lobe of pronotum, scutellum, clavus, corium, propleura, mesopleura and metapleura, acetabula and abdomen with scattered punctures, each puncture with short decumbent silvery bristle-like hair, intermixed with long erect bristles on antennal segments, legs, and abdominal sterna; dorsal surface of head, anterior lobe of pronotum, and connexival segments impunctate.

Male Genitalia.—Genital capsule. Posteroventral edge simple, transversely barely arcuate, with shallow notch at midline (Fig. 3).

Female Genitalia.—Abdominal sternite VII without plica and fissura; gonocoxae I enlarged anteroposteriorly, in lateral view with external face obliquely straight, in caudal view open; paratergite VIII short, almost square, with spiracle visible; paratergite IX larged than paratergite VIII (Fig. 4).

Diagnosis.—The reduction of wings, the prominent postocular tubercle, the pronotal disk with deep midline furrow, and tylus apically globose might suggest a relationship with *Grosshygioides* Brailovsky.

In *Weirhygia,* the antenniferous tubercle armed, the mandibular plate unarmed, posterior angle of connexivum extending into short and robust spine, abdominal sternite VII of female without plica and fissura, and frontal angles produced forward into conical teeth. In *Grosshygioides,* the antenniferous tubercle is unarmed, the mandibular plate armed, posterior angle of connexivum unarmed, abdominal sternite VII of female with plica and fissura, and frontal angles projecting forward as small rounded teeth.

Distribution.—Only known from Australia.

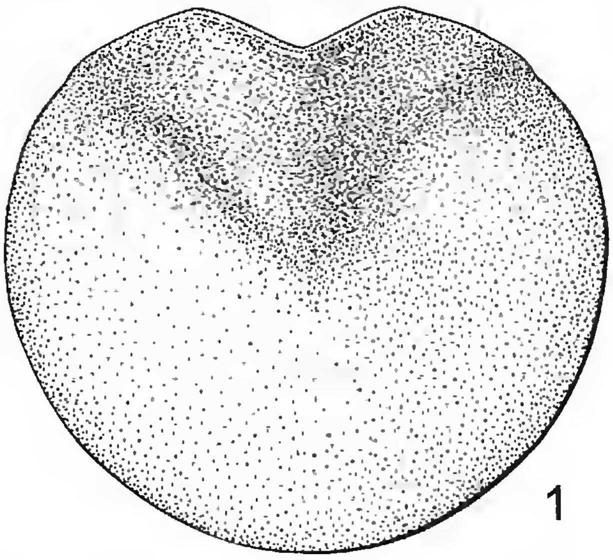
Etymology.—Named for Tom Weir, distinguished Australian entomologist.

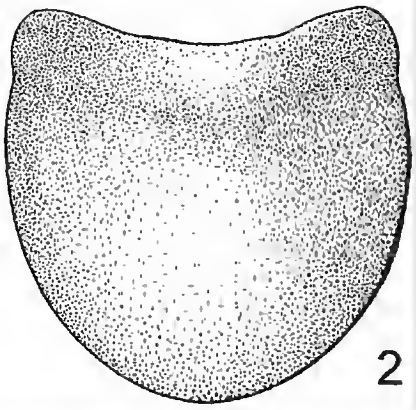
WEIRHYGIA FACETA BRAILOVSKY, NEW SPECIES
(Figs. 3, 4, 7)

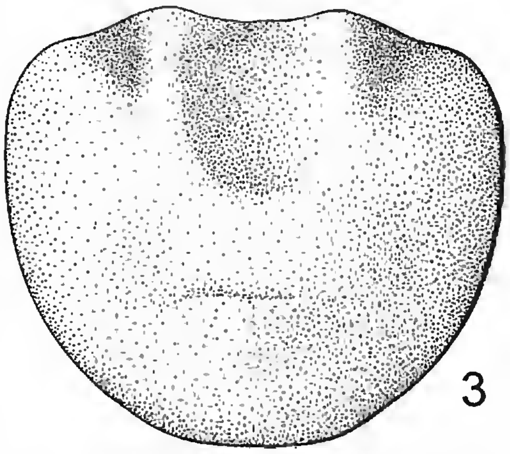
Types.—Holotype male: Australia. NE Queensland, Isley Hills, 1050 m, 17°03′ S 145°42′ E, 30 Nov 1993, Cook, Monteith and Janetzki. Deposited in Queensland Museum, Brisbane, Australia. Paratypes: 1 male, 1 female; data: same as holotype. Deposited in the "Colección Entomológica del Instituto de Biología, UNAM, México, and Queensland Museum, Brisbane, Australia. 1 male; data: Australia: NE Queensland, Upper Isley Ck., 750 m, 17°03′ S 145°41′ E, 29 Nov 1993, Monteith, and Janetzki. Deposited in Queensland Museum, Brisbane, Australia.

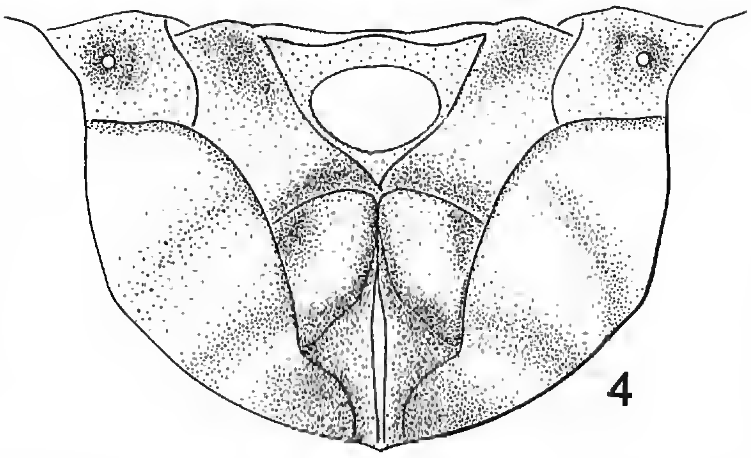
Description.—Male (holotype). Dorsal coloration: chestnut orange with inner face of antenniferous tubercle, dorsal aspect of postocular tubercle, frontal angles, short longitudinal stripe at middle third of posterior lobe of pronotal disk, and posterior angles of connexival segments II to VII yellow to orange yellow; antennal segments I to III chestnut orange, IV yellow with basal join chestnut; hemelytral membrane yellow with inner angle black. Ventral coloration: Chestnut orange with rostral segments I to IV, buccula, acetabula (punctures chestnut orange), anterior and posterior lobe of metathoracic peritreme, evaporative area, and genital capsule yellow to orange yellow; rim of abdominal spiracular peritreme black; punctures of abdominal sternite V to VII reddish orange; coxae yellow with dark brown spots; trochanters yellow and apically dark brown; femora yellow, and dorsally covered with dark brown to light chestnut brown spots; tibiae yellow with four to five red rings; tarsi yellow with diffuse reddish to dark brown marks.

Female.—Dorsal coloration: head chestnut orange, sprinkled with small reddish tubercles and with following areas yellow: dorsal aspect of postocular tubercle and longitudinal stripe adjacent to eyes; antennal segment I chestnut orange, segment II dark yellow with apical third reddish orange, segment III reddish orange with basal joint yellow, and IV yellow with basal joint reddish orange; pronotum, scutellum, corium, clavus and dorsal abdominal segments with punctures reddish brown to dark brown; connexival segments reddish brown with posterior angle yellow; hemelytral membrane black to dark brown with middle third yellow. Ventral coloration: yellow with reddish brown to dark brown punctures and irregular spots scattered throughout the body; rostral segments I–II chestnut brown, III–IV yellow (apex of IV chestnut orange); anterior and posterior lobe of metathoracic peritreme creamy









Figures 1–2. Male genital capsule of *Grosshygia* spp.
Figure 1. *G. formosa* Brailovsky, NEW SPECIES.
Figure 2. *G. pisina* Brailovsky, NEW SPECIES.
Figures 3–4. *Weirhygia faceta* Brailovsky, NEW GENUS, NEW SPECIES. Figure 3. Male genital capsule. Figure 4. Female genitalia.

yellow and evaporative area yellow; coxae yellow with diffuse dark brown spots; trochanters yellow with apex dark brown; femora and tibiae yellow, with four to five reddish orange to black irregular rings; tarsi yellow with diffuse reddish to dark brown marks; abdominal spiracular peritreme black.

Measurements.—Male (female). Head length: 1.88 mm (1.98 mm); width across eyes: 1.52 mm (1.64 mm); interocular space: 1.00 mm (1.02 mm); interocellar space: 0.50 mm (0.46 mm); preocular distance: 1.30 mm (1.36 mm); antennal segments lengths: I, 1.12 mm (1.12 mm); II, 1.72 mm (1.76 mm); III, 1.40 mm (1.40 mm); IV, 1.20 mm (1.16 mm). Pronotal length: 1.72 mm (1.80 mm); width across frontal angles: 1.68 mm (1.84 mm); width across humeral angles: 3.32 mm (3.56 mm). Scutellar length: 1.00 mm (1.04 mm); width: 1.28 mm (1.48 mm). Maximum width of abdomen: 5.04 mm (5.84 mm). Total body length: 10.20 mm (11.63 mm).

Etymology.—From the Latin, *facetus,* meaning elegant, fine.

GROSSHYGIA FORMOSA BRAILOVSKY, NEW SPECIES
(Figs. 1, 5)

Types.—Holotype male: Australia. Queensland, Kroombit Tops, 65 km SW Gladstone (Sieved litter. Q.M. Berlesate no. 383, in rainforest), 1100 m, 22–26 Feb 1982, G. Monteith and G. Thompson. Deposited in Queensland Museum, Brisbane, Australia.

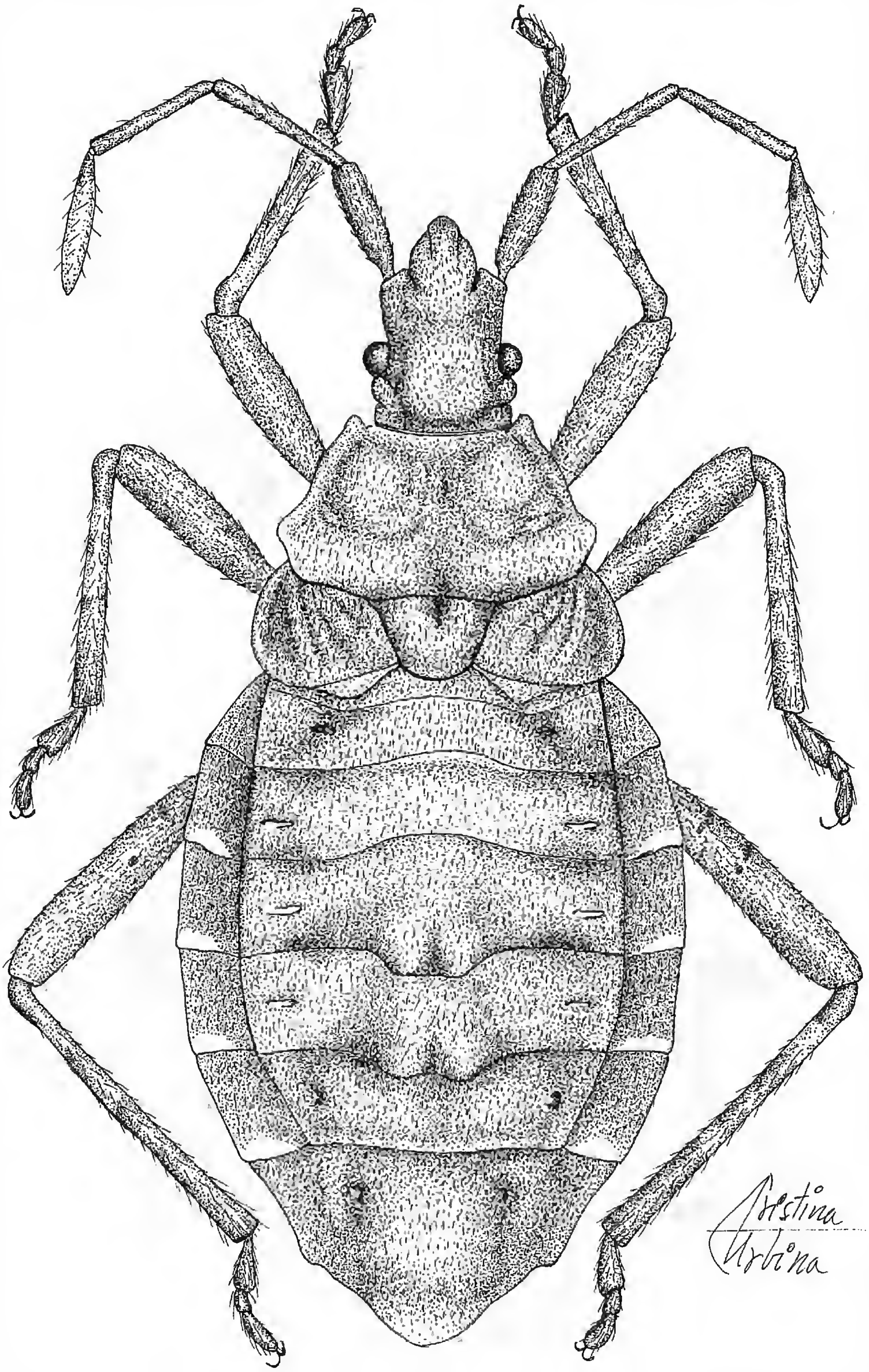


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Figure 5. Dorsal view of *Grosshygia formosa* Brailovsky, NEW SPECIES.

Description.—Male (holotype). Coloration: dark reddish brown; antennal segment I dark chestnut orange II, and III pale chestnut orange, IV yellow with basal joint pale chestnut orange; hemelytral membrane yellow; inner margin of acetabula, coxae, and trochanters dirty chestnut orange; femora chestnut orange with basal joint, and few subapical spots dirty yellow; tibiae chestnut orange with three to four irregular yellow rings; tarsi chestnut orange with dirty yellow reflections; upper margin of connexival segments black. Structural characters.—Head: longer than wide across eyes, pentagonal, conspicuously convex dorsally; antenniferous tubercles unarmed; rostrum reaching anterior margin of abdominal sternite VII; vertex uniformly convex, without conical tubercles. Pronotum: slightly trapeziform, bilobed, nondeclivent; anterolateral margins convexly rounded, moderately elevated, and slightly reflexed; callar region transversely nodulose; anterior and posterior lobe along the middle line with wide longitudinal depression. Legs: unarmed. Scutellum: apex globose. Hemelytra: micropterous, reaching posterior margin of abdominal segment I; hemelytral membrane reduced to small pads, separated from each other, leaving the abdomen exposed mesally. Genital capsule: posteroventral edge simple, with median triangular expansion (Fig. 1).

Female.—Unknown.

Measurements.—Head length: 1.86 mm; width across eyes: 1.34 mm; interocular space: 1.06 mm; preocular distance: 1.32 mm; antennal segments lengths: I, 1.12 mm; II, 1.44 mm; III, 1.38 mm; IV, 1.28 mm. Pronotal length: 1.28 mm; maximum width of anterior lobe: 2.28 mm; maximum width of posterior lobe: 2.92 mm. Scutellar length: 0.72 mm; width: 1.18 mm. Maximum width of abdomen: 4.60 mm. Total body length: 10.30 mm.

Discussion.—Grosshygia nigra Brailovsky and *G. formosa,* are the only species of the genus with the scutellar apex globose. In the other known species, it is subacute. In *G. formosa* the head is longer than wide, the vertex is uniformly convex without conical lobes, the antenniferous tubercles are unarmed, and the posteroventral edge of male genital capsule has a median triangular expansion (Fig. 1). In *G. nigra* the head is wider than long, the vertex has two conical elevations, the antenniferous tubercles are armed with extremely long lobes, and the posteroventral edge of male genital capsule is transversely straight and entire.

Etymology.—From the Latin, *formosus,* meaning beautifully formed.

GROSSHYGIA LEPIDA BRAILOVSKY, NEW SPECIES
(Fig. 6)

Types.—Holotype female: Australia. N Queensland, Mt. Barflie Frere, Swiftlet Cave, 900 m, 8 Dec 1990, Monteith, Thompson, Cook and Sheridan. Deposited in Queensland Museum, Brisbane, Australia.

Description.—Female. (holotype). Coloration: dark chestnut orange with following areas dark yellow: dorsal aspect of postocular tubercle, rostral segments I to IV, posterior edge of connexival segments and abdominal pleural sterna III to VI, diffuse reflections on abdominal sterna III to VII, and genital plates; head and scutellum reddish brown; antennal segments I to III chestnut orange with basal joint of III yellow; antennal segment IV yellow with basal joint chestnut orange; anterior and posterior lobe of metathoracic peritreme bright chestnut orange; coxae reddish orange; trochanters and tibiae chestnut orange fore and middle femora chestnut orange with diffuse yellow rings; hind femur yellow with apical joint and two or three incomplete chestnut orange rings; tarsi yellow. Structural characters. Head: longer than wide across eyes, pentagonal, conspicuously convex dorsally; antenniferous tubercles armed, lobes raised, arcute, recurved, converging anteriorly, apically subacute, almost touching basal joint of antenna segment I; ocelli absent; rostrum reaching middle third of abdominal sternite VI; vertex globose with thin transverse depression, dividing it into two elevations, the anterior one broader, conical and higher than posterior one which is slightly rounded. Pronotum: scarcely quadrate, bilobed, nondeclivent; anterolateral margins convexly rounded, moderately elevated, and slightly reflexed; callar region transversely nodulose; anterior and posterior lobe along the middle line with wide longitudinal depression. Legs: unarmed. Scutellum: apex subacute. Hemelytra: micropterous, reaching middle third of abdominal segment III; wings reduced to small pads, separated from each other, leaving abdomen exposed mesally.

Male.—Unknown.

Measurements.—Head length: 1.80 mm; width across eyes: 1.72 mm; interocular space: 1.20 mm; preocular distance: 1.30 mm; antennal segments lengths: I, 1.00 mm; II, 1.60 mm; III, 1.04 mm; IV, 1.04 mm. Pronotal length: 1.60 mm; maximum width of anterior lobe: 2.20 mm; maximum width of

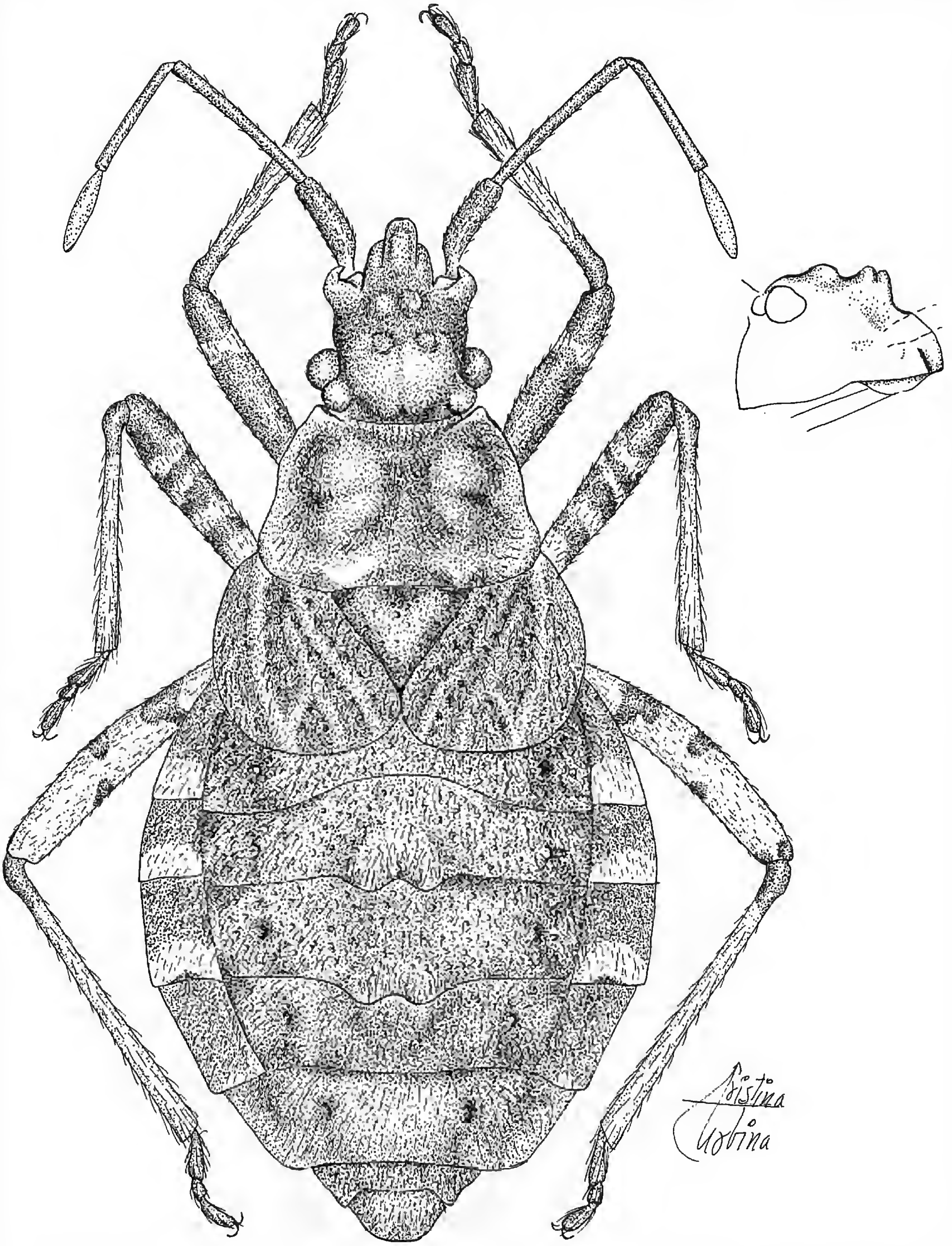

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Figure 6. Dorsal view of *Grosshygia lepida* Brailovsky, NEW SPECIES.

posterior lobe: 2.68 mm. Scutellar length: 0.92 mm; width: 1.16 mm. Maximum width of abdomen: 4.84 mm. Total body length: 9.55 mm.

Discussion.—Grosshygia lepida and its closely related species *G. lobatula* Brailovsky and *G. monticeps* Brailovsky, has the head longer than wide, the scutellar

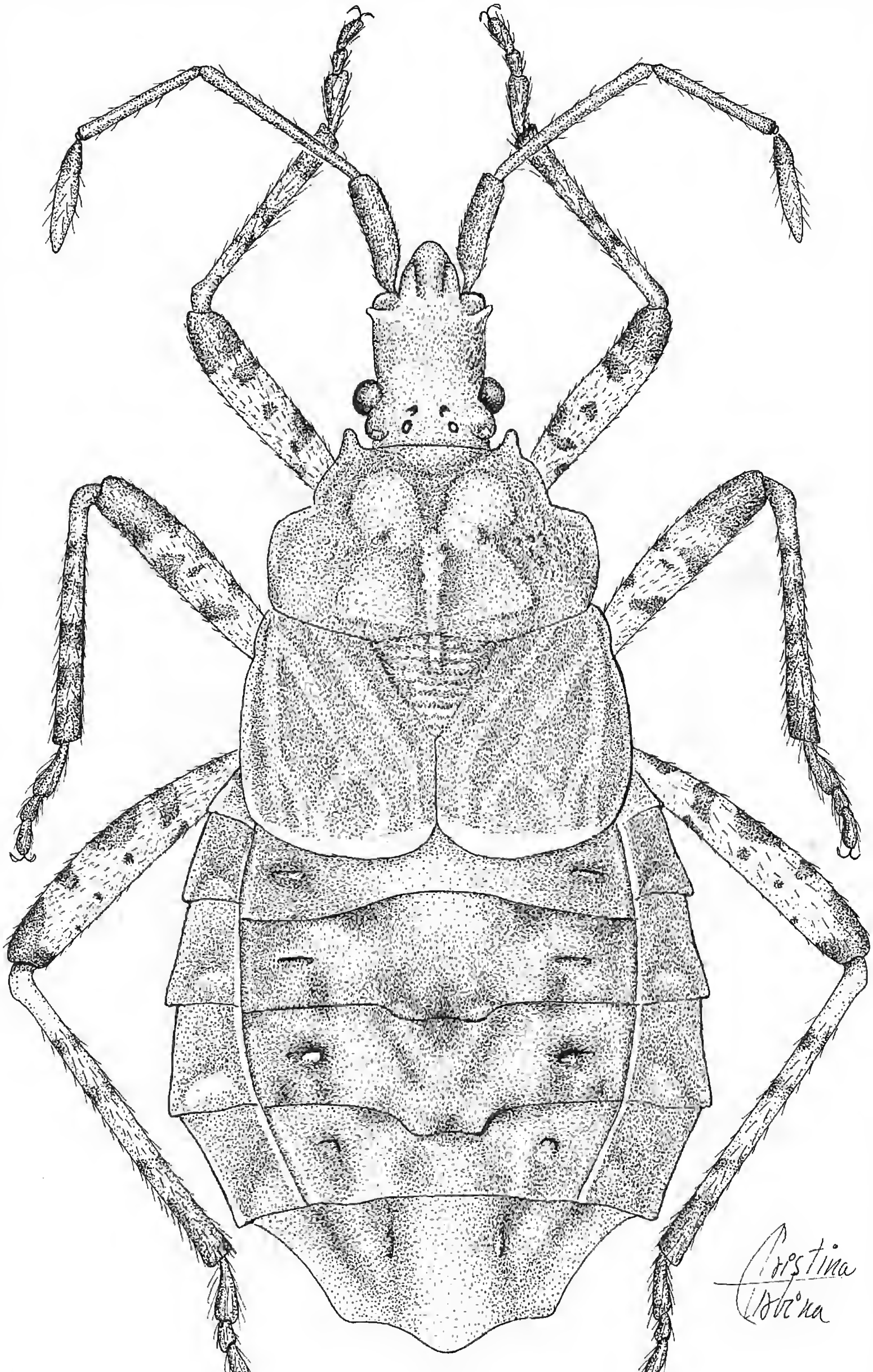

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Figure 7. Dorsal view of *Weirhygia faceta* Brailovsky, NEW GENUS, NEW SPECIES.

apex subacute, and the hemelytra reaching the medial third of abdominal segment III. In *G. lepida* the external lobes of the antenniferous tubercles converget anteriorly, conspicuously arcuate, recurved, and almost touching the basal joint of antennal segment I (Fig. 6), and the vertex has two conical elevations separated along middle third by a deep longitudinal depression. In the other two species the external lobes of antenniferous tubercles are obliquely projecting, diverging anteriorly, and the two anterior conical elevations of vertex are almost fused.

Etymology.—From the Latin, *lepidus,* meaning pleasant, elegant.

GROSSHYGIA PISINA BRAILOVSKY, NEW SPECIES
(Fig. 2.)

Types.—Holotype male: Australia. NE Queensland, 20 km WNW of Cape Tribulation (Site 2), 50 m, 23 Sep 1982, Monteith, Yeates and Thompson. Deposited in Queensland Museum, Brisbane, Australia.

Description.—Male (holotype). Dorsal coloration: head reddish brown with dorsal aspect of postocular tubercle yellow; antennal segments I to III chestnut orange with basal joint of III yellow; antennal segment IV yellow with basal joint chestnut orange; anterior lobe of pronotum reddish brown, posterior lobe chestnut orange, anterolateral margins yellow; scutellum dark chestnut orange; hemelytral membrane chestnut orange; connexival segments bright reddish with posterior margins of segments III to VI yellow; dorsal abdominal segments reddish brown. Ventral coloration: Head reddish brown, rostral segments I to IV and small spot close to eyes yellow; thorax reddish brown with acetabula dark reddish, pro, meso, and metapleura dirty yellow with punctures dark brown; coxae bright reddish; trochanters bright chestnut yellow; fore and middle femora chestnut orange with basal third, subapical third, and few scattered spots yellow; hind femur yellow with apical third and four irregular rings chestnut brown; tibiae and tarsi yellow; abdominal sterna dark reddish brown, scattered with yellow diffuse areas; pleural abdominal sterna bright reddish with posterior third of sterna III to VI yellow; genital capsule reddish brown with posteroventral margin pale orange yellow. Structural characters. Head: longer than wide across eyes, pentagonal, conspicuously convex dorsally; antenniferous tubercles each armed with short and robust lobe, obliquely projecting, diverging anteriorly and subacute apically; rostrum reaching anterior margin of abdominal sternite VII; vertex uniformly convex without conical elevations. Pronotum: slightly trapezoidal, bilobed, and nondeclivent; anterolateral margins convexly rounded, moderately elevated, and slightly reflexed; callar region transversely nodulose; anterior and posterior lobe along medially with wide longitudinal depression. Legs: unarmed. Scutellum: apex subacute. Hemelytra: micropterous, reaching posterior third of abdominal segment III; hemelytral membrane absent. Genital capsule: posteroventral edge simple, transversely concave, entire (Fig. 2).

Female.—Unknown.

Measurements.—Head length: 1.82 mm; width across eyes: 1.48 mm; interocular space: 1.00 mm; preocular distance: 1.24 mm; antennal segments lengths: I, 1.14 mm; II, 1.84 mm; III, 1.14 mm; IV, 1.12 mm. Pronotal length: 1.48 mm; maximum width of anterior lobe: 1.88 mm; maximum width of posterior lobe: 2.28 mm. Scutellar length: 0.80 mm; width: 0.96 mm. Maximum width of abdomen: 3.68 mm. Total body length: 9.10 mm.

Discussion.—Like *G. monticeps* Brailovsky, the head is longer than wide, the scutellar apex is subacute, the antenniferous tubercles each is armed with a short lobe, and the total length of antennal segment II is shorter than 1.86 mm. In *G. pisina,* the vertex is uniformly convex without conical elevations, the membrane of the hemelytra is absent, and the posteroventral edge of male genital capsule simple, transversely concave and entire (Fig. 2). In *G. monticeps* the vertex is globose with a thin transverse depression, dividing it into two conical elevations, the hemelytra membrane is reduced to small lobe, and the posteroventral edge of male genital capsule is indented medially and excavated laterally.

Grosshygia lobatula Brailovsky has the head longer than wide, the scutellar apex subacute, the posteroventral edge of male genital capsule simple, the antenniferous tubercles each is armed with a long lobe, the length of antennal segment II is longer than 1.96 mm, the vertex has conical elevations, and the hemelytra membrane is reduced to a small flap.

Etymology.—From the Latin, *pisina,* small.

ACKNOWLEDGMENT

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LITERATURE CITED

Brailovsky, H. 1993. A revision of the Tribe Colpurini from Australia (Hemiptera-Heteroptera-Coreidae). Memoirs of the Queensland Museum 34: 35–60.

Brailovsky, H. y E. Barrera. 1996. Revisión del Complejo Sciophyrus (Hemiptera: Coreidae: Colpurini). Folia Entomol. Mex. 96: 15–106.

Steinbauer, M. J. & A. R. Clarke. 1996. Revision of the Genus Acantholybas Breddin (Hemiptera: Coreidae). Ann. Entomol. Soc. Am. 89: 519–525.

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SPIDERS FROM RIVERSIDIAN COASTAL SAGE SCRUB WITH COMPARISONS TO DIEGAN SCRUB FAUNA (ARACHNIDA: ARANEAE)

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Abstract.—We provide a list of 166 spider species collected from Riversidian coastal sage scrub (CSS) located within the Southwestern Riverside County Multispecies Reserve in southern California. Spiders were collected over a two-year period from pitfall traps, vacuum samples, and malaise traps; additional species were collected by hand or in yellow pan traps. One hundred and twenty-seven species, representing 30 araneomorph families and one mygalomorph family, were separated from the combined pitfall, vacuum, and malaise samples from 24 undisturbed Riversidian CSS plots. Three species occurred only in malaise samples, 58 species occurred only in pitfall samples, and 37 species occurred only in vacuum samples. An additional 39 species were collected by hand or in yellow pan traps (two species), among which were representatives of two mygalomorph families not represented in pitfall catches. Over 33% of the Riversidian species were unrecorded from our recent Diegan CSS study bringing the combined total to 255 species. Eighteen species are new records for Riverside County. At least eleven species are believed to be undescribed. Six non-native species, *Holocnemus pluchei* (Scopoli), *Dysdera crocata* C. L. Koch, *Zelotes nilicola* O. P.-Cambridge, *Oecobius annulipes* Lucas, *Steatoda triangulosa* (Walckenaer), and *Menemerus bivittatus* (Dufour), were among the species collected. Phenology data are provided for the 12 most prevalent species. Natural history data are provided for habitat preference of several species and on ant predation by three species. Non-native and endemic spider taxa are discussed. Comparison of Riversidian fauna to Diegan fauna suggested higher species diversity in Diegan CSS.

Key Words.—Arachnida, Araneae, spiders, species list, coastal sage scrub, endemic species.

We present here a significant addition to the knowledge of the spider fauna of coastal sage scrub (CSS) from samples obtained from an ecologically threatened southern California coastal sage scrub association, Riversidian CSS (Westman 1983). Because CSS communities, in general, are distributed at lower elevations in California along the coast or adjacently inland, they are subject to extensive clearing as the demands of urbanization are met. This study provides an invaluable database for potential use by conservationists, developers, and planners, involved either directly in CSS ecosystem research or indirectly in the planning and development of reserves to protect this fragile ecotype in southern California. It also provides arachnologists and ecologists alike with data pertaining to species composition and richness, relative abundance, endemism, and the apparent impact of non-native species in CSS. To date, this study and our previous Diegan CSS study (Prentice et al. 1998) remain the only examinations of CSS spider fauna and, together, create one of the most comprehensive lists of Araneae assembled for any specific ecosystem type in the United States.

Our study sites were located within the Southwestern Riverside County Multispecies Reserve (SRCMR), a reserve owned by Metropolitan Water District (MWD) and jointly managed by federal, state, county, and MWD personnel. This area includes undisturbed coastal sage scrub surrounding Lake Skinner and extending 1 km south, 4 km east to the Tucalota Hills, and 9.5 km to the north, climbing in elevation up through Rawson Canyon and then descending to (what is now) Diamond Valley Lake. Chaparral communities, oak groves, and riparian areas are associated with CSS in several regions within the reserve. The 1993 Winchester Fire burned large portions of SRCMR, leaving a mosaic of unburned areas on the north side of the lake (Fig. 1, regions C (northern third), D, E). The areas to the west and south of Lake Skinner were missed by the fire (Fig. 1, regions A, B, C (southern two thirds)), but a large portion of the CSS and chaparral through Rawson Canyon to the northern boundary was destroyed (Fig. 1, regions G, F).

There are four major California CSS associations. Three have geographical limits along the Pacific coast; one occurs further inland (Westman 1983). These floristic associations are defined mainly by a geographic/climatic gradient of evapotranspiative stress, which increases from north to south and from coastal to inland (Axelrod 1978; Desimone & Burk 1992; Westman 1981, 1983). Soil nitrogen levels and air pollution are also believed to be critical factors that influence floristic associations (Westman 1981). Riversidian CSS extends from inland Los Angeles County through the southwestern corner of San Bernardino County, western Riverside County, and into inland San Diego County and has a somewhat different floristic composition than the more coastally distributed Diegan CSS (Westman 1983). Although the percentage of annual forb and grass cover generally increases in CSS from north to south, the Riversidian region has a significantly higher percentage of annual cover (primarily introduced species) and a lower percentage of shrub cover than the Diegan region (Westman 1983). The relatively sparse shrub cover and dense annual cover in Riversidian CSS are believed to be mainly the result of evapotranspiative stress (due to higher summertime temperatures) and increased ozone levels (Westman 1983). Vegetation surveys (unpublished data) conducted within both our Diegan and Riversidian sites showed that unburned sites at SRCMR had both relatively sparse shrub cover and lower shrub stature than sites at MCBCP/MNAS. California Buckwheat (*Eriogonum fasciculatum*), Yerba Santa (*Eriodictyon crassifolium*), Brittlebush (*Encelia farinosa*), Black Sage (*Salvia mellifera*), and Bush Mallow (*Malacothamnus fasciculatus*) were more common in unburned sites at SRCMR while California Sage (*Artemesia californica*), White Sage (*Salvia apiana*), and Laural Sumac (*Malosma laurina*) were more common in sites at MCBCP/MNAS. Bush Monkeyflower (*Mimulus aurantiacus*) and both Broom Baccharis (*Baccharis sarothroides*) and Coyote Brush (*Baccharis pilularis*) were common at MCBCP/MNAS sites but absent from sites at SRCMR. In contrast, Bush Penstemon (*Kekiella* sp.) was common at SRCMR but absent from sites at MCBCP/MNAS.

Our objectives are to: (1) develop an inventory of the spider fauna collected in Riversidian CSS which includes the number of adults of each sex per species per collecting period, (2) compare spider assemblages of Riversidian and Diegan CSS, (3) develop phenology data for the most abundantly sampled Riversidian species with comparisons to the same taxa sampled in Diegan scrub (Prentice et al. 1998), (4) propose a subset of probable endemic species to Riversidian and/

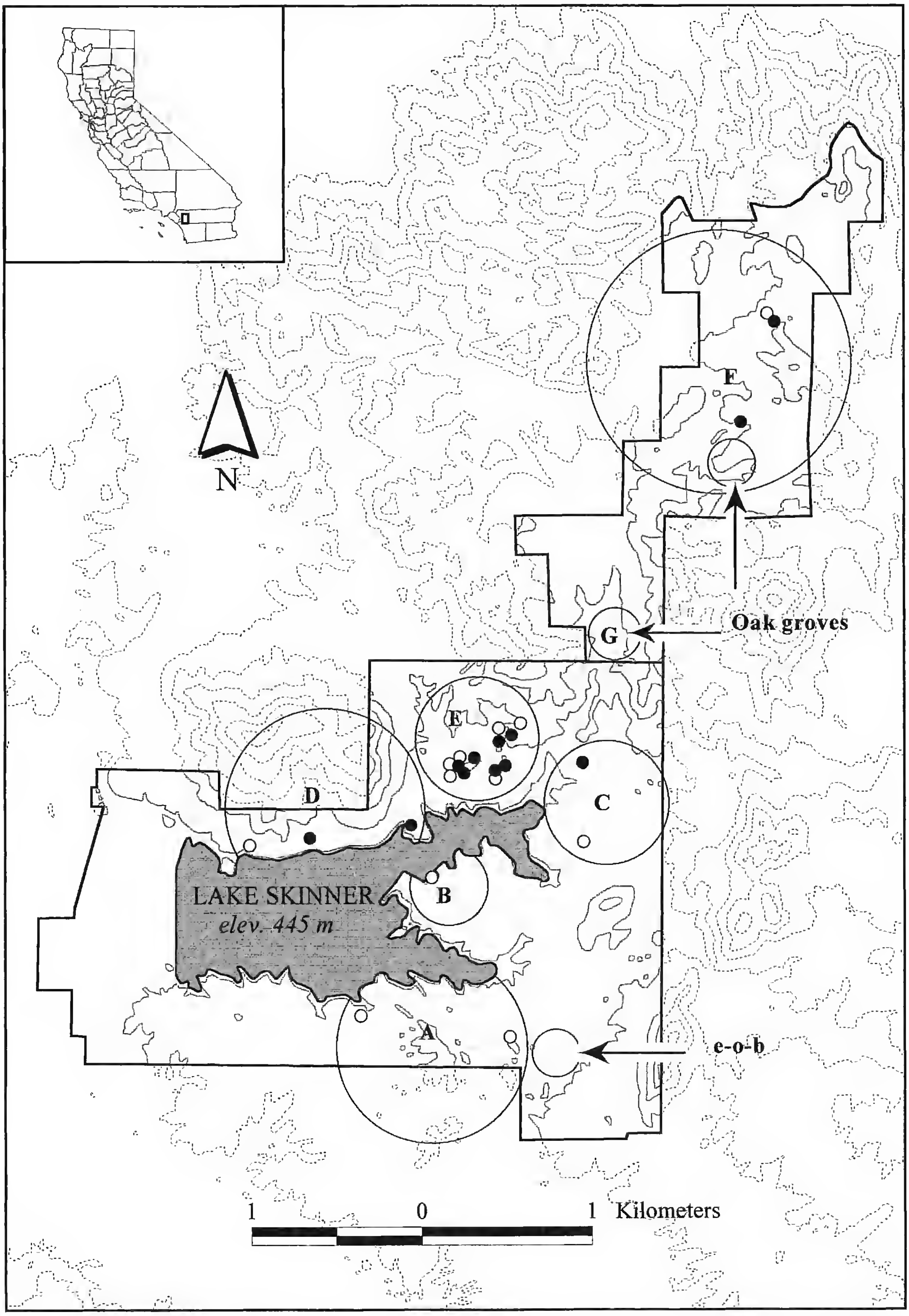

Figure 1. Map of SRCMR in SW Riverside County, CA showing geographic regions of collections. Regions ‘A–F’ encompass pitfall, vacuum, and malaise sampling sites. Regions ‘G’, ‘e-o-b’ (entrance station outbuilding area), and the smaller encircled area within region ‘F’ (oak grove), were localities of hand collection only. The open circles (○) within regions ‘A–F’ represent unburned sites and the solid circles (●) represent sites burned by the Winchester Fire of 1993. Regions ‘A’, ‘B’, and ‘e-o-b’ were not burned; the understory of the oak groves (regions F and G) was burned but the oaks survived.

or Diegan CSS (area endemics), (5) discuss the apparent status of non-native species in CSS, and (6) provide natural history data on habitat preference and ant predation by two subsets of species, respectively.

MATERIALS AND METHODS

Study Sites.—We selected 24 circular sites representative of undisturbed Riversidian CSS scrub, each 100 m in diameter. Half (12) of these sites were located in areas recovering from the Winchester Fire of 1993 and the other half (12) were within areas that remained unburned (Fig. 1, regions A–F). Plots in the burned areas had substantially reduced shrub canopy cover and greater annual grass and forb cover than those plots in unburned areas which generally had dense canopies and little forb and grass understory, except occasionally around the trunks of the shrubs and under the overhanging branches. Unburned sites were chosen in a manner that maximized site distribution over SRCMR without encroaching on chaparral, oak, or riparian communities and that encompassed, within the combined twelve sites, as much of the variation in CSS composition as possible. Burned sites were selected, when possible, as pairs, adjacent to their unburned counterparts, but were otherwise selected to maximize site distribution.

Selection of Geographical Regions.—The grouping of sites into regions (Fig. 1) was based on three criteria, provision of locality data, geographical relationship, and practicality. Foremost, was to provide locality data for future workers wishing to sample any of the taxa that we collected at SRCMR. Although we have more precise locality data for each specimen sampled, inclusion here would prove both cumbersome and unnecessary. Therefore, the only logical method of reporting these data, was to assign sites to regions based on both proximity of the sites and geographical distinction of the encompassed regions (Fig. 1). Sites in regions A and B are on the south side of the lake or an arm of the lake (region B site is within 50 m of the shoreline) in an area that was not burned by the Winchester Fire. Sites in region C are the only sites that are relatively close to riparian areas, although the northern site was burned in the 1993 fire. Sites in region D are closely adjacent to the lake's north shore and more exposed to the predominant SW winds than other sites near the lake. Region E encompasses sites that are in close proximity to one another (burned and unburned). Sites in region F are isolated from other sites both by distance and elevation (640 m vs. 460 m). Region G encircles an oak grove (closely adjacent to CSS) where various hand-collected species were taken; it is intermediate in elevation (550 m).

Sampling Periods.—Sampling was performed by pitfall trap, vacuum, and malaise trap methods in September and December of 1996, in March, June, September, and December of 1997, and in March and June of 1998. Collections spanned the first two weeks of each sampling month. Although sampling was also performed in March and June 1996, pitfall and malaise traps were not set in June 1996 and only five pitfall traps were set (rather than seven, thereafter) in March 1996. As a result, specimens collected during these periods are excluded from the data presented in this study, with the exception of representatives of thirteen species, seven of which were collected only during these samplings (see Results). These 17 specimens are listed because their inclusion contributes to the knowledge of Riversidian spider fauna (Table 1).

Malaise Trap Sampling.—A single malaise trap (Bioquip® design, model

Table 1 A list of 166 species of Araneae from Riversidian CSS at Southwestern Riverside County Multispecies Reserve (SRCMR) in California. Of these, 127 species were collected from pitfall traps, vacuum samples, and malaise traps in September and December of 1996, March, June, September, and December of 1997, and March and June of 1998 (all specimens of 7 of these species were collected only in March or June 1996 samples and are reflected in the various totals). Specimens of the opposite sex of 11 of the 127 species and all specimens of the additional 39 species listed were collected only by hand (hand, Yellow Pan Trap (YPT), or sweepnet); hand-collected specimens are not included in the totals. Geographic regions are shown in Figure 1.

Species	[1]Geographic Regions		[2]Coll.	[3]Collection Periods				Specim.
	Burned	Unburned	Method	Mar	Jun	Sep	Dec	Total
MYGALOMORPHAE								
Ctenizidae								
Bothriocyrtum californicum (O. P.-Cambridge), 1874: 260	(E)		(h)					(1♀)
Cyrtaucheniidae								
Aptostichus atomarius Simon, 1891:317	D	A,(A,E)	P (h)				4♂	4, (2♀)
Aptostichus sp. #1 (#118)[4]		E	P				1♂	1
Theraphosidae								
Aphonopelma steindachneri (Ausserer), 1875: 199 (TRP coll.)		(E,F)	(h)					(6♂ 1♀)
Aphonopelma sp. #1 ('*eutylenum*' type'): Prentice, 1997 (TRP coll.)	(D,E)	(A,E)	(h)					(9♂ 4♀)
ARANEOMORPHAE								
Agelenidae								
Agelenopsis aperta Gertsch, 1934: 25		E	P			1♀		1
Calilena stylophora Chamberlin & Ivie, 1941: 610	C,E,F	E,F	P	3♀	6♂ 1♀	4♂ 1♀	13♀	28
Rualena balboae (Schenkel), 1950: 82		F	P				1♀	1
Amaurobiidae								
species #1: undescribed species, new genus (CAS; TRP coll.)	C,E	B,E	P	2♀			1♂ 1♀	4
Anyphaenidae								
Anyphaena californica (Banks), 1904: 339		[E]	[M]	[1♂]				1
Araneidae								
Argiope argentata (Fabricius), 1775: 443		(E)	(h)					(1♀)
Argiope trifasciata (Forskal), 1775: 86	E	A	V			2♂		2
Cyclosa turbinata (Walckenaer), 1841: 140	C		V	1♀				1
Eustala californiensis (Keyserling), 1885: 525	E	D,E	V M	1♂ 1♀	1♂			3
Eustala conchlea (McCook), 1888: 199	(D)		(h)					(1♀)
Eustala rosae Chamberlin & Ivie, 1935: 22	(D)		(h)					(1♀)
Hypsosinga funebris (Keyserling), 1893: 37	[E]		[V]	[1♂ 1♀]				2
Larinia directa (Hentz), 1847: 478		D	V		1♀			1
Mastophora cornigera (Hentz), 1850: 20	[E]		[V]		[1♂]			1
Metepeira crassipes Chamberlin & Ivie, 1942: 66	D	C,E	V		4♂ 2♀			6

Table 1. Continued.

Metepeira foxi Gertsch & Ivie, 1936: 66		(D)	(h)					(1♂)
Metepeira grandiosa grandiosa Chamberlin & Ivie, 1941: 17	D,E,F	F	V	6♂ 2♀				8
Neoscona crucifera (Lucas), 1839: 42	(C)		(h)					(1♀)
Neoscona oaxacensis (Keyserling), 1863: 97	D		V P			1♂ 1♀		2
Caponiidae								
Orthonops zebra Platnick, 1995: 15	C	E	P		2♂			2
Corinnidae								
Castianeira athena Reiskind, 1969: 228		(F, oak grove)	(h)					(1♀)
Castianeira occidens Reiskind, 1969: 211		A	P		1♂			1
Dictynidae								
^{RC}*Blabomma sanctum* Chamberlin & Ivie, 1937: 221		B,E	P	2♀			13♂ 5♀	20
Blabomma sp. #4 (#436)		A,C,E	P	1♀			2♀	3
Blabomma sp. #5 (#446)	D,E	B,D,E,F	P	2♂			14♂	16
Blabomma sp. #6 (#445)		C,E	P	1♀			1♀	2
Cicurina utahana Chamberlin, 1919: 257	G	A	P				3♂	3
Dictyna abundans Chamberlin & Ivie, 1941: 6	C,D,E	A,E	V	1♂ 4♀	3♂ 3♀		2♀	13
Dictyna agressa Ivie, 1947: 2	(e-o-b)		(h)					(2♀)
Dictyna calcarata Banks, 1904: 342	(e-o-b)		(h)					(1♂)
Dictyna cholla Gertsch & Davis, 1942: 12		(B),E	P (h)		1♀			1, (1♂)
^{RC}*Dictyna sierra* Chamberlin, 1948: 8		B,E	V	1♂ 1♀				2
^{RC}*Emblyna consulta* (Gertsch & Ivie), 1936: 6		(E)	(h)					(1♂)
Emblyna hoya (Chamberlin & Ivie), 1941: 7		B	P		1♂			1
Emblyna linda (Chamberlin & Gertsch), 1958: 148	D,E,F	B,D,F	P *V	2♂ 1♀	2♂ 11♀			16
Emblyna reticulata (Gertsch & Ivie), 1936: 7	D,E	B,E	V		3♂ 2♀			5
^{RC}*Mallos pearcei* Chamberlin & Gertsch, 1958: 45	(F, oak grove)		(h)					(1♀)
Tivyna moaba (Ivie), 1947: 2	F	(B)	P (h)		1♂			1, (3♀)
Tricholathys jacinto Chamberlin & Gertsch, 1958: 20	(G)		(h)					(1♀)
Tricholathys monterea Chamberlin & Gertsch, 1958: 22	D,E	A,E	P	33♂ 4♀	3♂ 4♀			44
Yorima angelica Roth, 1956: 4		E	P	4♂ 1♀				5
Diguetidae								
Diguetia canites (McCook), 1890, in 1889-1894: 135		E	V		1♀			1
Dysderidae								
^{NN}*Dysdera crocata* C. L. Koch, 1839: 81		A	P	1♀				1
Filistatidae								
Filistatinella sp. #3 (#522)		A,C,E	P		3♂			3
Gnaphosidae								
Callilepis gosoga Chamberlin & Gertsch, 1941: 10	C-F	A,B,C,E,F	P		107♂ 25♀	4♂ 11♀		147

Table 1. Continued.

Cesonia classica Chamberlin, 1924: 619		A,E,F	P		5♂ 1♀	1f		7
Drassyllus fractus Chamberlin, 1936: 14	E	B,E	P		8♂ 3♀			11
Drassyllus insularis (Banks), 1900: 97	C-F	A-F	P	14♂ 1♀	26♂ 30♀	8♂ 24♀		103
^{RC}*Drassyllus lamprus* (Chamberlin), 1920: 193	E		P		1♂			1
Gnaphosa californica Banks, 1904a: 335	D,E	D,F	P		4♂	1♂ 2♀		7
Haplodrassus maculatus (Banks), 1904: 336	D,E,F	A-F	P	41♂ 26♀	1♀		4♂	72
Herpyllus hesperolus Chamberlin, 1928, in Cham. & Gert. 1928: 176	E		M	1♂				1
Herpyllus propinquus (Keyserling), 1887: 430		C	P		1♂			1
Micaria deserticola Gertsch, 1933: 2	E,[F]		P [M]	[1♂] 1♀				2
Micaria gosiuta Gertsch, 1942: 1	E		P				1♀	1
Micaria icenoglei Platnick & Shadab, 1988: 57	F		P		1♂			1
Micaria jeanae Gertsch, 1942: 4	D,E	A,B,E	P V M	1♂	1♂ 3♀	1♀		6
^{RC}*Nodocion utus* (Chamberlin), 1936a: 7		F	P		1♀			1
Scopoides catharius Chamberlin, 1922: 156	(E)	E	P (h)			1♀		1, (1♂)
Zelotes gynethus Chamberlin, 1919: 7	D,E,F	A,B,E,F	P	2♂ 15♀	2♀	1♂	7♂ 2♀	29
Zelotes monachus Chamberlin, 1924: 621	E	A,D,E,F	P		6♂ 5♀			11
^{NN}*Zelotes nilicola* (O. P.-Cambridge), 1874: 380		A,E	P		1♂ 1♀			2
Zelotes skinnerensis Platnick & Prentice, 1999: 672		E	P		2♂ 1♀			3
Hahniidae								
Neoantistea santana Chamberlin & Ivie, 1942: 29		E	P	1♀			1♀	2
Heteropodidae								
Olios schistus Chamberlin, 1919: 10	(E)		(h)					(1♂)
Homalonychidae								
Homalonychus theologus Chamberlin, 1924: 631	D	D,F	P		3♂			3
Linyphiidae								
Ceraticelus sp. #1 (#7)	[C]	E	V		[1♂]		2♀	3
Erigone autumnalis Emerton, 1882: 58		E	P	1♀				1
Erigone dentosa O. P.-Cambridge, 1894, in 1890-1902: 128	D,E,F	B,D,E,F	V *P		28♂ 19♀		2♂	49
Frontinella pyramitela (Walckenaer), 1841: 261	E		V		1♂			1
^{RC}*Linyphantes aliso* Chamberlin & Ivie, 1942: 53	E		V		1♀			1
^{RC}*Linyphantes microps* Chamberlin & Ivie, 1942: 53	E,F	C	P	2♂ 2♀				4
Linyphantes sp. # 5	(E)		(h)					(1♀)
Meioneta sp. #2 (#53)	D,E,F	B,D,E,F	P	5♂ 5♀	2♂ 4♀		7♂ 1♀	24
Meioneta sp. #3 (#460P)	E	A,E	V P	3♂ 2♀	1♀		1♀	7
Microlinyphia mandibulata punctata Chamberlin & Ivie, 1943: 24	E	E	V P	1♂	1♂ 2♀			4
Spirembolus erratus Millidge, 1980: 151		(B)	(h)					(1♂)
Spirembolus phylax Chamberlin & Ivie, 1935: 19	C,E	A	V P	1♀	1♀		1♂	3

Table 1. Continued.

Spirembolus pusillus Millidge, 1980: 128	D,E,F	A,E	P	1♀			7♂	8
Spirembolus tortuosus (Crosby), in Chamberlin, 1925: 116	C-F	A,C-F	P *V	5♀			85♂	90
Spirembolus redondo (Chamberlin & Ivie), 1945: 225	(F)		(h)					(1♀)
Tennesseellum formicum (Emerton), 1882: 71	C,E,(F)		P (h)	3♀	1♀			4, (1♂)
^{RC}*Wubana drassoides* (Emerton), 1882: 72		(B)	(h)					(1♂ 2♀)
Liocranidae								
Drassinella gertschi Platnick & Ubick, 1989: 5	(E)		(h)					(1♂ 1♀)
Phrurotimpus mateonus (Chamberlin & Gertsch), 1930: 141	F	A-E	P	1♂ 4♀	1♂ 2♀			8
^{RC}*Scotinella kastoni* (Schenkel), 1950: 73	E	E	P	2♀	1♀		1♀	4
Lycosidae								
Alopecosa kochi (Keyserling), 1876: 636	C-F	B,E,F	P	18♂ 6♀			10♂ 1♀	35
Pardosa californica Keyserling, 1887: 483	(F)		(h)					(1♂)
Pardosa ramulosa (McCook), 1894, in 1889-1894, pl. 30	[E]	E	P	[1♂] 1♀				2
Schizocosa maxima Dondale & Redner, 1978: 165		(A)	(h)					(1♂)
Schizocosa mccooki (Montgomery), 1904: 283	D,E,F	A,B,D,E,F	P		25♂ 2♀	1♀	1♀	29
Mimetidae								
Mimetus hesperus Chamberlin, 1923: 5	C,E,F		V M P	4♀				4
Miturgidae								
Cheiracanthium inclusum (Hentz), 1847: 451	C-F	A,E	M V	2♂ 1♀	4♂ 1♀	1♂ 3♀	1♀	13
Syspira synthetica Chamberlin, 1924: 665	E	C	P		2♀			2
Oecobiidae								
^{NN}*Oecobius annulipes* Lucas, 1849: 102		D,E	V				1♂ 1♀	2
Oonopidae								
Oonops sp. #1 (TRP coll.)		(B)	(h)					(9♂ 9♀)
Scaphiella hespera Chamberlin, 1924: 594	C,D,E	E	P	1♂	2♂	2♂ 2♀		7
Oxyopidae								
Oxyopes salticus Hentz, 1845: 196	E,[E]		V		[1♂] 1♀			2
Oxyopes scalaris Hentz, 1845: 196	E	A	V		1♂ 1♀			2
Oxyopes tridens Brady, 1964: 472	E	A,C,D,E	P V		2♂ 2♀	1♀		5
Peucetia longipalpis F. P.-Cambridge, 1902, in 1897-1905: 340	E	F	V		1♂ 1♀			2
Peucetia viridens (Hentz), 1832: 105	D,E		V		1♂ 1♀	1♀		3
Philodromidae								
Apollophanes texanus Banks, 1904: 113		E	V		1♀			1
^{RC}*Ebo albocaudatus* Schick, 1965: 77		D	P		1♂			1
^{RC}*Ebo andreaannae* Schick, 1965: 82		(B)	(h)					(1♂)
Ebo californicus (Gertsch), 1933: 14	C,D	E	V M P	3♂			2♀	5
^{RC}*Ebo evansae* Sauer & Platnick, 1972: 41	(E)		(h)					(1♀)

Table 1. Continued.

Ebo mexicanus Banks, 1898: 256		A	V	1♂			1♂	2
Philodromus californicus Keyserling, 1884: 676		(e-o-b)	(h)					(1♂ 1♀)
Philodromus chamisis Schick, 1965: 50	D,E		V M	1♂	1♂			2
^{RC}*Thanatus formicinus* (Clerck), 1757: 134		(D)	(h)					(1♀)
Tibellus chamberlini Gertsch, 1933: 10	E	E,F	V		1♂ 2♀			3
Pholcidae								
Holocnemus pluchei (Scopoli), 1763: 404		(e-o-b)	(h)					(1♀)
Physocyclus californicus Chamberlin & Gertsch, 1929: 102		(e-o-b)	(h)					(2♂ 3♀)
Psilochorus sp. #1 (#103)	C-F	A-E	P	8♂ 7♀	14♂ 6♀	24♂ 14♀	4♀	77
Plectreuridae								
Plectreurys conifera Gertsch, 1958: 14	D,F	B	P	1♂	1♂ 1♀			3
Salticidae								
Habronattus californicus (Banks), 1904: 117	C,E,F	A-E	P *M	1♂ 2♀	2♂ 11♀	3♂ 21♀		40
Habronattus hirsutus (Peckham & Peckham), 1888: 64		B,D,E,F	V	1♂	2♂ 1♀	2♂ 2♀	1♂	9
Habronattus pyrrithrix (Chamberlin), 1924: 693	(E)		(h)					(1♀)
Habronattus schlingeri (Griswold), 1979: 135		(B)	(h)					(1♂)
Habronattus tranquillus Peckham & Peckham, 1901: 201	D,E,F	F	V P		2♂ 6♀			8
Menemerus bivittatus (Dufour), 1831; 369		(e-o-b)	(h)					(1♂ 1♀)
Metaphidippus chera (Chamberlin), 1924: 683	C,E		V M	1♂	1♂	1♀		3
Metaphidippus mannii (Peckham & Peckham), 1901: 326	E		V	1♀				1
Metaphidippus vitis (Cockerell), 1894: 207	C,D,E	C-F	V M	3♂ 3♀	2♂ 4♀	2♂	1♂ 2♀	17
Pelegrina aeneola (Curtis), 1892: 332		F	M	1♀				1
Pellenes limatus Peckham & Peckham, 1901: 217	(F)		(h)					(1♂ 1♀)
Phidippus ardens Peckham & Peckham, 1901: 288		B,(A,E)	P (h)			1♀		1, (2♂)
Phidippus californicus Peckham & Peckham, 1901: 289		[A]	[V]		[1♂]			1
Phidippus johnsoni Peckham & Peckham, 1883: 22	C,F,(D,E)	(A)	M P (h)	3♂				3, (5♀)
Phidippus nikites Chamberlin & Ivie, 1935: 41	(E)	F	P (h)	1♀				1, (2♂)
Phidippus octopunctatus (Peckham & Peckham), 1883: 6	D	(E)	P (h)			1♀		1, (2♂)
Salticus palpalis (Banks), 1904: 360	C-F	D,E	V P M	1♂ 4♀	3♀			8
Sarinda cutleri (Richman), 1965: 133		B	V		1♀			1
Sitticus dorsatus (Banks), 1895: 97	E	E	P V	1♂ 1♀	1♂ 2♀			5
Synageles occidentalis Cutler, 1987: 343	E,F		V M	2♂	2♀			4
Tengellidae								
^{RC}*Anachemmis dolichopus* Chamberlin, 1919: 139	[E],F	A,F	P	2♂ [1♀]			1♂	4
Tetragnathidae								
Tetragnatha guatemalensis O. P.-Cambridge, 1889, in 1889-1902: 8	D	D	V M		4♂ 1♀			5
^{RC}*Tetragnatha pallescens* F. P.-Cambridge, 1903, in 1897-1905: 436	[D,E]		[V]	[2♀]				2

Table 1. Continued.

Tetragnatha versicolor Walckenaer, 1841: 215		D	V M		2♂ 1♀			3
Theridiidae								
Achaearanea tepidariorum (C. L. Koch), 1841: 75		(nr. e-o-b)	(h)					(1♀)
Dipoena abdita Gertsch & Mulaik, 1936: 6		C	P			1♀		1
^{RC}*Enoplognatha selma* Chamberlin & Ivie, 1946: 3	(E)	E,(B)	P (h)	1♂				1, (4♀)
Euryopis californica Banks, 1904: 345	D		V		1♀			1
Latrodectus hesperus Chamberlin & Ivie, 1935: 15		(E)	(h)					(1♀)
^{NN}*Steatoda triangulosa* (Walckenaer), 1802: 207		(culvert nr. e-o-b)	(h)					(1♂ 2♀)
Steatoda washona Gertsch, 1960: 21	(E)		(h)					(1♂)
Theridion dilutum Levi, 1957: 37	E	A	V	1♂	2♀			3
^{RC}*Theridion llano* Levi, 1957: 28	[E]	[A,D],(B)	[V P] (h)	[1♀]	[2♀]			3, (1♂)
Theridion melanurum Hahn, 1931: (pl. 3, fig. a.)		(culvert nr. e-o-b)	(h)					(1♀)
Theridion rabuni Chamberlin & Ivie, 1944: 53		B,[D],E	V		[1♂] 3♀			4
Tidarren haemorrhoidale (Bertkau), 1880: 78	(F)		(h)					(1♀)
Thomisidae								
Misumenops aikoae Schick, 1965: 131		vac shaff	V	1♀				1
Misumenops californicus (Banks), 1896: 91	[E]		[V]	[1♀]				1
Misemenops deserti Schick, 1965: 124	D,E		V		1♂ 2♀			3
Misumenops importunus belkini Schick, 1965: 131	E	B,C	V	3♂ 1♀	1♂		1♂	6
Misumenops lepidus (Thorell), 1877: 498	C,E,F	A,C	V	8♂	1♂ 2♀			11
Misumenops rothi Schick, 1965: 117	E	D,E,F	V		4♂ 1♀			5
Xysticus californicus Keyserling, 1880: 37	C-F		P *V	27♂ 3♀	3♀			33
Xysticus gertschi Schick, 1965: 159		E	V	1♀				1
Xysticus montanensis Keyserling, 1887: 479	(F)	(B)	(h)					(2♀)
Total				**354**	**511**	**147**	**211**	**1223**

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[1] Geographic Regions A–G; letters in Burned and Unburned columns refer to condition of sites within the various regions; e-o-b = entrance station outbuilding (see Fig. 1).

[2] P = pitfall trap, V = vacuum sample, M = malaise trap, (h) = hand-collected. Collection methods are listed in order of greatest to least number of specimens collected by the particular method; second letter preceded by an asterisk (*) indicates that very few specimens were collected by that particular method.

[3] Number of specimens collected are recorded under each period.

[4] Number following an undetermined species number is the OTU reference number assigned to the particular species in our collection (i.e., *Aptostichus* sp. #1 (#118)).

^{NN,RC} (superscript to the left of listed species): NN = non-native species; RC = new species record for Riverside County, California.

() Hand collected specimens; parentheses around particulars in all except Species and Collection Period columns (dates of collection are provided in Table 2).

[ ] Specimens collected only in March or June 1996 by pitfall, vacuum, or malaise; brackets around particulars in all columns except Species and Total columns.

#2875AG) was erected near the center of each site and left for three days during each sampling period. Arthropods collected in the kill heads (containing KCN or 80% EtOH) were then transferred to plastic bottles containing 80% EtOH. A total of 192 malaise samples (576 trap/days) were collected.

Vacuum Sampling.—Five one-minute vacuum samples were collected at each site during each sampling period (Buffington & Redak 1998). Vegetation was vacuumed along portions of five 25 m line transects established from a center pole by randomly chosen degree points from North. Each sample consisted of vacuuming a 10 × 1 m (10 m^2) band along the transect for one minute beginning at either the 5 or 15 m mark (randomly selected). Live arthropods were extracted from the collected chaff using one-gallon cardboard extraction drums. The drums (ice-cream containers) were painted black inside and each lid fitted with the funnel-shaped neck portion (glued in place, narrow end out) of one-liter plastic soda bottle. Each funnel was roughened on the inside (for traction) and painted black. A plastic vial cap was bored to tightly fit over the mouth of each funnel in a manner that would allow a 40-dram collecting vial to be attached to the lid. Contents of the vacuum bags were placed into the drums. Drums were turned sideways with the plastic vial portion under blacklights for a period of three hours. Arthropods that had collected in the vials were then anesthetized with carbon dioxide and stored in 80% ethanol. Vacuum chaff was examined for additional specimens for a period of one minute. A total of 960 vacuum samples were collected and extracted.

Pitfall Trap Sampling.—Seven pitfall traps were placed at each site in a stratified random manner and left in place for the entire course of the study. Each trap consisted of a 473 ml (16 oz) plastic cup (9 cm, inside diameter) equipped with a funnel that narrowed to 3.2 cm and a fluid filled collection cup (fluid composition: 2.0 tablespoons odorless detergent and 1.0 tablespoon salt per gallon water). Pitfall cups were placed so that the rims were flush with the substrate surface. A square masonite board, supported by three 20-penny galvanized nails at approximately 2 cm above each trap, was used to protect the trap from desiccation and/or flooding and provided a dark refuge for arthropods. Traps were opened for a period of three days at each site during each sampling period. Pitfall contents were strained and transferred to 80% ethanol within seven hours of collection. A total of 1344 pitfall samples (4032 trap/days) were collected.

Vegetation Sampling.—Four 48 m transects were established at each plot. A pole marked in decimeters was dropped at a random location (point) within every 2 m section along each transect (n = 96 points per plot). Canopy species, height, and structure (by number of contacts within each decimeter), as well as ground cover, were then recorded at each point. Along three of the four transects at each plot, ground and canopy cover, per decimeter, were recorded. We were able to estimate relative cover of major shrubs, shrub structure, ground cover and rockiness at each site with these data.

Statistical Analysis.—We used species accumulation curves to compare spider diversity in Diegan and Riversidian CSS. This method allowed us to correct for the disparity in total number of specimens collected from each location. Curves and error bars were constructed with EcoSim, Version 3 (Gotelli & Entsminger 1999), by resampling using Monte Carlo randomizations of species abundance data. All adults and any immatures, identifiable as distinct species, were included.

Specimens from malaise samples were not considered because malaise traps were not implemented in Diegan sampling. We intend to include a more involved statistical comparison of the Arthropoda collected at both locations in a community-level study (in preparation).

Manuscript Organization and Terms.—The organization of the manuscript follows, for the most part, that of our previous Diegan CSS study (Prentice et al. 1998) to facilitate comparison of Riversidian and Diegan spider fauna. The use of the terms 'Diegan' and 'Riversidian' is in reference to our Diegan CSS study (and to Diegan CSS) and our present Riversidian CSS study (and to Riversidian CSS), respectively.

Specimens Examined and Species List.—A total of 5676 specimens from pitfall, vacuum, and malaise samples, 108 hand collected specimens, 2 specimens from yellow pan traps, and one specimen collected by sweepnet were examined. Only adults were considered in the species list (Table 1). Specimens that were collected by hand are not added in the various totals in Table 1; collection data for these specimens are in Table 2. Taxonomy follows Platnick (1989, 1993, 1997). Undetermined species are designated as sp. #1, sp. #2, etc.; listings starting with sp. #2, #3, etc. indicate that the species are considered to be different congeneric species than those designated as sp. #1, #2, etc. in Prentice et al. (1998). Gender and number of specimens are provided for each species for each season collected; collection method(s) and geographical region of collection are also provided for each species (Table 1; Fig. 1). Table 1 is the central component of the manuscript and should be referred to throughout the course of the text. Voucher specimens of listed species (Table 1) are deposited in the University of California, Riverside, Entomological Research Museum.

Abbreviations.—CAS, California Academy of Sciences; MCBCP, Marine Corps Base Camp Pendleton (San Diego County); MNAS, Miramar Naval Air Station (now Marine Corps Air Station Miramar) (San Diego County); SRCMR, Southwestern Riverside County Multispecies Reserve.

Sampling Biases.—The trapping materials and methods used during this study (excepting malaise traps) were essentially the same as those used during our Diegan study. Therefore, the sampling biases discussed in Prentice et al. (1998) also pertain to the present study. We provide here a brief summary of these biases. The small size of our pitfall traps precluded the collection of specimens of large size. Burrowing species were not accounted for unless collected by hand or an occasional wandering male fell into the trap. Web spinners that used subterranean retreats, had strong webs, and/or were nocturnal were minimally, if at all, collected by the vacuum method. Specimens of many web spinners and arboreal hunters and ambushers, that habitually drop or jump to the ground under conditions of unusually strong vibration, were minimally collected by the vacuum method.

RESULTS AND DISCUSSION

Spider Fauna of Riversidian CSS.—In addition to the previously published floristic distinctions between Riversidian and Diegan CSS types (Kirkpatrick & Hutchinson 1977; Westman 1981, 1983; DeSimone 1995), we found accompanying distinctions between the respective spider faunas. It appears that factors influencing the floristic structures of Riversidian and Diegan CSS ecosystems, such as seasonal rainfall patterns (including effective summer and winter mois-

Table 2. List of species collected by hand (hand, YPT, or sweepnet). An asterisk * preceding a binomial indicates that only specimens of the opposite sex, of the respective species collected by pitfall, vacuum, or malaise methods, were hand-collected; all specimens of all other species were collected only by hand. Dates of collection and data pertaining to particular habitats are provided. Unless otherwise indicated, specimens were collected in CSS; other collections were in areas adjacent to CSS communities. Collection of specimens other than by one of authors is denoted in the Collection Date column.

Species	Collection Date	Habitat
MYGALOMORPHAE		
Cyrtaucheniidae		
**Aptostichus atomarius*	13 Dec 1997, 2 ♀: Coll: J. Bond	banks of ravine cuts
Theraphosidae		
Aphonopelma steindachneri	17 Jul 1997, 2 ♂; 21 Jul 1997, 1 ♂; 4 Aug 1997, 3 ♂; 28 Sep 1997, 1 ♀	(♂) on dirt rds., (♀) in burrow
Aphonopelma sp. #1	mid-May 1996, 1 ♀; 3 Sep 1997, 2 ♂; 11 Sep 1997, 2 ♂; 28 Sep 1997, 3 ♂; 29 Oct 1997, 1 ♂, 1 ♀; 26 Nov 1997, 1 ♂; 7 May 1998, 1 ♀	(♂) on dirt rds., (♀) in burrows
Ctenizidae		
Bothriocyrtum californicum	early Jul 1997, 1 ♀	in burrow
ARANEOMORPHAE		
Araneidae		
Argiope argentata	9 Sep 1997, 1 ♀	in web betw. shrubs
Eustala conchlea	16 Mar 1997, 1 ♀	against stem of shrub
Eustala rosae	21 Mar 1997, 1 ♀	against mustard stem
Metepeira foxi	10 Feb 1998, 1 ♂	on drag line betw. shrubs
Neoscona crucifera	mid-Oct 1997, 1 ♀	riparian
Corinnidae		
Castianeira athena	7 Jun 1999, 1 ♀: Coll: C. Dunning	in fallen acorn, oak grove
Dictynidae		
Dictyna agressa	25 Mar 1997, 2 ♀	in webs, entr. stn. outbldg.
Dictyna calcarata	21 Mar 1998, 1 ♂	in web, entr. stn. outbldg.
**Dictyna cholla*	20 Dec 1998, 1 ♂	grass/leaf litter
Emblyna consulta	4 Jun 1998, 1 ♂	in web, Calif. Buckwheat, branch tip
Mallos pearcei	21 May 1999, 1 ♀: Coll: C. Dunning	on oak leaf, oak grove
**Tivyna moaba*	6 Dec 1998, 3 ♀	grass/leaf litter
Tricholathys jacinto	26 May 1999, 1 ♀: Coll: C. Dunning	in grass litter, oak grove
Gnaphosidae		
**Scopoides catharius*	10 Mar 1998, 1 ♂ (pen.; def. molt 16 Mar 1998)	under rock
Heteropodidae		
Olios schistus	17 May 1998, 1 ♂	under dead stump
Linyphiidae		
Linyphantes sp #1	22 Nov 1997, 1 ♀	on wild oat stem
Spirembolus erratus	1 Dec 1998, 1 ♂; 29 Dec 1998, 1 ♂; 31 Dec 1998, 1 ♀	grass litter
Spirembolus redondo	3-5 Mar 1998, 1 ♀: Coll: M. Buffington	riparian, YPT
**Tennesseellum formicum*	11-13 Mar 1998, 1 ♂: Coll: M Buffington	in shallow drainage, YPT
Liocranidae		
Drassinella gertschi	31 Dec 1998, 1 ♂, 1 ♀	under dead root, chaparral

Table 2. Continued.

Lycosidae		
Pardosa californica	9 Mar 1998, 1♂: Coll: M. Buffington	in shallow drainage, YPT
Schizocosa maxima	16 Mar 1997, 1♂ (pen.; def. molt, late May-early June 1997)	under board
Oonopidae		
Oonops sp. #1	1 Dec 1998, 1♂, 2♀; 20 Dec 1998, 8♂, 7♀	in fine, fluffed dead grass
Philodromidae		
Ebo andreaanne	19 Jun 1997, 1♂ (pen.; def. molt, 6-7 Dec 1997)	on shrub
Ebo evansae	17 Jul 1997, 1♀	on shrub
Philodromus californicus	27 Jan 1997, 1♂; 26 Feb 1998, 1♀	entr. stn outbldg
Thanatus formicinus	21 Mar 1997, 1♀	on ground
Pholcidae		
Holocnemus pluchei	31 Aug 1998, 1♀	in web, entr. stn. outbldg.
Physocyclus californicus	16 Jan 1997, 1♀; 25 Jun 1997, 1♀; early Jul 1997, 1♂, 1♀; mid-Sep 1997, 1♂	in web, entr. stn. outbldg.
Salticidae		
Habronattus pyrrithrix	12 Mar 1998, 1♀	on dirt road
Habronattus schlingeri	6 Dec 1998, 1♂ (pen.; def. molt, 4 Apr 1999)	sparse grass litter
Menemerus bivittatus	11 Sep 1997, 1♂ (pen.), 1♀; (def. molt (♂), 21-25 Nov 1997)	on wall, entr. stn. outbldg.
Pellenes limatus	1 Dec 1997, 1♂ (pen.; def. molt, early June 1998); 12 Mar 1998, 1♀	on ground; field with low grass
**Phidippus ardens*	16 Jun 1997, 1♂; 25 Jun 1997, 1♂	under masonite pitfall lid; on Calif. Buckwheat
**Phidippus johnsoni*	7 Mar 1997, 1♀; 16 Mar 1997, 1♀ (pen.; w/♂; molt, 20-24 Mar 1997); 20 Mar 1997, 1♀; 30 Mar 1997, 1♀; 6 Mar 1998, 1♀	on ground.; under wood; in PVC pipe centerpole
**Phidippus nikites*	30 Jul-3 Aug & mid-Jul 1998 (def. molts), 2♂ (both (♂) reared from (♀) collected 10 Sep 1997)	(♀) under masonite over pitfall trap
**Phidippus octopunctatus*	4-7 Jun & 20-21 Jun 1998 (def. molts), 2♂ (both (♂) reared from (♀) collected 11 Sep 1997)	(♀) on Calif. Buckwheat
Theridiidae		
Achaearanea tepidariorum	6 Feb 1997, 1♀	in web on low shrub
**Enoplognatha selma*	9-31 Dec 1998, 4♀ (pen.; molts 30 Dec 1998-25 Jan 1999)	grass/leaf litter
Latrodectus hesperus	5 Mar 1997, 1♀	in cavity under rock
Steatoda triangulosa	27 Jan 1997, 1♀; 14 Mar 1997, 1♀; 7 Jun 1998, 1♂	in web, inside culvert; in webs, entr. stn. outbldg.
Steatoda washona	4 Jun 1998, 1♂	on ground
**Theridion llano*	29 Dec 1998, 1♂ (pen.; def. molt, 10-11 Jan 1998)	in web on shrub
Theridion melanurum	6 Feb 1997, 1♀	in web, entr. stn. outbldg.
Tidarren haemorrhoidale	13 Mar 1997, 1♀	in web, cavity of oak tree, oak grove
Thomisidae		
Xysticus montanensis	10 Mar 1997, 1♀; 1 Dec 1998, 1♀	grass litter

ture), variability in weather conditions and temperature, elevation gradients, general topography, and soil types, also affect the associated spider faunas. Not only did sampling comparisons between the Diegan and Riversidian CSS spider fauna reveal differences in species composition and relative abundance, but suggested a much higher species diversity in CSS (in general) than originally indicated in our Diegan study.

A total of 166 species (Table 1), representing 96 genera in 30 araneomorph and 3 mygalomorph families, were collected from Riversidian CSS communities at SRCMR compared with 200 species (112 genera in 31 araneomorph and 4 mygalomorph families) collected from Diegan CSS (Prentice et al. 1998). Of those collected at SRCMR, 127 species were collected by traditional trap or vacuum methods while 39 species were collected by hand. Three species occurred only in malaise samples, 58 species occurred only in pitfall samples, and 37 species occurred only in vacuum samples. In samples from the traditional methods (malaise, vacuum, and/or pitfall), Gnaphosidae were represented by the greatest number of species (19), followed by Salticidae (16), Dictynidae (14), Linyphiidae (13), Araneidae (9), Thomisidae (8), Theridiidae and Philodromidae (each with 6), Oxyopidae (5), Agelenidae, Liocranidae, Lycosidae, and Tetragnathidae (each with 3) (Table 3). The remaining families were represented by only one or two species. In our Diegan study, the eight most speciose families (excluding hand-collected species) in descending order were Gnaphosidae, Salticidae, Theridiidae, Linyphiidae, Dictynidae, Araneidae, Thomisidae, and Philodromidae (Table 3). Of the total number of species from SRCMR (including hand collected species), over 33% (55 species) were absent in Diegan samples, although 14 of these species were probably represented by juveniles (only) in Diegan samples (juveniles not included on species lists of either study).

Diversity within most taxa was generally greater in Diegan than in Riversidian CSS (Table 3). This pattern remained after we corrected for differences in specimen numbers across the respective CSS types (Fig. 2). For Riversidian CSS, the maximum species richness for specimens collected from pitfall traps and vacuum samples was 136. Given the species accumulation curves in Fig. 2, we estimated spider species richness in Diegan CSS to be 18% greater than in Riversidian CSS at the same specimen abundance (3302 specimens).

Mecicobothriidae (Mygalomorphae), Cybaeidae, and Nesticidae were represented only in Diegan samples but Caponiidae was represented only in Riversidian samples (Table 3). However, various species of Mecicobothriidae and Caponiidae have been collected from CSS/chaparral transition zones in both San Diego and Riverside Counties. One species of Nesticidae is known from both counties, and, at least, one species of Cybaeidae (most California species are distributed in central and northern counties) has been collected in San Diego County.

At the genus level, diversity was greater in Diegan CSS within ten shared families, most notably the Salticidae, but in Riversidian CSS diversity was greater within only four shared families, most notably the Pholcidae (Table 3). Although species composition was, in general, richer in Diegan than in Riversidian CSS, the reverse was true within six shared families, Cyrtaucheniidae, Araneidae, Dictynidae, Oxyopidae, Philodromidae, and Pholcidae (most notably, Dictynidae, Philodromidae, and Pholcidae), and seven shared genera (*Aptostichus, Metepeira, Oxyopes, Peucetia, Ebo, Steatoda,* and *Misumenops*). Diegan fauna was substantially more speciose within the Theridiidae and Gnaphosidae and, to a lesser extent, within the Salticidae and Linyphiidae (Table 3).

March and June 1996 Sampling Additions.—Specimens (11) of species that were collected only in March and/or June 1996 samples are included on the species list and counted in the various totals. The species are as follows: *Hyposinga funebris* (Keyserling), *Mastophora cornigera* (Hentz), *Anyphaena californica* (Banks), *Phidippus californicus* Peckham & Peckham, *Theridion llano* Levi, *Tetragnatha pallescens* F. P.-Cambridge, and *Misumenops californicus* (Banks). The males of *Ceraticelus* sp. #1, *Micaria deserticola* Gertsch, *Pardosa ramulosa* (McCook), *Oxyopes salticus* Hentz, and *Theridion rabuni* Chamberlin & Ivie, and the female of *Liocranoides dolichopus* (Chamberlin) were also collected during these sampling periods and are included on the species list and counted in the various totals (6 specimens).

Hand-Collected Species.—Table 2 provides additional collection and habitat data, not provided in Table 1, for specimens of 50 species collected by hand. All specimens of 39 of these species were collected only by hand (hand, Yellow Pan Trap, or sweepnet). For each of the remaining 11 species, hand-collected specimens of only one sex (either male or female) are recorded in Table 2; specimens of the opposite sex of each of these species, respectively, were collected in pitfall, vacuum, and/or malaise samples.

New Riverside County Records.—Eighteen species are new records for Riverside County (indicated in Table 1 by the superscript 'RC'). County listings are provided here for three species reported only in counties north of and including Santa Barbara County: *Nodocion utus* (Chamberlin): Ventura County (Platnick & Shadab 1980); *Thanatus formicinus* (Clerck): Santa Barbara County, Monterey County, Yosemite National Park (Mariposa and/or Tuolumne Counties) (Dondale, Turnbull, & Redner 1964); *Dictyna sierra* Chamberlin: Sierra County (Chamberlin & Gertsch 1958). Boe (1986—unpublished; available at UC Riverside Science Library) reported *D. sierra* from Riverside County but we were unable to authenticate this record.

Females, determined to be *D. sierra:* (Chamberlin & Gertsch 1958), were previously known only from SE Oregon. The female epigynum as illustrated in Chamberlin & Gertsch (1958) is, decidedly, not the epigynum of the female that we collected at SRCMR. However, general coloration and morphological similarities between our male and female, as well as the close proximity of the sites from which they were collected, suggest that our specimens are conspecific.

Undescribed Species.—Approximately 6.5% and 9.5% of the listed Riversidian and Diegan species, respectively, are believed to be undescribed taxa. Taken together, the Riversidian and Diegan studies provided 26 undescribed species or approximately 10% of the combined totals of 255 species. These percentages, as well as the 18 new species records (above) for Riverside County and the 35 new records for San Diego County (Diegan study), are indicators of just how little we know of the arthropod community structure within the CSS system, in general.

The following 11–12 species (ten or eleven araneomorph and one mygalomorph species) collected at SRCMR, are believed to be undescribed taxa: *Blabomma* sp. #4, #5, #6 (Dictynidae); sp. #4 is probably the female of sp. #5 (undescribed status confirmed by D. Ubick (CAS)); species #1 (m, f), undescribed genus (Amaurobiidae) (family status suggested by D. Ubick, (CAS)); *Filistatinella* sp.

Table 3. Differences in the generic composition and the number of species within spider families represented in both Riversidian CSS samples (present study) and Diegan CSS samples (Prentice et al. 1998). Unlisted families were either represented in only one of the studies or were represented in both studies by the same species. Juveniles were considered in the elimination of unique genera. Representatives (Riversidian species) of a probable new genus/new species (n. g./n. s.) are tentatively placed in the Amaurobiidae. Riversid. = Riversidian.

Family	Riverside. # gen.	Diegan # gen.	Riversid. unique gen.	Diegan unique gen.	Riverside. sp./fam.	Diegan sp./fam.
Agelenidae	3	4		*?Hololena*	3	4
Amaurobiidae	1	2	n. g./n. s.	*Metaltella* *Zanomys*	1	2
Anyphaenidae	1	1	*?Anyphaena*	*Teudis*	1	1
Araneidae	8	7	*Mastophora*		14	13
Corinnidae	1	3		*Corinna* *Meriola*	2	4
Cyrtaucheniidae	1	1			2	1
Dictynidae	8	7	*Mallos*		19	16
Filistatidae	1	1			1	2
Gnaphosidae	10	12		*Urozelotes*	19	28
Hahniidae	1	2		*Calymmaria*	1	2
Linyphiidae	9	10	*Wubana*	*Idonella* *Ostearius*	17	21
Liocranidae	3	4		*Agrocea*	3	4
Lycosidae	3	3			5	6
Mimetidae	1	1			1	2
Oonopidae	2	3	*Oonops*	*Opopaca* *Orchestina*	2	3
Oxyopidae	2	2			5	3
Philodromidae	5	4	*Thanatus*		10	7
Pholcidae	3	1	*Holocnemus* *Physocyclus*		3	1
Plectreuridae	1	2		*Kibramoa*	1	3
Salticidae	10	15		*Metacyrba* *Pckhamia* *Phanias* *Terralonus* *Thiodina*	20	26

Table 3. Continued.

Family	Riverside. # gen.	Diegan # gen.	Riversid. unique gen.	Diegan unique gen.	Riverside. sp./fam.	Diegan sp./fam.
Tengellidae	1	1			1	2
Theridiidae	8	10		*Argyrodes* *Crustulina* ?*Thymoites*	12	24
Thomisidae	2	3		*Coriarachne*	9	11

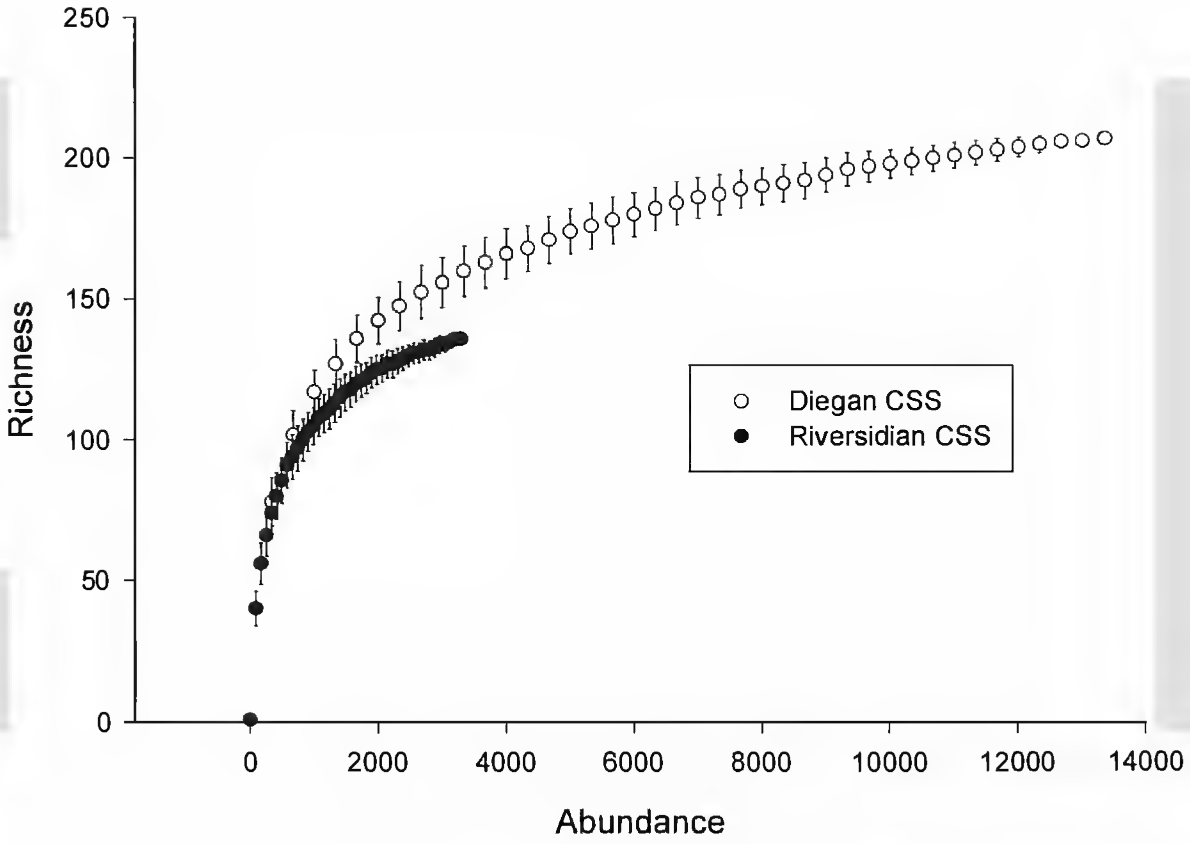

Figure 2. Species diversity of Araneae in Diegan and Riversidian CSS. Species accumulation curves were constructed by resampling species abundance data. Only adults and immature specimens, distinct enough not to be confused with other species, were included in calculations. Error bars represent 95% confidence intervals from Monte Carlo randomizations.

#3 (Filistatidae); *Ceraticelus* sp. #1, *Linyphantes* sp. #5, *Meioneta* sp. #2, #3 (Linyphiidae); *Oonops* sp. #1 (Oonopidae); *Psilochorus* sp. #1 (Pholcidae); *Aptostichus* sp. #1 (Cyrtaucheniidae) (status determined by J. Bond (Field Museum, Chicago)). Specimens of only four of these species, *Ceraticelus* sp. #1, *Meioneta* sp. #2, *Psilochorus* sp. #1, and *Aptostichus* sp. #1, were found in Diegan samples.

Phenology.—Twelve species, eleven from pitfall traps and one from vacuum samples, were collected in numbers large enough (n > 25) to provide an abstraction of their life cycles or, more precisely, their adult activity patterns. The phenologies of *Calilena stylophora* Chamberlin & Ivie (n = 28) and six other species (n = 16–24) are not discussed either because the species was not observed in the field, revision of genus in question is in need, comparative natural history literature was lacking, and/or specimens were hand collected.

In the majority of spider species with discreet breeding periods, first male maturation just precedes or roughly corresponds to the beginning of the respective breeding season, with maximum male activity peaking some time later. Peak female activity, on the other hand, roughly corresponds to copulatory periods and increased foraging or searching for oviposition sites prior to egg deposition (DeKeer & Maelfait 1997, Draney 1997). Phenograms (Fig. 3) do not reflect juvenile activity because many congeneric immatures could not be reliably separated.

Our two most prevalent species, *Callilepis gosoga* Chamberlin & Gertsch and *Drassyllus insularis* (Banks) (Figs. 3A and 3B, respectively), are apparently most active in Riversidian CSS between late spring to late summer and presumably mate during this period. In Diegan CSS, both species likely remain active somewhat longer (*C. gosoga* with slightly decreasing activity and *D. insularis* with increasing activity between June and August) (Prentice et al. 1998). Although adult *D. insularis* did not occur in December samples, two of us (TRP & WRI) have hand-collected adults from November–February. Platnick & Shadab (1982) also reported that adults occur year-round. Adults of *C. gosoga* have been collected only between mid-April and early September (Platnick 1975). The female to male ratio of *C. gosoga* (~1:3) in samples (Fig. 3A) is decidedly lower than in *D. insularis* (~1.1:1) (Fig. 3B) which suggests foraging dissimilarities between females of the two species. We hypothesize that *C. gosoga* is an ant specialist (see: *Natural History* subsection: *Ant Predators* below). Mature females, in preparation for egg deposition, may restrict their hunting ranges to areas near harvester ant nests, in which case, they may only occasionally fall into randomly placed pitfall traps. Contrarily, males probably wander in search of females (rather than in search of prey), which increases their chances of falling into pitfall traps. Adults of *D. insularis* are probably active generalist predators with, perhaps, broad hunting ranges which may render females (and males) more subject to pitfall collection.

The remaining two common gnaphosids, *Haplodrassus maculatus* (Banks) and *Zelotes gynethus* Chamberlin, show increasing activity from late fall to early spring with peak activity in March (Figs. 3C, 3D, respectively). *Zelotes gynethus* seems to be more prevalent than *H. maculatus* in December, which may indicate an earlier and/or more prolonged mating period than that of the latter species. Moreover, *Z. gynethus* adults occurred year-round but those of *H. maculatus* were absent in September samples. Because only one *H. maculatus* female was collected in June samples, it seems likely the majority of adults expire during May. According to Platnick and Shadab (1975), adults had been previously taken from early January through mid-May. The lack of March samples from our Diegan study may have accounted for the apparent absence of *H. maculatus*; only a few juveniles were collected, which may have been either *H. maculatus* or *H. signifier.* Although California collection records indicate an inland distribution of *H. maculatus,* specimens have been collected within approximately 3 km of the coast in Baja, California (Platnick & Shadab 1975). In all probability, *H. maculatus* inhabits southern California Diegan CSS although it may not be as common as in Riversidian CSS.

In both our Diegan and Riversidian CSS studies, *Alopecosa kochi* (Keyserling) and *Schizocosa mccooki* (Montgomery) were the two most frequently collected wolf spiders; specimens of both species were collected together in many of the same plots during both studies. Although *A. kochi* are generally smaller than *S. mccooki,* there is substantial size overlap between the species which may result in competition for like-size prey items. The partitioning of resources may be accomplished both by differences in breeding seasons and daily activity patterns. *Alopecosa kochi* displays increasing activity from December to March (Fig. 3) and is diurnal (Hagstrum 1970) whereas *S. mccooki* shows peak activity in Riversidian CSS in June (Fig. 3G) and is nocturnal (Dondale & Redner 1978).

In Diegan CSS peak activity of *S. mccooki* occurred in August. The presence of penultimates (only) in late May and early June Diegan samples and the collection of two females in late August (26th and 29th) with partial broods still clinging to their abdomens suggest that breeding probably occurs between late June and late July in Diegan CSS. Had we sampled in July and early August

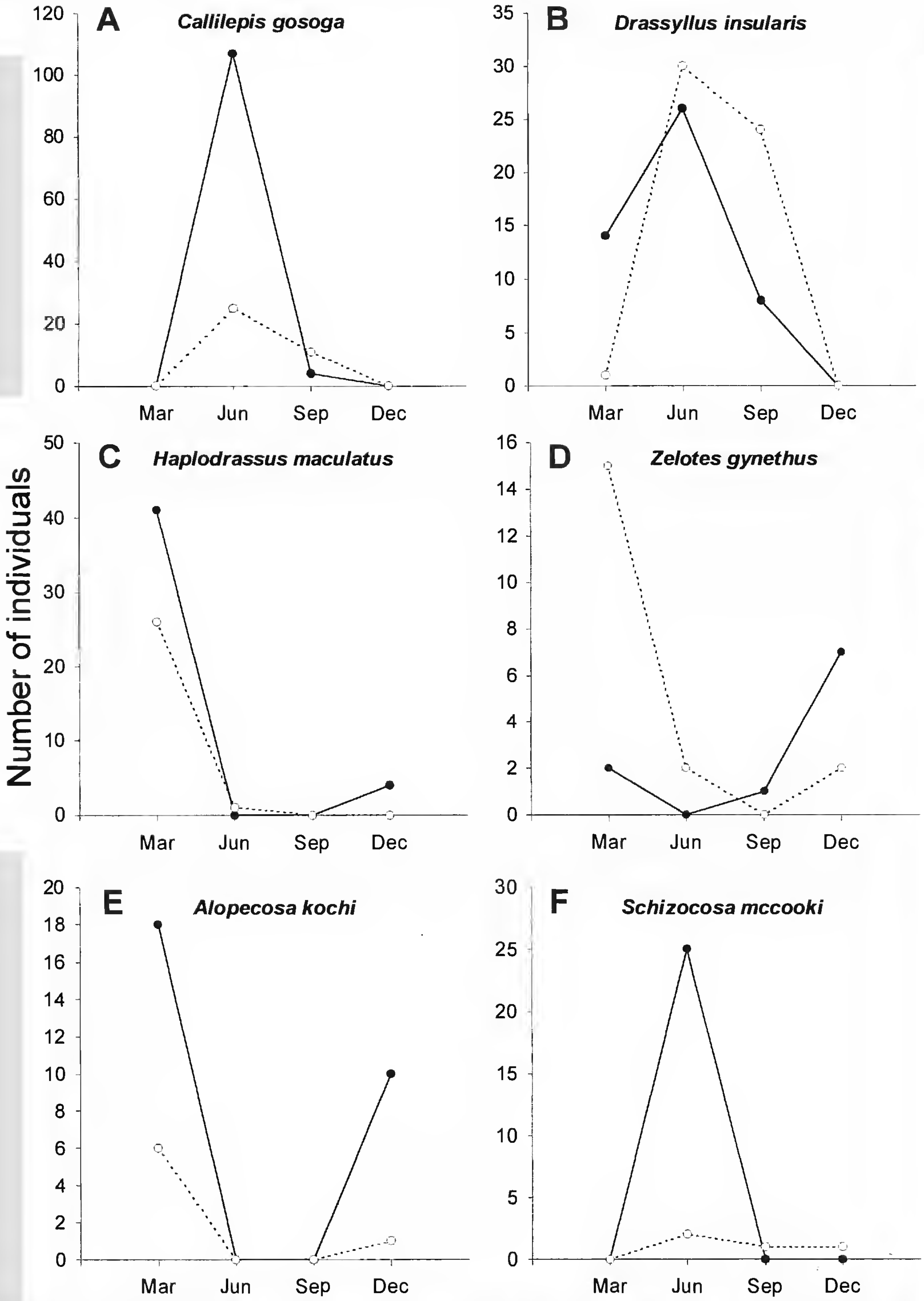

Figure 3. Phenograms of twelve spider species (adults only): A–D, Gnaphosidae; E–F, Lycosidae; G–H, Linyphiidae; I, Pholcidae; J, Salticidae; K, Dictynidae; L, Thomisidae. Collecting periods illustrated on the abscissa were during the first two weeks of each month listed. Pitfall traps (7 per plot; 24 plots) were left open for 72 h ± 4 h. Five one-minute vacuum samples per plot (24 plots) were collected during each sampling period. Closed circles (●) connected by solid lines represent male collections; open circles (○) connected by dashed lines represent female collections.

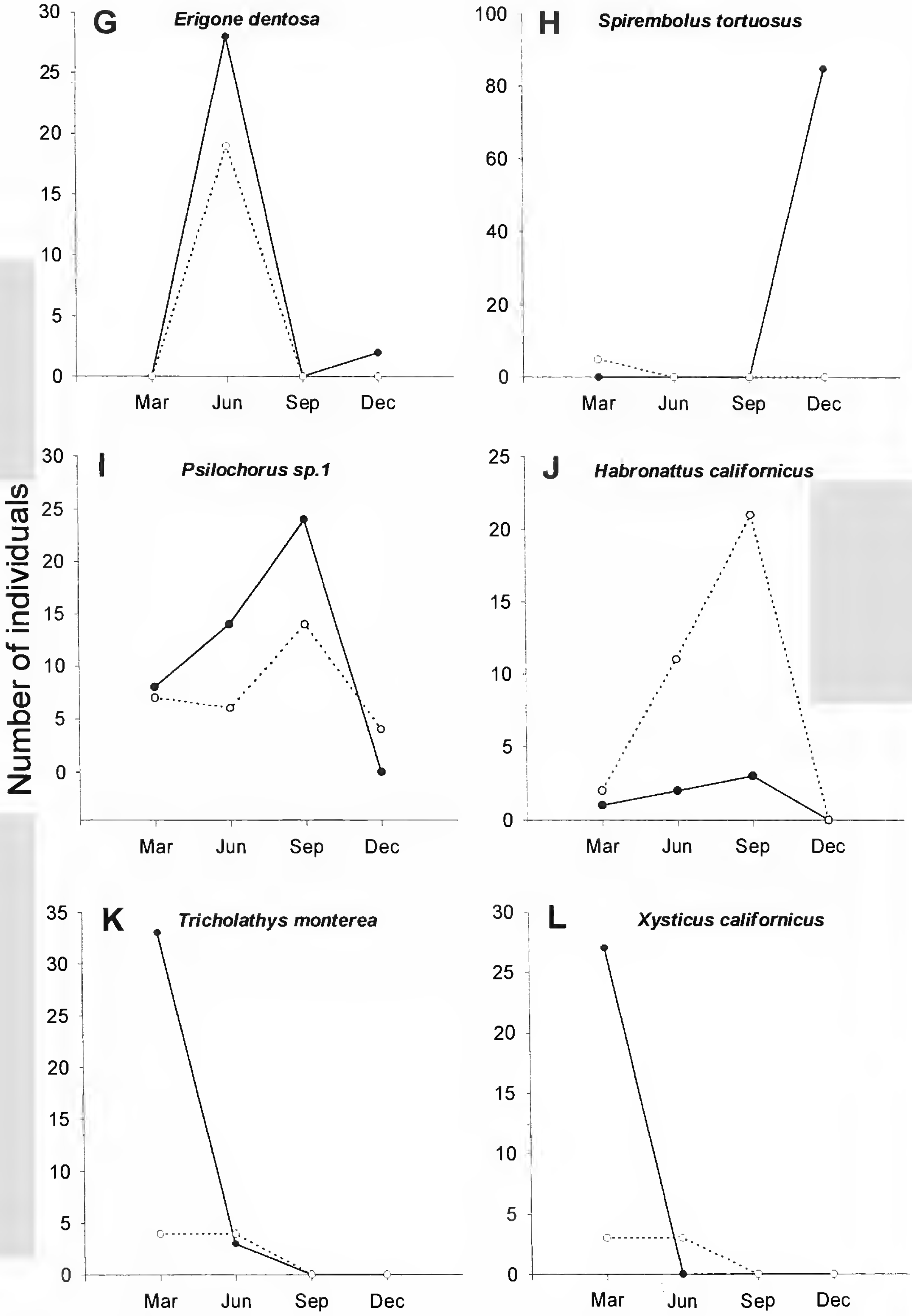

Figure 3. Continued.

during our Riversidian study we may have seen an increase in female activity past the apparent June peak (Fig. 3G). However, the absence of males in early September Riversidian samples may be an indication of a slightly earlier breeding season than that of Diegan populations. The large size of *S. mccooki* and the presence of two distinct juvenile size classes in samples suggest both a biennial life cycle and alternating generations (Dondale 1977, Hagstrum 1970). However, in populations from pinon-juniper forests in New Mexico, Stratton & Lowrie (1984) found *S. mccooki* to have an annual life cycle.

Alopecosa kochi, inhabiting pine forests in the San Bernardino National Forest, is reported to have a similar two-year life-cycle with alternate generations (Hagstrum 1970). In the mountain populations, penultimates mature in fall with adults overwintering, followed by mating in early spring and egg deposition in early May. In our studies, December and March pitfall catches, as well as hand collection of both males and females in early February from both Riversidian and Diegan study sites, indicate continuous activity throughout the winter months. Unlike pine forest inhabitants, CSS inhabitants presumably mate during the winter months and produce eggs in early March; females with egg sacs were collected as early as 4 March from SRCMR. The absence of adults in both June and September Riversidian samples and in August Diegan samples suggests that adults may expire prior to the hottest and driest part of the summer.

Spirembolus tortuosus (Crosby) and *Erigone dentosa* O. P.-Cambridge were the two most prevalent linyphiid species. All female and all except two males of *E. dentosa* were collected in June 1998 vacuum samples (Fig. 3G); only one male was taken (in June) during the Diegan study. Yeargan & Dondale (1974) reported the take of *E. dentosa* by all methods used (vacuum, sweepnet, pitfall trap) in their study of the spider fauna in alfalfa fields of northern California. Crosby & Bishop (1928) indicate collection records of both sexes from May to September. However, two of our males occurred in March 1996 samples (data not used here) from SRCMR and males, together with females, were collected by hand in early March at SRCMR and in early February at MCBCP. It appears as though adults are present throughout the year but may likely be most active between early June and middle or late August. Males of *S. tortuosus* (Crosby) were collected exclusively in December samples from both Diegan plots and Lake Skinner (Fig. 3H); the few Riversidian females taken occurred only in March samples (December in Diegan samples) and, of these, two were obviously gravid when collected. Millidge (1980) reported male collections in October, November, and January and female collections in September, October, and December through February or March. During independent collecting efforts by one of us in 1998 (TRP), both penultimates and adults were taken from low grasses and by litter sifting between the last week of November and the first week in December. For the remainder of December, only adults were found, suggesting that the peak breeding period occurred in Lake Skinner populations after the first week of December. In agreement with Millidge (1980), we believe that the species breeds during the winter months prior to early March when only females are present. The small proportion of females in samples is probably due to both habitat structure and female behavior. Like many erigonine species, female and juvenile *S. tortuosus* may live in small webs (captive adults spin small, flat webs) that are constructed within moist leaf litter, whereas males actively search for females during the breeding season. Such behavioral differences would account for the disproportionate catch of males in both Diegan and Riversidian studies.

Phenograms of the prevalent pholcid and salticid species, *Psilochorus* sp. #1 and *Habronattus californicus* (Banks), respectively, reflect similar activity patterns (Figs. 3I, 3J, respectively). Field collections of both male and female *Psilochorus* sp. #1 in December and February at MCBCP and at SRCMR indicate, however, that adults of the species are most likely present year-round. December field collections at both locations yielded only female *H. californicus*; males were not found in December at MCBCP nor between November and late January at SRCMR. Both species are thought to have an annual life cycle. Maturation of captive *H. californicus* spiderlings (egg sacs produced and young reared in lab) occurred in approximately six to seven months. The presence of juveniles of several size classes within both *H. californicus* and *Psilochorus* in a given June or September sample suggests that the respective females may breed and produce egg sacs during several months of the year. This stands to reason given that *Psilochorus* males are found throughout the year, *H. californicus* males occur during ten of the twelve months, and gravid *H. californicus* females were collected in both June and September samples. The September peak of *H. californicus* (Fig. 3J) may be indicative of increased foraging activities, which may be necessary due to the scarcity of prey. By September, most of the vegetation, that the spider's prey may depend upon for sustenance, has either long since senesced or become summer dormant. Unlike that of *H. californicus,* the September peak of *Psilochorus* (Fig. 3I) may reflect shelter-seeking activity, which may be necessary to avoid desiccation from the summer heat. The vast majority of the specimens observed in the field were discovered beneath rocks or under other objects that provided both a dark refuge and insulation from the heat. Although unset pitfall cups were covered with both plastic lids and masonite boards (weighted with rocks), *Psilochorus* adults and subadults were repeatedly discovered in small webs within the cups, immediately before the traps were set in early September. When initially opened, most pitfall cups had condensation droplets on the inside surfaces. Set traps likely provided a very similar environment, attracting *Psilochorus* seeking shelter, and, in turn, accounting for the September take.

Phenograms of the dictynid, *Tricholathys monterea* (Chamberlin & Gertsch), and the thomisid, *Xysticus californicus* Keyserling, indicate late winter activity of males but little cursorial activity of females in either late winter or spring (Figs. 3K, 3L, respectively). In Diegan CSS, both males and females of *T. monterea* were relatively common in mid- to late spring but the only specimens of *X. californicus* collected (3 females) were taken in May/June samples. Chamberlin & Gertsch (1958) report collection dates for adult *T. monterea* from late March to late May with the majority of specimens examined collected in early to mid-May. Taken together with our data, it appears that the species' breeding season peaks between early and late spring. Egg deposition may occur during the early part of the summer. Schick (1965) reported common collection of *X. californicus* adults from March to July throughout most of the species' southern California distribution. However, during several visits to both study areas in early February of 1997 and 1998, we observed an abundance of penultimates and adults of both sex, although the adult to penultimate ratio was apparently greater in males (> 0.5) than in females (< 0.5). Based on the apparent disappearance of males in Riversidian CSS by early June (Fig. 3L) we can predict a mid-winter to mid-spring breeding season within these populations.

Occurrence Patterns in Burned vs. Unburned Plots.—For characterizations of burned and unburned plots refer to *Study Sites* under Methods. Few species were collected in large enough numbers to discern a pattern of occurrence in burned vs. unburned plots. Of the 12 most prevalent species discussed immediately above, five species occurred in equal numbers (± 4%) in burned and unburned plots. One species, *Alopecosa kochi,* was collected more frequently in unburned plots (60% of specimens), and six species, *S. mccooki, S. tortuosus, E. dentosa, Psilochorus* sp. #1, *X. californicus, T. monterea,* occurred more frequently in burned plots (59, 79, 76, 60, 100, and 66% of specimens, respectively). Ten of the 11 *Zelotes monachus* Chamberlin and all specimens of *Habronattus hirsutus* (Peckham & Peckham) were taken from unburned plots, 5 of 6 *Scaphiella hespera* Chamberlin and 10 of 13 *Dictyna abundans* Chamberlin & Ivie specimens came from burned plots. *Spirembolus tortuosus, X. californicus,* and several other species (not listed above) that exhibited patterns of occurrence are further discussed below in the *Natural History* subsection, *Habitat Preferences.*

Probable Endemic Species.—Because we did not sample in chaparral communities, nor in other communities which are often intimately associated with CSS communities in southern California, we use the term *endemic* to mean "restricted to a particular area" following Anderson (1994). Eight species are here considered as probable endemics to southern California (Riverside, San Bernardino, Los Angeles, Orange, and/or San Diego counties) exclusive of the mountain and desert regions: *Orthonops zebra* Platnick, *Micaria capistrano* Platnick & Shadab, *M. icenoglei* Platnick & Shadab, *Zelotes skinnerensis* Platnick & Prentice, *Linyphantes aliso* Chamberlin & Ivie, *L. microps* Chamberlin & Ivie, *L. obscurus* Chamberlin & Ivie, *Scotinella kastoni* (Schenkel). One species, *Plectreurys tecate* Gertsch is believed to be endemic to SW San Diego County and adjacent Baja, California. Refer to Prentice et al. (1998) for additional data on species collected only during our Diegan study.

Orthonops zebra (Caponiidae): In his revision of *Orthonops,* Platnick (1995) examined 41 specimens, most of which were collected by one of us (WRI) from Riversidian CSS near Winchester (approximately 15 km N of SRCMR). Two specimens were collected in chaparral communities in the Santa Ana Mountains (Orange and Riverside counties, respectively), west of Murietta. We collected two additional males in June pitfall samples from Riversidian CSS at SRCMR (the majority of the males that Platnick examined were collected in March). All known specimens were taken within an 18 km radius of Murietta. Three of the other nine known *Orthonops* species are presumed to have limited distributions in southern California (Platnick 1995); one of these species, *O. johnsoni* Platnick, is known only from Johnson Canyon (San Diego County), a habitat of chaparral and Diegan CSS.

Micaria capistrano (Gnaphosidae): Seven of the nine known specimens (male unknown) were collected from either Diegan CSS or chaparral communities (Baja specimens) in either SW San Diego County (MCBCP and MNAS) (3 females) or in Baja California Norte (4 females, see Platnick & Shadab 1988). These localities are separated by approximately 265 km. Of the two remaining known specimens, one was collected from the Box Springs Mountains, Riverside County (Riversidian CSS), the other in the Santa Ana Mountains near the Riverside County border (probably from chaparral). The lack of specimens in Riversidian samples during the present study and in independently collected CSS samples (collections spanning nearly 30 years) near Winchester by one of us (WRI), suggests that the species is very rare, if it naturally occurs, this far north.

Micaria icenoglei (Gnaphosidae): A total of 23 specimens, collected exclusively from or closely adjacent to CSS, are known. Eight of these were collected from Riversidian CSS, seven near Winchester (two males were collected near buildings adjacent to CSS) (see Platnick & Shadab 1988), and one male during our present study. The remaining 15 specimens were collected during our Diegan CSS study. If the distribution of *M. icenoglei* is continuous from Winchester to San Diego County it seems likely that the species also inhabits chaparral communities, at least the lower elevation communities.

Zelotes skinnerensis (Gnaphosidae): The three known specimens (Platnick & Prentice 1999), two males and one female, were collected from two plots within 600 m of the NE lakeshore of Lake Skinner (SRCMR). Because the revision (Platnick & Shadab 1983) of the genus was based on a large amount of material and because one of us (WRI) has collected Araneae in southern California for thirty years without encountering the species, *Z. skinnerensis* is here considered either rare or very secretive.

Linyphantes aliso (Linyphiidae): This species was described from a female holotype from Laguna Beach (also female paratypes); the male was then unknown and as yet remains undescribed. Although degrees of latitude and longitude were provided in the original description (Chamberlin & Ivie 1942), it is next to impossible to determine the exact habitat from which the specimens were taken in light of the development within the Laguna Beach area since 1942. Both CSS and chaparral are (presently) common in the undeveloped and undisturbed areas just north of the town proper. An additional 30 specimens were collected from Diegan CSS, including 10 males, several of which were present with females in various plot samples. The species was absent from Riversidian samples although one male and one female were collected in pitfall traps at Santa Rosa Plateau Ecological Reserve in SW Riverside County. The most southerly-inhabited region (within MNAS) is approximately 100 km S of the type locality; all known collection localities are within approximately 40 km of the coast.

Linyphantes microps (Linyphiidae): This species was described from a single male taken in Irvine, Orange County (latitude and longitude provided in original description) (Chamberlin & Ivie 1942). To our knowledge, the male holotype is the only published record of *L. microps* prior to our work here. During our present study, we collected two males in March samples from Riversidian CSS along with two females that we determined to be conspecifics.

Linyphantes obscurus (Linyphiidae): This species was described from a single female collected in December; the type locality is the same as that of *L. aliso.* We collected 17 males (*Linyphantes* sp. #3) in December samples during our Diegan study but were unable to determine the species then because the male of *L. obscurus* has not been described. A female of *L. obscurus,* along with 28 males (determined to be conspecific to both the female and the 17 males from San Diego County) were taken (Coll.: C. Dunning) in December by pitfall trap at Santa Rosa Plateau Ecological Preserve in SW Riverside County. The plots from which these specimens came are composed primarily of Engelmann oak, coast live oak, and native perennial grassland. Specimens were not discovered at SRCMR. To date, the species is known only from San Diego, Orange, and Riverside counties.

Fourteen of the 19 described *Linyphantes* species occur in California (Chamberlin & Ivie 1942), 11 of which are known only from California. The type species, *L. aeronauticus* (Petrunkevitch) is the only member of the genus known to have an extensive distribution, occurring in Idaho, Wyoming, Oregon, Utah, Nevada, California, Arizona, and probably several additional states. All other congeners are known only from western coastal localities (Canada, Washington, Oregon, California, or Mexico). At least three of our seven purported *Linyphantes* species (from both studies) are believed to be undescribed. When generic revision of *Linyphantes* is eventually undertaken, we may find that there are several *Linyphantes* species that are endemic to our region.

Scotinella kastoni (Liocranidae): This species was described from a single female collected 28 Dec 1938 from Balboa Park, San Diego (Schenkel 1950); the male has not been described. Because the hills in and around the zoo are of low elevation and were likely to have supported CSS (rather than chaparral) prior to urbanization, it is probable that the landscape from which the specimen was collected was composed primarily of CSS. We have collected an additional 108 specimens, 25 from CSS (7 males, 14 females during our Diegan study and 4 females during our present study) and 83 from oak-savanna habitats at Santa Rosa Plateau. To our knowledge, there are no additional published locality records of *S. kastoni.* The apparent distributional limits of the species (assuming a continuous distribution) extend from Lake Skinner to Balboa Park, a terrain composed of chaparral and CSS, covering a distance of approximately 100 km.

Plectreurys tecate (Plectreuridae): The only three heretofore known specimens (2 males, 1 female) were collected 16 May 1952, 8 mi. W of Tecate, Baja California (Gertsch 1958). CSS is present in the general area although it appears to be either restricted to relatively small discontinuous patches or intermixed with Californian chaparral, which provides the major canopy cover in the region. Specimens of *P. tecate* were not taken in Riversidian samples but two additional males were collected from the same plot at MNAS (between 12–19 May 1996). The canopy cover of this plot has both CSS and chaparral components, the latter including *Adenostoma fasciculatum* Hooker & Arnott (chamise) and *Yucca whipplei* Torrey. Throughout the approximate 40 km gap between the type locality and MNAS both CSS and chaparral are the primary vegetation types. Data indicate that *P. tecate* prefers relatively dry habitats with enough surface soil and moisture to support the growth of the transitional (chaparral to CSS) chaparral elements. In all likelihood, the distribution of this species is probably more extensive in Baja, California than in California. The remaining species in the *P. castanea* group (9 species) are known only from California. Seven of these species apparently have restricted distributions in southwestern part of the state; the other two species, *P. monterea* Gertsch and *P. castanea* Simon, are known only from Monterey County and from San Mateo County to San Diego County, respectively (Gertsch 1958).

Non-native Species.—The following six known non-native species were collected either in Riversidian CSS samples or by hand (Table 1; denoted by the superscript 'NN'): *Oecobius annulipes* Lucas, *Zelotes nilicola* (O.P.-Cambridge), *Dysdera crocata* C. L. Koch, *Holocnemus pluchei* (Scopoli), *Steatoda triangulosa* (Walckenaer), and *Menemerus bivittatus* (Dufour). Only one male and female of both *O. annulipes* and *Z. nilicola* and one female of *D. crocata* were found in Riversidian samples. Specimens of *H. pluchei, S. triangulosa, M. bivittatus* were collected by hand at or near the entrance station and are discussed below. Refer to Prentice et al. (1998) for data on *O. annulipes, Z. nilicola,* and *D. crocata.*

Holocnemus pluchei (Pholcidae): Of Mediterranean origin (Porter & Jakob 1990), *H. pluchei* appeared in California during the early 1970s. One of us (WRI) collected the species in Sutter County, California in 1974, which may be the earliest California record (Porter & Jakob 1990). We found no records that indicated when the species was first reported within the United States. Boe (1986-unpublished) reported collection records in Imperial, Los Angeles, Napa, Riverside, and Sonoma Counties and from the San Joaquin and Sacramento Valleys. Porter & Jakob (1990) conducted their studies of *H. pluchei* from populations in Riverside, Los Angeles, Kern, Fresno, and Yolo Counties. The species has since been observed by one of us (TRP) in San Bernardino County (Loma Linda) and in San Diego Co. (Spring Valley). Our one specimen (female) was collected in 1998 from its web in the angle of the soffet and walls of the entrance station outbuilding. Two additional specimens appearing to be subadults were also present in the web. In both 1996 and 1997, another pholcid, *Physocyclus californicus* Chamberlin & Gertsch, had occupied the available spaces under these eaves but in 1998 was absent, suggesting displacement by *H. pluchei* (not observed in previous years). In another example of probable displacement by *H. pluchei,* we refer to a third pholcid species, *Artema atlanta* Walckenaer. One of us (WRI) had observed, for several years, a healthy population of this very large, primarily neotropical species under the Hwy 115 bridge crossing the Alamo River just west of Holtville, Imperial County, California. In October 1998, two of us (WRI & TRP) revisited the site to find a dwindling *A. atlanta* population and, for the first time, *H. pluchei,* the population of which outnumbered that of *A. atlanta* by an estimated 2/1 ratio.

Steatoda triangulosa (Theridiidae): Quite possibly of European origin, *S. triangulosa* may have been reported in the United States (Georgia) as early as 1850 (see Levi 1957). The majority of early collection records indicate that the species was originally introduced in one of the eastern seaboard states prior to 1900. Levi (1957) indicated records in California in only two counties, Alameda and Solano. Boe reported its distribution from San Diego and Imperial counties north to Siskiyou and Nevada counties. Two of our three specimens (male, female) were collected from the same outbuilding on which the pholcids had resided. Notably, both specimens were collected from small webs confined to the extreme corners slightly above the expanded webs of the resident pholcids, the female above *Physocyclus californicus* in 1997 and the male above *Holocnemus pluchei* in 1998. The third specimen (female) was collected from its web in a recess on the upper inner surface of a road culvert (culvert approximately 1 km S of entrance outbuilding).

Menemerus bivittatus (Salticidae): Probably originating in the Old World Tropics (Edwards 1979), the species now occurs in Puerto Rico, Costa Rica, and Mexico, north to the southern United States. In the U.S., there are records in most of the southern states from Florida to California. In California the species is found as far north as Sonoma County. Both specimens collected at SRCMR were found on the walls of the entrance station outbuilding. Throughout the course of our study, both juveniles and adults were commonly seen on the building when the days were warm and sunny, but were never observed within the native vegetation.

Non-native spider invasions appeared to be minimal in Riversidian CSS compared to those in coastal Diegan CSS. Evidence from our Diegan study suggests that the non-native spider species are more likely to occur in greater numbers in CSS habitats that are less variable in temperature and have higher summertime humidity than Riversidian CSS habitats. Secondly, human traffic promotes the introduction and subsequent spread of non-native species inadvertently hitching rides. Obviously, the human element has a substantially greater impact on the introduction and spread of non-native species at MCBCP and MNAS (both heavily traveled and in very populated areas) than at SRCMR (most parts are closed to human traffic and the reserve is in a relatively isolated area). *Holocnemus pluchei, S. triangulosa,* and *M. bivittatus* were probably not encountered during our Diegan study because we failed to search manmade structures at either base. All three species have been collected by one of us (TRP) from two residences in Spring Valley, San Diego County.

Natural History.—Habitat Preference: Only a few of the species collected in either Riversidian or Diegan CSS were prevalent enough in samples to provide any insight into their habitat preferences. Collection results suggest that two of the common Riversidian species, *Spirembolus tortuosus* (Linyphiidae) and *Xysticus californicus* (Thomisidae) prefer relatively open microhabitats with an understory of grassy areas and a significant amount of grass or leaf litter or small prostrate forbs. *Spirembolus tortuosus* seems to prefer valleys or gentle south facing hillslopes with a significant amount of ground litter. In our Diegan study, *S. tortuosus* was distributed in 40 of the 60 plots. However, plots with sparse shrub cover and ample ground litter provided nearly half of the specimens. Of the specimens that occurred in plots with a dense shrub cover, most (70%) were from valley plots with grassy areas and abundant leaf or grass litter. Over 80% of the specimens collected during our present study occurred in plots recovering from the 1993 Winchester burn (burned plots); all of these plots were characterized with a sparse shrub cover, ample annual grass and forb cover, and abundant litter. The ground-dwelling thomisid, *Xysticus californicus,* also seems to prefer open grassy areas with either grass and/or leaf litter or a patchy prostrate forb layer. All of the Riversidian specimens occurred in samples from recovering burned plots; the three specimens collected in Diegan samples came from plots with similar percentages of shrub cover and understory composition. The largest number of specimens (> 50) that we observed at any one time was on a gentle, bare SW slope (MCBCP) carpeted with an *Erodium* sp. (storksbill).

Among the Dictynidae, collection results from both our Riversidian and Diegan studies suggest that *Blabomma* spp. prefer CSS habitats that offer the most humid microhabitat conditions (i.e., valleys, northern exposures, dense canopy layer, significant leaf litter, and grassy areas). *Blabomma sanctum* Chamberlin & Ivie occurred only in unburned plots with dense shrub canopies at SRCMR; nearly 80% of the specimens came from north facing plots. Of these, close to 95% were taken from one plot (Fig. 1, region E) characterized by a very dense shrub cover primarily of California Sage (*Artemesia californica*) and secondarily of California Buckwheat (*Eriogonum fasciculatum*) and Black Sage (*Salvia mellifera*) and an essentially bare substrate with sparsely distributed *Schismus* grass. Leaf litter was abundant but present only near the shrub bases. The two specimens occurring in Diegan samples were from plots with patchy shrub cover but with a relatively dense understory of annual grasses. All specimens of the undescribed (or undetermined) *Blabomma* species (sp. #1, #2, #3) from Diegan samples were taken from plots with chaparral elements (primarily chamise) as either major or important minor shrub components (the presence of chaparral elements is indicative of more moist conditions than those supporting only CSS). Two of these plots were in valleys and two were SW and SSE exposures, respectively, with dense shrub covers and little bare ground between shrubs. All except one specimen (*Blabomma* sp. #5) of the three undescribed (or undetermined) Riversidian *Blabomma* species (sp. #4, #5, #6) were collected from plots that either had dense shrub canopies, were located on north slopes, or had abundant grassy patches and ground litter. Of the 41 total *Blabomma* specimens taken, only four males of *Blabomma* sp. #5 were in samples from burned plots.

Among the Tetragnathidae, the three species of *Tetragnatha* collected at SRCMR occurred only in plots near Lake Skinner's north shore. Both *T. guatemalensis* O. P.-Cambridge and *T. versicolor* Walckeraer were taken within 250 m of the shoreline (Fig. 1 region D), while *T. pallescens* F. P.-Cambridge was found at a maximum distance of 600 m from shoreline (Fig. 1, region E). Levi (1981) reported *T. versicolor* as one of two *Tetragnatha* species occurring furthest away from water. Given the hot and dry summer conditions of inland southern California, it was not surprising to find this species so close to water (Fig. 1, region D). The *T. pallescens* female found furthest from water was collected from a gentle north facing hillslope. During July and August, literally hundreds of *T. guatemalensis* webs were spun every evening between the stems of dead mustard plants along a service road, less than 100 m from the N shoreline (Fig. 1, region D). Males and females, in copula, were observed at night in the female webs throughout July and early August. By day, only traces of the webs were seen, the inhabitants almost invisibly stretched out against the mustard stems. *Larinia directa* (Hentz) and *Neoscona* (primarily juveniles) webs were commonly interspersed among the tetragnathid webs during these months.

Although relatively few adults of the araneid species, *Metepeira crassipes* Chamberlin & Ivie and *M. grandiosa grandiosa* Chamberlin & Ivie, were collected in samples, both species are very common at SRCMR, particularly on the north side of Lake Skinner (Fig. 1, regions D, E). Observational evidence suggests that these congeners prefer to construct their webs in CSS in areas where the canopy cover is patchy and in vegetation types that provide natural spaces within the shrub itself for web construction. *Eriogonum fasciculatum* (California buckwheat) appeared to be, by far, the most commonly used CSS shrub (refer to Levi 1977), generally occupied by *M. grandiosa grandiosa* in the spring and by *M. crassipes* in the fall. Secondary web sites observed include dead mustard (where dense) and *S. mellifera* (black sage). Of the major CSS shrub components, *A. californica* (California sage) appeared to be the least frequently used (contra natural history reported by Levi (1977)).

Ant Predators: On various occasions in the spring of 1999, two gnaphosid species and one theridiid species were observed attacking and feeding on ants at MCBCP. A penultimate *Callilepis gosoga* male was observed attacking a harvester ant worker (*Pogonomyrmex subnitidus* Emery) approximately 3 m from the harvester mound. While still in its penultimate instar, the *C. gosoga* male was provided a second species of harvester ant, *Messor andrei* (Mayr) which it attacked and fed on. The European congeneric species, *Callilepis nocturna* (L.), is a known ant specialist (Heller 1974, 1976; in Foelix 1982).

The male of the gnaphosid species, *Gnaphosa californica* Banks, was observed attacking a worker formicine (*Formica francoeuri* Bolton) in a fashion similar to that of a wolf spider attacking large prey. In such an attack, the prey is bitten and simultaneously wrapped with all eight legs of the spider.

The theridiid species, *Steatoda fulva* (Keyserling) is known to feed on harvester ants (Hölldobler 1970). This species was not collected during the course of either this or the Diegan study but was subsequently collected at MCBCP. A penultimate male was observed in the process of wrapping a struggling harvester ant (*Pogonomyrmex subnitidus*) within its web in a depression on the ant mound.

CONCLUSIONS

Species diversity within the majority of taxonomic levels examined was greater in Diegan CSS than in Riversidian CSS, especially within the Theridiidae, Gnaphosidae, and Salticidae. This, we believe, is largely due to the coastal climate, which produces both more summertime moisture and moderate temperatures than the corresponding inland areas and promotes the growth of a wider variety of shrub species. For example, several of the theridiid species sampled in coastal Diegan CSS are known primarily from coastal localities and/or inland canyons. Such species include *Dipoena atopa* (Chamberlin), *D. prona* (Menge), *Thymoites expulsus* (Gertsch & Mulaik), *Theridion punctipes* Emerton, and *Wamba crispulus* Simon (*Theridion intervallatum* Emerton, synonym). The relatively flat topography of SRCMR and absence of deep canyons, as well as dry summertime conditions, may preclude the establishment of the species. Similarly, gnaphosids such as *Callilepis eremella* Chamberlin, *Drassyllus conformans* Chamberlin, *D. saphes* Chamberlin, and *Zelotes gabriel* Platnick & Shadab are generally known from more mesic localities than those found at SRCMR. These species were collected in coastal Diegan CSS but were not found during this study.

Both the greater number of non-native species (especially cosmopolitan species) and the relatively greater density, per non-native species, in Diegan versus Riversidian samples, suggest that the coastal conditions provide a more hospitable environment than the inland lowlands do for species that desiccate easily. We also found proportionately greater percentages of both new species records and undescribed species for San Diego County (17% and 9.5%, respectively) than for Riverside County (11% and 6.5%, respectively). These records likely reflect a combination of both species immigration and inadequate sampling in the past. Assuming that these variables are approximately equal in both CSS systems, the proportionally greater percentages for San Diego County suggest that the Diegan climate is more conducive to habitation by less adaptable forms than the more extreme Riversidian climate. Proportionately fewer species can tolerate the xeric summertime conditions and seasonal temperature extremes of the inland Riversidian system.

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LITERATURE CITED

Anderson, S. 1994. Area and Endemism. Quart. Rev. Biol., 69: 451–471.

Axelrod, D. I. 1978. The origin of coastal sage vegetation, Alta and Baja, California. Amer. Jour. Bot., 65: 1117–1131.

Buffington, M. L. & R. A. Redak. 1998. A comparison of vacuum sampling versus sweep-netting for arthropod bio-diversity measurements in California coastal sage scrub. Jour. Insect Cons., 2: 99–106.

Chamberlin, R. V. & W. J. Gertsch. 1958. The spider family Dictynidae in America north of Mexico. Bull. Am. Mus. Nat. Hist., 116: 1–152.

Chamberlin, R. V. & W. Ivie. 1942. A hundred new species of American spiders. Bull. Univ. Utah, 32: 1–117.

Crosby, C. R. & S. C. Bishop. 1928. Revision of the spider genera *Erigone, Eperigone,* and *Catabrithorax* (Erigoneae). Bull. New York State Mus., 278: 3–74.

Dekeer, R. & J.-P. Maelfait. 1987. Life histories of *Oedothorax fuscus* (Blackwall, 1834) (Araneae, Linyphiidae) in a heavily grazed pasture. Rev. Biol. Sol., 24: 171–185.

DeSimone, S. A. 1995. California's coastal sage scrub. Fremontia, 24: 3–8.

DeSimone, S. A. & J. H. Burk. 1992. Local variation in floristics and distributional factors in Californian coastal sage scrub. Madroño, 39: 170–188.

Dondale, C. D. 1977. Life histories and distribution patterns of hunting spiders (Araneida) in an Ontario meadow. J. Arachnol., 4: 73–93.

Dondale, C. D. & J. H. Redner. 1978. Revision of the nearctic wolf spider genus *Schizocosa* (Araneida: Lycosidae). Can. Entomol., 110: 143–181.

Dondale, C. D., A. L. Turnbull, & J. H. Redner. 1964. Revision of the nearctic species of *Thanatus* C. L. Koch (Araneae: Thomisidae). Can. Entomol., 96: 636–656.

Draney, M. L. 1997. Ground-layer spiders (Araneae) of a Georgia piedmont floodplain agroecosystem: species list, phenology and habitat selection. J. Arachnol., 25: 333–351.

Edwards, G. B. 1979. Pantropical jumping spiders occurring in Florida (Araneae: Salticidae). Florida Department of Agriculture and Consumer Services, Entomology Circular No. 100.

Foelix, R. F. 1982. Biology of spiders. Harvard University Press. 306 pp.

Gertsch, W. J. 1958. The spider family Plectreuridae. Am. Mus. Novit., 1920: 1–53.

Gotelli, N. J. & G. L. Entsminger. 1999. EcoSim: Null models software for ecology. Version 4.0. Acquired Intelligence Inc. & Kesey-Bear. (+ website).

Hagstrum, D. W. 1970. Ecological energetics of the spider *Tarentula kochi* (Araneae: Lycosidae). Ann. Entomol. Soc. Am., 63: 1297–1304.

Heller, G. 1974. Zur biologie der ameisenfressenden spinnen *Callilepis nocturna* L., 1758 (Aranea, Drassodidae). Diss., Mainz, 1974.

Heller, G. 1976. Zum Beutefangverhalten der ameisenfressenden Spinne *Callilepis nocturna* (Arachnida: Araneae: Drassodidae). Ent. Germ., 3: 13.

Hölldobler, B. 1970. *Steatoda fulva* (Theridiidae), a spider that feeds on harvester ants. Psyche, 77: 202–208.

Kirkpatrick, J. B. & C. F. Hutchinson. 1977. The community composition of Californian coastal sage scrub. Vegetatio, 35: 21–33.

Levi, H. W. 1957. The spider genera *Crustulina* and *Steatoda* in North America, Central America, and the West Indes (Araneae, Theridiidae). Bull. Mus. Comp. Zool., 117: 367–424.

Levi, H. W. 1977. The orb-weaver genera *Metepeira, Kaira,* and *Aculepeira* in America north of Mexico (Araneae: Araneidae). Bull. Mus. Comp. Zool., 148: 185–238.

Levi, H. W. 1981. The American orb-weaver genera *Dolichognatha* and *Tetragnatha* north of Mexico (Araneae: Araneidae, Tetragnathinae). Bull. Mus. Comp. Zool., 149: 271–318.

Millidge, A. F. 1980. The Erigonine spiders of North America. Part 2. The genus *Spirembolus* Chamberlin (Araneae: Linyphiidae). J. Arachnol., 8: 109–158.

Platnick, N. I. 1975. A revision of the holarctic genus *Callilepis* (Araneae, Gnaphosidae). Am. Mus. Novit., 2573: 1–32.

Platnick, N. I. 1989. Advances in spider taxonomy 1981–1987: a supplement to Brignoli's A catalogue of the Araneae described between 1940 and 1981. Manchester University Press.

Platnick, N. I. 1993. Advances in spider taxonomy 1988–1991, with synonymies and transfers 1940–1980. N. Y. Entomol. Soc. in association with Am. Mus. Nat. Hist.

Platnick, N. I. 1995. A revision of the spider genus *Orthonops* (Araneae, Caponiidae). Am. Mus. Novit., 3150: 1–18.

Platnick, N. I. 1997. Advances in spider taxonomy 1992–1995 with redescriptions 1940–1980. N. Y. Entomol. Soc. in association with Am. Mus. Nat. Hist.

Platnick, N. I. & T. R. Prentice. 1999. A new species of the spider genus *Zelotes* (Araneae, Gnaphosidae) from California. J. Arachnol., 27: 672–674.

Platnick, N. I. & M. U. Shadab. 1975. A revision of the spider genera *Haplodrassus* and *Orodrassus* (Araneae, Gnaphosidae). Am. Mus. Novit., 2583: 1–40.

Platnick, N. I. & M. U. Shadab. 1980. A revision of the North American spider genera *Nodocion, Litopyllus,* and *Synaphosus* (Araneae, Gnaphosidae). Am. Mus. Novit., 2691: 1–26.

Platnick, N. I. & M. U. Shadab. 1982. A revision of the American spiders of the genus *Drassyllus* (Araneae, Gnaphosidae). Bull. Am. Mus. Nat. Hist., 173: 1–97.

Platnick, N. I. & M. U. Shadab. 1983. A revision of the American spiders of the genus *Zelotes* (Araneae, Gnaphosidae). Bull. Am. Mus. Nat. Hist., 174: 97–192.

Platnick, N. I. & M. U. Shadab. 1988. A revision of the American spiders of the genus *Micaria* (Araneae, Gnaphosidae). Am. Mus. Novit., 2916: 1–64.

Porter, A. H. & E. M. Jakob. 1990. Allozyme variation in the introduced spider *Holocnemus pluchei* (Araneae, Pholcidae) in California. J. Arachnol., 18: 313–319.

Prentice, T. R. 1997. Theraphosidae of the Mojave Desert west and north of the Colorado River (Araneae, Mygalomorphae, Theraphosidae). J. Arachnol., 25: 137–176.

Prentice, T. R., J. C. Burger, W. R. Icenogle & R. A. Redak. 1998. Spiders from Diegan coastal sage scrub (Arachnida: Araneae). Pan-Pac. Entomol., 74: 181–202.

Schenkel, V. W. 1950. Spinnentiere aus dem westlichen Nordamerika. Verh. Naturf. Ges. Basel, 61: 28–92.

Schick, R. X. 1965. The crab spiders of California. (Araneida, Thomisidae). Bull. Am. Mus. Nat. Hist., 129: 1–180.

Stratton, G. E. & D. C. Lowrie. 1984. Courtship behavior and life cycle of the wolf spider *Schizocosa mccooki* (Araneae, Lycosidae). J. Arachnol., 12: 223–228.

Westman, W. E. 1981. Factors influencing the distribution of species of California coastal sage scrub. Ecology, 62: 439–455.

Westman, W. E. 1983. Xeric Mediterranean-type shrubland associations of Alta and Baja California and the community/continuum debate. Vegetatio, 52: 3–19.

Yeargan, K. V. & C. D. Dondale. 1974. The spider fauna of alfalfa fields in northern California. Ann. Ent. Soc. Am., 67: 861–862.

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Scientific Note

A NEW AND UNUSUAL HOST RECORD FOR *HEMICOELUS GIBBICOLLIS* (LECONTE) (COLEOPTERA: ANOBIIDAE)

Hemicoelus gibbicollis (LeConte), referred to as the California deathwatch beetle (Linsley, E. G. 1943. Pests and Their Control, 11: 11–14, 23–26.; Ebeling W. 1975. Urban Entomology, pp. 128–216, Univ. Calif. Div. Agric. Sci., Los Angeles, California; Kramer R. D. 1997. Wood-Boring Beetles. In: Mallis, A. Handbook of Pest Control, Mallis Handbook and Training Company [8th ed.]. pp. 357–391.), is the most economically significant anobiid infesting structures along the Pacific Coast of North America (Suomi, D. A. & R. D. Akre. 1992. J. Econ. Entomol., 85: 1188–1193.). In nature, *H. gibbicollis* larvae feed on a wide range of softwoods and hardwoods (Knutson, L. V. 1963. Proc. Entomol. Soc. Wash., 65: 177–195; see attached Host List). In a recent survey of structures in the Pacific Northwest, Suomi and Akre (1992) (J. Entomol. Soc. Brit. Columbia, 89: 63–70.) found that the primary wood species infested by *H. gibbicollis* was Douglas-fir, *Pseudotsuga menziesii* (Mirbel) Franco, followed by western redcedar, *Thuja plicata* Donn ex D. Don, and western hemlock, *Tsuga heterophylla* (Rafinesque) Sargent. The high frequency of occurrence in *P. menziesii* probably reflects this wood's extensive use in home construction.

On 21 Nov. 1990, I inspected a home in San Francisco where the homeowner had reported a beetle infestation of the joists and subflooring. During my inspection I noticed that the basement was extremely damp with standing water in peripheral floor gutters. There were numerous emergence holes in the wooden substructure of the home with pelleted frass in the galleries. This type of damage in the San Francisco Bay Area is characteristic of colonization by *H. gibbicollis.* The homeowner explained that vernal springs occurred in this area of the city near the Presidio and this water contributed to the consistently high moisture in the basement area. As evidence of the high population density of the insect, the homeowner showed me the heavily infested wooden housing of an old television set that had been kept in the basement (wood species unknown). I also noticed a stand of bamboo that shaded the basement entry and further exacerbated the high moisture conditions in the basement. Examination of the bamboo culms (stalks) revealed many circular emergence holes, some of which contained dead anobiid adults. The culms contained numerous frass-packed galleries indicative of larval feeding and development. The fecal pellets were characteristic of *H. gibbicollis* and dead adults removed from the bamboo were identified as *H. gibbicollis.* Species-level identification of bamboo is not possible from the culms, but anatomical analysis of the infested bamboo revealed that it was a species in a leptomorphic (Type I) genus such as *Arundinaria, Phyllostachys, Fargesia, Sasa,* or *Pseudosasa,* all of which are temperate climate bamboos (Liese, W. L. 1995. European Bamboo Soc. Journal, May 6th, pp. 5–12).

Bamboo is frequently noted as a host for true powderpost beetles (Lyctidae) (because the bamboo has a large pore size required for oviposition or because it

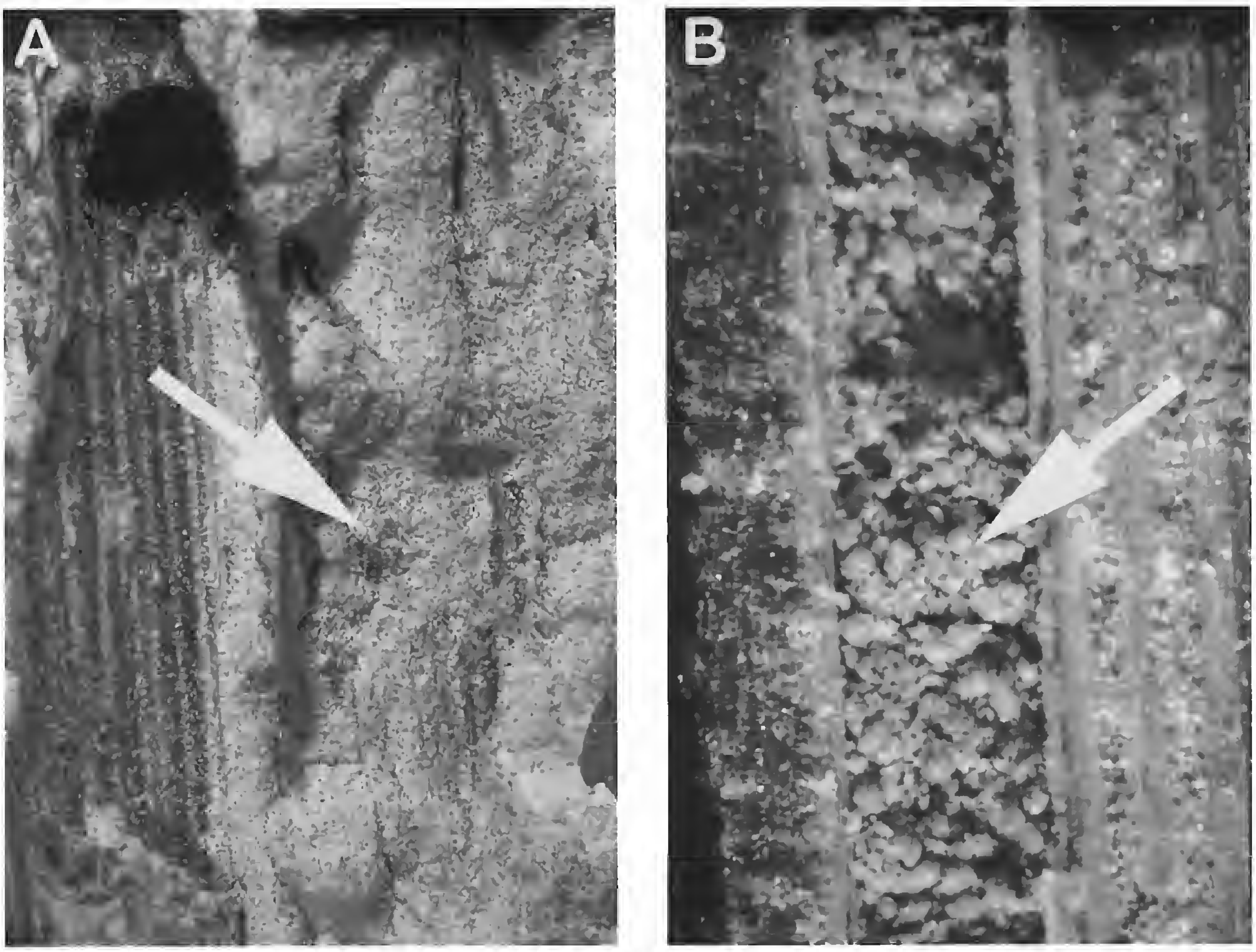

Figure 1. Feeding damage to bamboo by (A) Lyctidae and (B) *Hemicoelus gibbicollis* (Anobiidae). Arrows indicate the finely grained or flour-like frass produced by the lyctid and the pelleted frass produced by the anobiid.

has a high starch content) and for false powderpost beetles (Bostrichidae) (because of their abundance in the tropics where many bamboo products are derived) (Ebeling 1975, Kramer 1997). Compared with lyctid-infested bamboo, which has a finely grained or flour-like frass (Fig. 1A), *H. gibbicollis*-infested bamboo has galleries packed with pelleted frass (Fig. 1B). A review of the literature indicates that bamboo has never been reported before as a host for *H. gibbicollis.* It is likely, in this instance, that the population density of *H. gibbicollis* was so high in and around the structure that the beetles attacked this uncommon host. Additionally, *H. gibbicollis* is known to develop optimally when wood moisture content is between 14% and 17% (Suomi, D. A. & R. D. Akre. 1993. Pan-Pac. Entomol., 69: 221–235.), which may be typical for sub areas and basements in coastal northern California. Presumably, the high level of moisture in the wood in the basement and in wood in the surrounding area contributed to colonization of the bamboo as well.

Host List for Hemicoelus gibbicollis

Alder [*Alnus* spp.][4]
Red alder [*Alnus rubra* Bong.][7]
Blueblossom [*Ceanothus thyrsiflorus* Eschsh.][7]
Cherry [*Prunus* spp.][4]

Bitter cherry [*Prunus emarginata* (Dougl.) Walp.][3,6,7]
Wild prune [*Prunus subcordata* Benth.][1]
California hazel [*Corylus californica* (A. DC.) Sharp][7]
Douglas-fir [*Pseudotsuga menziesii* (Mirbel) Franco][2,4,7]
Fir [*Abies* spp.][4]
White fir [*Abies concolor* (Gordon & Glendinning) Hildebrand][7]
Grand fir [*Abies grandis* (Dougl. ex D. Don) Lindl.][7]
Hemlock, Western [*Tsuga heterophylla* (Raf.) Sarg.][4,7]
Maple [*Acer* spp.][1,4]
Bigleaf maple [*Acer macrophyllum* Pursh][3,6,7]
Oak [*Quercus* spp.][4]
Interior live oak [*Quercus wislizensii* A. DC.][7]
Redcedar, Western [*Thuja plicata* Donn ex D. Don][8]
Redwood [*Sequoia sempervirens* (D. Don) Endl.][4,6]
Spruce [*Picea* spp.][4,5]
Willow [*Salix* spp.][4]
Pacific or black willow [*Salix lasiandra* Benth.][7]
Yew, Pacific [*Taxus brevifolia* Nutt.][7]

Record.—USA. CALIFORNIA. SAN FRANCISCO CO.: ~2 km E. Mountain Lake (in Presidio), Baker Street, San Francisco, 21 Nov 1990, S. J. Seybold, *Bamboo.*

Acknowledgment.—I thank P. Klausen (University of Minnesota) for helping to process the specimens of *H. gibbicollis*; D. L. Wood (University of California at Berkeley) and B. J. Cabrera (University of Minnesota) for critical reviews of earlier drafts of this report; Prof. Dr. W. Liese (Universität Hamburg) for indentification of bamboo; and D. Blackford for assistance with photography. Manuscript preparation was supported by a grant from the California Department of Consumer Affairs, Structural Pest Control Board awarded to V. R. Lewis (University of California at Berkeley) and SJS. Specimens of *H. gibbicollis* recovered from bamboo were confirmed by Dr. R. E. White (USNM, retired) and deposited in the California Academy of Sciences Entomology Collection, Golden Gate Park, San Francisco, California 94118.

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[1] Chamberlain, W. J. 1960. Insects Affecting Forest Products and Other Materials. Oregon State College Coop. Assoc., Corvallis. 159 pp.

[2] Ebeling, W. 1975. Urban Entomology. Univ. Calif. Div. Agric. Sci., Los Angeles, California

[3] Furniss, R. L. 1938. Proc. Entomol. Soc. Brit. Columbia, 35: 5–8.

[4] Furniss, R. L. & Carolin, V. M. 1992. Western Forest Insects, USDA For. Serv. Misc. Publ. No. 1339.

[5] Hatch, M. H. 1946. J. Econ. Entomol., 39: 274.

[6] Keen, F. P. 1952. Insect Enemies of Western Forests, USDA Misc. Publ. No. 273

[7] Knutson, L. V. 1963. Proc. Entomol. Soc. Wash., 65: 177–195.

[8] Suomi, D. A. & Akre, R. D. 1992. J. Entomol. Soc. Brit. Columbia, 89: 63–70.

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Scientific Note

MALFUNCTION OF ELECTRICAL EQUIPMENT CAUSED BY *SOLENOPSIS AUREA* WHEELER (HYMENOPTERA: FORMICIDAE)

Fire ants of the genus *Solenopsis,* especially *S. invicta* Buren and *S. xyloni* McCook, attack and destroy the efficacy of electrical equipment (Mackay, W., S. Majdi, S. B. Vinson & C. Messer. 1990. Effects of the fire ant, *Solenopsis invicta,* on electrical equipment. pp. 496–503. *In* Applied Myrmecology, A World Perspective, R. Vandermeer, K. Jaffe & A. Cedeno (eds.). Westview Press; Mackay, W., D. Sparks & S. B. Vinson. 1990. Pan-Pac. Entomol., 66: 174–175). Although ants appear to be attracted to electrical fields generated by such equipment (Mackay, W., S. Majdi, J. Irving, S. B. Vinson & C. Messer. 1992. J. Kans. Entomol. Soc., 65: 39–43; Mackay, W., S. B. Vinson, J. Irving, S. Majdi & C. Messer. 1992. Environ. Entomol., 21: 866–870), this may not occur (Slowik, T., H. Thorvilson & B. Green. 1996. J. Econ. Entomol., 89: 347–352). Control of these pests in electrical equipment can often be relatively easy (Mackay, W., S. B. Vinson, J. Irving, S. Majdi & C. Messer. 1991. Sociobiology, 19: 309–322).

We here describe damage caused by a third species of fire ant, the native *S. aurea* Wheeler. This species infests intrusion monitors (or vibration sensors) in Big Bend National Park, Texas. The ants were able to penetrate the O-ring on the periphery of the monitor box, and gain access to the electronic sensors. Once in the box, they become wedged in the electronic system and act as conductors of false signals. The large numbers of ants in the systems cause malfunction of the equipment and must be removed by technicians. The system, made by Spartan Technology (Model No. 4411-PT) is powered by four 6-volt batteries and the electronics are controlled by sets of dipswitches. The solution to this problem appears to be the use of hard rubber O-rings. None of the older devices, with hard rings, placed in the same general areas were infested. It is not clear what attracts the ants, but it is suspected it is the electrical system of the unit. The unit does not vibrate, it only senses the vibration.

Acknowledgment.—Our research was supported by Science and Resource Management, Big Bend National Park, by the Fire Ant Initiative of the Texas Department of Agriculture, and by the Department of Biological Sciences of the University of Texas.

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PAN-PACIFIC ENTOMOLOGIST
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See volume 74: 248–255, October 1997, 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.

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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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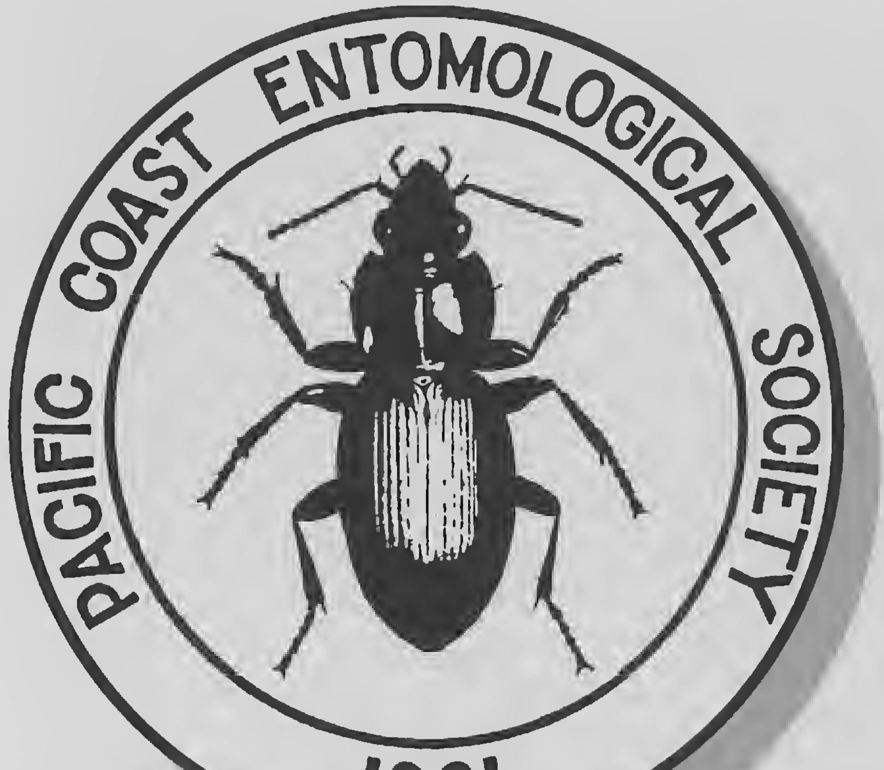

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STUDIES IN THE EUPHORIINA OF THE AMERICAS (COLEOPTERA: SCARABAEIDAE)
II. STATUS OF NAMES IN *EUPHORIA,* TYPES AND SYNONYMIES, WITH NOTES ON THE SOUTH AMERICAN SPECIES[1]

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Abstract.—The nomenclature of taxa used in the genus *Euphoria* is reviewed, and numerous synonymies, based upon an examination of the available type material and approximately 20,000 specimens are proposed. Notes upon the types examined are presented, and lectotypes designated where necessary. A listing of the 125 names and variant spellings is presented, along with their current taxonomic status. Three entities are currently unrecognizable or unplacable.

Comments upon the six recorded South American species are presented with their synonymies. Relevant literature is cited.

Key Words.—Coleoptera, Scarabaeidae, Cetoniinae, Euphoriina, *Euphoria,* nomenclature, types, lectotypes.

Material used in this study was borrowed from numerous institutions and individuals (*see* Part I). Most of this has been recently returned, with labels reflecting the taxonomic arrangement presented below. This paper is presented in order to permit understanding of the changes proposed. In addition to the taxa listed below, there are an additional half-dozen species yet to be described. The geminata species group is very confused and much more material is needed for a satisfactory resolution of the numerous problems encountered. There are probably a number of unrecognized, undescribed species included in the material examined from this group, but the range of variability within all species couldn't be determined with the material at hand. The conclusions presented below are based on an evaluation of material as was considered adequate to indicate morphological variability in the species involved.

The species groups proposed below are tentative, pending further analysis, but serve to group species sharing morphological characters, although the variable nature of the group makes definition difficult in some cases.

Literature citations given below are not comprehensive; only those dealing with synonymies or nomenclatorial changes are cited with a few exceptions.

An attempt was made to locate and examine all primary types. Where types were not located or examined, it has been so noted. No attempt was made to examine types of infrasubspecific taxa.

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[1] Part I, Introduction and Generic Concepts, appeared in The Coleopterist's Bulletin, 42(1): 1–9, 1988.

EUPHORIA
FULGIDA GROUP
EUPHORIA FULGIDA FULGIDA

Cetonia fulgida Fabricius 1775: 48
Type locality "Carolina." Type in British Museum [not seen].
Erirhipis fulgida; Burmeister 1842: 393.
Euphoria fulgida; Horn 1880: 405.
Scarabaeus turchesinus Voet 1778: 8. Type locality not given. Type lost ? NEW SYNONYMY.

EUPHORIA FULGIDA LIMBALIS, NEW COMBINATION

Euphoria limbalis Fall 1905: 273. Type locality Enterprize, Florida. Type in MCZ [seen].

EUPHORIA FULGIDA FUSCOCYANEA

Euphoria (*Erirhipis*) *fuscocyanea* Casey 1915: 303. Type locality "Texas." Type in USNM [seen].
E. fulgida fuscocyanea; Brown 1930: 5.

EUPHORIA FULGIDA HOLOCHLORIS, NEW COMBINATION

Euphoria holochloris Fall 1905: 273. Type locality Fort Huachuca, Arizona. Type in MCZ; Lectotype here designated: male, with the following labels: Ft. Huachuca Ariz. [printed]/ holochloris TYPE [printed and handwritten]/ M.C.Z. Type 24876 [printed and handwritten, red]/ Lectotype Euphoria holochloris Fall 1905 By A. R. Hardy 1977 [handwritten, red].
E. (*Erirhipis*) *holochloris*] Casey 1915: 302

EUPHORIA SEPULCRALIS

Cetonia sepulcralis Fabricius 1801: 156. Type locality "Carolina." Type in Kiel [not seen].
Euphoria sepulcralis; Burmeister 1842: 376.
Euphoria (*Euphoria*) *sepulchralis* [sic]; Casey 1915: 321.
Cetonia lurida Olivier 1789: 43 [nec Fabricius]; 1790: 422.
Euphoria lurida; Schaum 1849: 266 [placement of Olivier's concept as *sepulcralis*].
Cetonia reich Gory & Percheron 1833: 58, 210. Type locality "Mexique." Type female in Geneva [seen].
Cetonia reichii; Burmeister 1842: 376 [as synonym of *sepulcralis*]; Bates 1889: 364 [as synonym of *leucographa*]; Casey 1915: 321 [as synonym of *sepulcralis*].
Euphoria (*Euphoria*) *sepulchralis crinitula* Casey 1915: 321. Type locality "Southern Illinois at St. Louis, Missouri." Type in USNM [seen]. NEW SYNONYMY.
Euphoria (*Euphoria*) *sepulchralis cuprascens* Casey 1915: 322. Type locality "Kansas (Medora)." Type in USNM [seen]. NEW SYNONYMY.
Euphoria (*Euphoria*) *sepulchralis floridana* Casey 1915: 321. Type locality "Florida (East coast, from Jacksonville to Palm Beach)." Type in USNM. Lectotype

here designated; male, with the following labels: 1) Jackson/ville Florida [handwritten] 2) CASEY/bequest/1925 [printed] 3) TYPE USNM/48677 [Printed, handwritten, red] 4) floridana/Csy [handwritten] 5) LECTOTYPE/Euphoria/sepulcralis/floridana Csy./By A. R. Hardy '78 [handwritten, red]. 14 paralectotypes. NEW SYNONYMY.

Euphoria (*Euphoria*) *sepulchralis kansana* Casey 1915: 321. Type locality Manhattan and Muncie, Kansas. Type in USNM. Lectotype here designated; male, with the following labels: 1) Manhattan/Ks [printed] 2) CASEY/bequest/1925 [printed] 3) kansana-3/PARATYPE USNM/48675 [printed, handwritten, red] 4) LECTOTYPE/Euphoria/sepulcralis/kansana Csy./By A. R. Hardy 1978 [handwritten, red]. 15 paralectotypes. NEW SYNONYMY.

Euphoria (*Euphoria*) *appalachia* Casey 1915: 322. Type locality Maryland to northern Alabama. Type in USNM. Lectotype here designated; male with the following labels: 1) Southern Pines/V-NC/A. H. Manee 09 [handwritten, printed] 2) CASEY/bequest/1925 [printed] 3) appalachia-2/PARATYPE USNM/ 48679 [handwritten, printed, red] 4) LECTOTYPE/ Euphoria/ appalachia/ By A. R. Hardy/ 1978 [handwritten, red]. 6 paralectotypes. NEW SYNONYMY.

Euphoria (*Euphoria*) *scolopacea* Casey 1915: 322. Type locality North Carolina to Florida. Type in USNM. Lectotype here designated; male with the following labels: 1) Black/ Mts. North Carolina/ [handwritten] 2) CASEY/ bequest/ 1925 [Printed] 3) TYPE USNM/ 48680 [printed, handwritten, red] 4) scolopacea/ Csy [handwritten] 5) LECTOTYPE/ Euphoria/ scolopacea/ CASEY=By/ A. R. Hardy [handwritten, red]. 25 paralectotypes. NEW SYNONYMY.

Euphoria (*Euphoria*) *oxysternum* Casey 1915: 323. Type locality Indiana. Type female in USNM. NEW SYNONYMY.

EUPHORIA SEPULCRALIS NITENS, NEW COMBINATION

Euphoria (*Euphoria*) *nitens* Casey 1915: 320. Type locality "Texas." Type in USNM. Lectotype here designated: male with the following labels: 1) melancholica/ Gory [handwritten, folded] 2) CASEY/ bequest/ 1925 [printed] 3) TYPE USNM/ 48683 [printed, handwritten, red] 4) nitens/ Csy [handwritten] 5) Euphoria/ nitens/ Casey [handwritten] 6) LECTOTYPE/ Euphoria/ nitens Csy./ By A. R. Hardy 1978 [handwritten, red]. (Casey identified three males and seven females as being in the type series. There are currently 14 specimens labelled as *nitens* in the Casey material at the USNM. One male specimen is of the dark color form formerly known as *E. kerni texana,* and so is here excluded from further consideration. Of the remaining 13, there are three males and 10 females. The three males (specimens numbered 1, 11, and 13) will be considered as part of the original cotypical series. The first specimen in the series is without a data label, but bears the label "melancholica Gory", and appears to be in Casey's hand. The remaining 10 (females) are all indistinguishable as to which were a part of the original series, and all have the label "Tex." For this reason, only the two remaining males were labeled as paralectotypes.

EUPHORIA SEPULCRALIS LEUCOGRAPHA, NEW COMBINATION

Cetonia leucographa Gory & Percheron 1833: 58, 208. Type locality "Mexico." Type in Paris? [Dejean colln., Oberthur colln.? Not seen.]

Euphoria leucographa; Burmeister 1842: 375.

Euphoria (*Erirhipis*) *leucographa*; Casey 1915: 305.

Euphoria limatula Janson 1881: 585. Type locality Guatemala. Type male in Leiden [seen]. NEW SYNONYMY.

Euphoria yucateca Bates 1889: 365. Type locality "Mexico, Temax in N. Yucatan." Type in BMNH. Lectotype here designated: male with the following labels: 1) SYN-/TYPE [white disc with blue edge, printed 2) Temax,/ N. Yucatan,/ Gaumer [printed] 3) B.C.A., Col., II(2)./ Euphoria/ yucateca [printed] 4) LECTOTYPE/ Euphoria/ yucateca/ Bates=By/ A. R. Hardy [handwritten, red]. 8 paralectotypes. NEW SYNONYMY.

Euphoria submetallica Casey 1915: 319. Type locality "Panama (Nata)." Type in USNM [seen]. NEW SYNONYMY.

EUPHORIA SEPULCRALIS RUFINA, NEW COMBINATION

Cetonia rufina Gory & Percheron 1833: 58, 206. Type locality "Mexico." Type in Dupont Collection (part of the Obertheur Collection), Paris Museum [seen].

Euphoria rufina; Burmeister 1842: 375.

Euphoria leucographa var. *rufina*; Bates 1889: 364.

Euphoria (*Erirhipis*) *rufina*; Casey 1915: 306.

Euphoria (*Erirhipis*) *testacea* Casey 1915: 305. Type locality "New Mexico and Arizona (Baboquivari, Santa Rita and Huachuca Mts.)." Type in USNM. Lectotype here designated; male specimen with the following labels: 1) Huachuca Mts./ July 1905 Ariz [printed]; 2) CASEY/ bequest/ 1925 [printed]; 3) testacea-2/ PARATYPE USNM/ 48668 [printed, handwritten, red]; 4) Lectotype/ Euphoria/ testacea Csy/ By A. R. Hardy 1978 [handwritten, red]. 7 paralectotypes. NEW SYNONYMY.

Euphoria subtomentosa var. *histrionella* Schaeffer 1907: 74 [nomen nudum].

EUPHORIA FASCIFERA FASCIFERA

Euryomia fascifera Leconte 1861: 336. Type locality "Cape San Lucas." Type male in MCZ [seen].

Euphoria fascifera; Horn 1880: 398, 404.

Euphoria (*Euphoria*) *fascifera*; Casey 1915: 324, 325.

EUPHORIA FASCIFERA TRAPEZIUM

Euphoria (*Euphoria*) *fascifera trapezium* Casey 1915: 324. Type locality "Arizona (Cochise Co.)." Type in USNM. Lectotype here designated; male with the following labels: 1) San Bernardino/ Ranch 3750 ft. [printed]; 2) CASEY/ bequest/ 1925 [printed]; 3) TYPE USNM/ 48684 [printed, handwritten, red]; 4) trapezium/ Csy [handwritten]; 5) LECTOTYPE/ Euphoria/ trapezium/ Casey=By/ A. R. Hardy '78 [handwritten, red]. 2 paralectotypes.

EUPHORIA CANDEZEI

Euphoria candezei Janson 1875: 375. Type locality "Central America; Guatemala; San Domingo, Chontales, Nicaragua." Type male in Leiden [seen].

Euphoria belti Sharp 1877: 137. Type locality "Chontales, Nicaragua." Type in BMNH. Lectotype here designated: male specimen with the following labels: 1) SYN- / TYPE [blue edged disc, printed]; 2) Chontales/ Nicaragua/ T. Belt [printed]; 3) Euphoria/ Belti/ Ind. typ./ D.S. [handwritten]; 4) B.C.A., Col.,II(2)./ Euphoria/ candezei [inverted, printed]; 5) LECTOTYPE/ Euphoria/ belti/ Sharp=By/ A. R. Hardy '78 [handwritten, red]. 2 paralectotypes.

HERBACEA GROUP

EUPHORIA LESUEURI

Cetonia Lesueur Gory & Percheron 1833: 58, 212. Type locality "Mexique." Type female[?] in Geneva [seen].

Euphoria Lesueuri; Burmeister 1842: 372.

Euphoria lesueuri; Schenkling 1921: 340.

Cetonia Latreille Gory & Percheron 1833: 58, 213. Type locality "Mexique." Type male in Geneva [seen].

Euphoria Latreillii; Burmeister 1842: 373.

Cetonia notulata Gory & Percheron 1833: 91, 244. Type locality "Mexique." Type male[?] in Leiden [seen].

EUPHORIA STEINHEILI

Euphoria Steinheili Janson 1878: 303. Type locality "Panama." Type male in Leiden [seen].

Euphoria steinheili; Bates 1889: 364.

EUPHORIA MONTICOLA

Euphoria monticola Bates 1889: 415; Schoch 1897: 474. Type locality "Mexico, Canelas in Sia. Madre de Durango." Type female in Paris.

EUPHORIA WESTERMANNI

Cetonia Westermann Gory & Percheron 1833: 212. Type locality "Mexico." Type female[?] in Geneva [seen].

Euphoria Westermanni; Burmeister 1842: 373.

Euphoria westermanni; Bates 1889: 363.

EUPHORIA HERBACEA

Cetonia herbacea Olivier 1789: 35; Burmeister 1842: 393 [in the treatment of *Erirhipis*] Type locality 'l'Amerique septentrionale." Type in Geneva? [not seen].

Euphoria herbacea; Horn 1880: 399, 406.

Cetonia antennata Gory & Percheron 1833: 56, 177; Burmeister 1842: 391 [synonymy with *pubera*]. Type locality "Philadelphie." Type female in Geneva [seen].

Cetonia pubera Gyllenhal in Schoenherr 1817: 138, 53. Type locality "America septentrionali." Type in Uppsala [not seen].

Erirhipis pubera; Burmeister 1842: 391; Schaum 1844: 375 [synonymy with *herbacea*]; Horn 1880: 408 [synonym of *herbacea*].

Erirhipis (*Euphoria*) *herbacea* var. *occidentalis* Knaus 1916: 84. Type locality "Crawford Co. and Cherokee Co., Kansas." Type in Lawrence Kansas [not seen]. NEW SYNONYMY.

EUPHORIA SUBMACULOSA

Cetonia submaculosa Gory & Percheron 1833: 58, 211. Type locality "Mexico." Type female in Geneva [seen].
Erirhipis submaculosa; Burmeister 1842: 392.
Euphoria submaculosa; Bates 1889: 369; Schoch 1895: 125.
Euphoria (*Erirhipis*) *submaculosa*; Casey 1915: 304.

EUPHORIA HUMILIS

Euphoria humilis Blanchard 1850: 13. Type locality "Mexico." Type female in Paris [seen].

EUPHORIA IRIDESCENS

Cetonia iridescens Schaum 1841: 45. Type locality "Guatemala." Type female in Geneva [seen].
Erirhipis iridescens; Burmeister 1842: 388.
Euphoria iridescens; Bates 1889: 368.

EUPHORIA MYSTICA

Euphoria mystica Thomson 1878: 27. Type locality "Mexico." Type male in Paris [seen].
segmentata Guerin [in litt., ms. name?]

EUPHORIA CHONTALENSIS

Euphoria chontalensis Bates 1889: 368. Type locality "Nicaragua, Chontales." Type in BMNH. Lectotype here designated: specimen with the following labels: 1) SYN-/ TYPE [blue edged disc, press printed]; 2) Chontales/ Nicaragua/ T. Belt. [press]; 3) B.C.A., Col., II(2)./ Euphoria/ chontalensis, Bates [handwritten, printed]; 4) LECTOTYPE/ Euphoria/ chontalensis/ Bates=By/ A.R. Hardy '78 [handwritten, red]. 1 paralectotype [evidently 3 other specimens scattered].

EUPHORIA PRECARIA

Euphoria precaria Janson 1881: 583. Type locality "New Grenada" [Colombia]. Type male in Leiden [seen].
Euphoria morosa Janson 1881: 582. Type locality "Quito, Ecuador." Type male in Leiden [seen]. NEW SYNONYMY. [Under the first revisor rule (Recommendation 24A) page priority can be suspended in cases where improved stability would result. As first revisor, I select *precaria* as the valid name, since it was used in the Biologia Centrali-Americana, and *morosa* has not been used since it was originally described.]
Euphoria (*Erirhipis*) *comminuta* Casey 1915: 307. Type locality "Chiriqui" [Panama]. Type female in USNM [seen].

INDA GROUP

EUPHORIA INDA

Scarabaeus indus Linnaeus 1760: 352. Type locality "India." Type in Uppsala [fide Landin 1956: 12; not seen].
Trichius indus; Fabricius 1775: 40.
Cetonia inda; Pallas 1781: 25.

Erirhipis inda; Burmeister 1842: 389.

Euphoria inda; Horn 1880: 399, 407.

Euphoria Erirhipis inda; Casey 1915: 308.

Cetonia barbata Say 1823: 239; Burmeister 1842: 389 [under *Erirhipis inda*; new synonymy?]. Type locality "Council Bluffs on the Missouri and on the Arkansas." Type probably destroyed.

Cetonia brunnea Gory & Percheron 1833: 63, 267; Burmeister 1842: 389 [under *Erirhipis inda*; new synonymy?]. Type locality "l'Amerique boreale." Type not located. [There is a male specimen in Geneva which has been suggested as the possible type. The label reads: Inda Linne var./ Amer. Bor./ W. Murray [handwritten]. Horn & Kahle list a W. Murray Coleoptera and Lepidoptera collection from an individual who died in 1885. Since Gory & Percheron was published 52 years before this date, it is conceivable, although not likely, that this specimen was in europe prior to 1833. There is no evidence of correspondence with J. LeConte, a contemporary, so it further seems unlikely that W. Murray was very active.]

Cetonia marilandica von Frölich 1792: 116; Burmeister 1842: 389 [under *Erirhipis inda*; new synonymy?]. Type locality unknown to me. Type in Munich? [not seen].

Euphoria inda var. *nigripennis* Klages 1894: 198. Type locality "Pittsburgh, Pa." Type in Cornell [not seen]. NEW SYNONYMY.

Euphoria (*Erirhipidia*) *inda nigripennis*; Casey 1915: 309.

Euphoria (*Erirhipidia*) *rufobrunnea* Casey 1915: 309. Type locality "New Mexico (fort wingate), Arizona, Colorado (Boulder Co.) and Washington State." Type in USNM. Lectotype here designated: specimen with the following labels: 1) Ft. Wingate/ N. Mex. [printed]; 2) CASEY/ bequest/ 1925 [printed]; 3) rufobrunnea 20/ Paratype USNM/ 48674 [handwritten, printed; red]; 4) Lectotype/ Euphoria/ rufobrunnea Csy/ By A.R./ Hardy 1978 [handwritten, red]. 19 paralectotypes. NEW SYNONYMY.

EUPHORIA HIRTIPES

Euphoria hirtipes Horn 1880: 398, 401. Type locality "Dodge co., Neb." Type in MCZ. Lectotype here designated: female[?] specimen with the following labels: 1) Dodge Co. Nebr. [printed]; 2) Type no. 3708 Euphoria hirtipes G. H. Horn [handwritten, printed; red]; 3) E. hirtipes Horn [handwritten, inverted; appears to be Horn's hand]; 4) Lectotype Euphoria hirtipes Horn 1880 by A. R. Hardy 1977 [handwritten, red] [This specimen seems, on the basis of measurements, to be the male as described by Horn]. 1 paralectotype.

Euphoriaspis hirtipes; Casey 1915: 298, 333.

EUPHORIA BASALIS

Cetonia basalis Gory & Percheron 1833: 64, 274. Type locality "Mexique." Type male in Geneva [seen].

Euphoria basalis; Burmeister 1842: 380.

Euphoria (*Euphoria*) *basalis*; Casey 1915: 324, 325.

Euphoria (*Euphoria*) *basalis crinicauda*; Casey 1915: 324, 325. Type locality "Mexico (Guerrero)." Type in USNM. Lectotype here designated: male with the following labels: 1) Guer. [printed]; 2) CASEY/ bequest/ 1925 [printed]; 3) crinicauda-4/ PARATYPE USNM/ 48685 [printed, red]; 4) LECTOTYPE/ Euphoria/ basalis/ crinicauda Csy./ By A. R. Hardy '78 [handwritten, red].

HISTRIONICA GROUP

EUPHORIA HISTRIONICA

Euphoria histrionica Thomson 1878: 27. Type locality "Mexico." Type male in Paris [seen].

Euphoria (*Euphorhipis*) *histrionica*; Casey 1915: 315.

Euphoria histrionica var. *sonorae* Bates 1889: 374. Type locality "Sonora." Type in BMNH [? not seen]. NEW SYNONYMY.

Euphoria sonorae; Casey 1915: 315.

Euphoria (*Euphorhipis*) *scabiosa* Casey 1915: 316. Type locality "Arizona (Southern)." Type in USNM. Lectotype here designated: female with the following labels: 1) Ariz. [printed]; 2) CASEY/ bequest/ 1925 [printed]; 3) TYPE USNM/ 48673 [handwritten, printed, red]; 4) scabiosa/ Csy [handwritten]; 5) Euphoria/ scabiosa/ Casey [handwritten]; 6) LECTOTYPE/ Euphoria/ scabiosa Csy./ By A. R. Hardy 1978 [handwritten, red]. 1 paralectotype. NEW SYNONYMY.

EUPHORIA SUBTOMENTOSA

Cetonia tomentosa Steven [nomen nudum]. Mannerheim indicates that *Cetonia tomentosa* Steven was never named by Steven, the name was given by Sturm, which is how Dejean carries it (1837: 192). Because of homonomy with *Cetonia tomentosa* Klug (= *Anoplochilus tomentosus*), Dejean cites the name as *subtomentosa* Hope for replacement. This name evidently was never validated, and *subtomentosa* should be credited to Dejean, not Mannerheim (see below).

Cetonia tomentosa Sturm [nomen nudum].

Cetonia tomentosa Gory & Percheron 1833: 64, 278 [preoccupied; nec Klug; see Gory & Percheron 1833: 63, 139, 266]. Type locality "Mexique." Type female[?] in Geneva [seen].

Cetonia subtomentosa Hope [nomen nudum?].

Cetonia subtomentosa Dejean 1837: 192 [replacement for *tomentosa* Sturm, = *tomentosa* Gory & Percheron].

Erirhipis subtomentosa; Burmeister 1842: 390.

Euphoria subtomentosa; Bates 1889: 373, 416.

EUPHORIA DEVULSA

Euphoria devulsa Horn 1880: 398, 402. Type locality "San Antonio, Texas." Type in MCZ. Lectotype here designated: male specimen with the following labels: 1) Tex. [printed]; 2) Type No. 3709 Euphoria devulsa G. H. Horn [handwritten, printed, red]; 3) E. devulsa Horn [inverted, handwritten; Horn's hand?]; 4) Lectotype Euphoria devulsa Horn 1880 By A. R. Hardy 1977 [handwritten, red]. No paralectotypes seen.

Euphoria (*Isorhipina*) *devulsa*; Casey 1915: 331, 332.

EUPHORIA LINEOLIGERA

Euphoria lineoligera Blanchard 1850: 13. Type locality "Mexico." Type in Paris [seen].

Euphoria (*Isorhipina*) *lineoligera* "Bates"; Casey 1915: 330.

Euphoria lineogera; Schoch 1895: 124 [error].

Euphoria xanthomelas Thomson 1878: 26. Type locality "Mexico." Type in Paris [seen].

EUPHORIA BIGUTTATA

Cetonia Bi-Guttata Gory & Percheron 1833: 64, 274. Type locality "Mexique." Type female in Geneva [seen].

Euphoria biguttata; Burmeister 1842: 384.

Euphoria (*Isorhipina*) *biguttata*; Casey 1915: 329.

Euphoria (*Isorhipina*) *biguttata binoculata* Casey 1915: 330. Type locality "Mexico (Guerrero)." Type in USNM. Lectotype here designated: male [?] with the following labels: 1) Guer. [printed]; 2) CASEY/ bequest/ 1925 [printed]; 3) TYPE USNM/ 48686 [handwritten, printed, red]; 4) binoculata/ Csy [handwritten]; 5) LECTOTYPE/ Euphoria/ biguttata/ binoculata/ CASEY=by/ A.R. Hardy '78 [handwritten, red]. 2 paralectotypes. NEW SYNONYMY.

Euphoria (*Isorhipina*) *biguttata biplagiata* Casey 1915: 330. Type locality "Guatemala." Type in USNM. Lectotype here designated: male[?] with the following labels: 1) G.T. [handwritten]; 2) CASEY/ bequest/ 1925 [printed]; 3) biplagiata-2/ PARATYPA USNM/ 48687 [handwritten, printed, red]; 4) LECTOTYPE/ Euphoria/ biguttata/ biplagiata/ CASEY=By/ A.R. Hardy '78 [handwritten, red]. 2 paralectotypes. NEW SYNONYMY.

EUPHORIA CANESCENS

Cetonia canescens Gory & Percheron 1833: 64, 277. Type locality "Mexique." Type female[?] in Geneva [seen].

Euphoria canescens; Burmeister 1842: 383.

Euphoria (*Isorhipina*) *canescens*; Casey 1915: 336.

Euphoria (*Isorhipina*) *solidula* Casey 1915: 329. Type locality "Guatemala" [label on type reads: Nebaj, Quiche, Guatemala]. Type male in USNM [seen]. NEW SYNONYMY.

EUPHORIA LEUCOPYGE

Euphoria leucopyge Bates 1889: 366. Type locality "Mexico, S.L.P.; Alamos; Ventanas in Dgo." Type in BMNH. Lectotype here designated: specimen with the following labels: 1) SYN-/ TYPE [printed, blue edged disc]; 2) Type [printed, red edged disc, inverted]; 3) Hacienda de/ Bleados,/ S. Luis Potosi./ Dr. Palmer. [printed]; 4) Euphoria/ leucopyge/ Bates [handwritten]; 5) B.C.A., Col., II(2)./ Euphoria [printed, inverted]; 6) LECTOTYPE/ Euphoria/ leucopyge/ Bates=By/ A.R. Hardy '78 [handwritten, red]. 1 paralectotype.

Euphoria leucopyga; Schoch 1895: 125 [error].

EUPHORIA DIMIDIATA

Cetonia dimidiata Gory & Percheron 1833: 64, 275. Type locality "Mexique." Type male in Geneva [seen].

Euphoria dimidiata; Burmeister 1842: 380.

Euphoria (*Isorhipina*) *dimidiata*; Casey 1915: 331.

PULCHELLA GROUP

EUPHORIA PULCHELLA

Cetonia pulchella Gory & Percheron 1833: 64, 279. Type locality "Mexique." Type male in Geneva [seen].

Euphoria pulchella; Burmeister 1842: 381.

Euphoria pulchela; Schoch 1895: 123 [error].

Euphoria (*Isorhipina*) *pulchella*; Casey 1915: 327.

Cetonia ferrugata Gory & Percheron 1833: 64, 276. Type locality "Mexique." Type female[?] in Geneva [seen].

Cetonia montesuma Gory & Percheron 1833: 64, 277. Type locality "Mexique." Type from "Colln. Children" not located, presumed lost.

Cetonia montezuma; Burmeister 1842: 382.

Cetonia children Gory & Percheron 1833: 64, 275. Type locality "Mexique." Type from "Colln. Children" not located, presumed lost. NEW SYNONYMY.

Euphoria childrenii; Burmeister 1842: 382.

Euphoria childreni; Bates 1889: 416.

Euphoria (*Isorhipina*) *childreni*; Casey 1915: 328, 331.

Cetonia thelasco Gory & Percheron 1833: 64, 279. Type locality "Mexique." Type from "Colln. Children" not located, presumed lost. NEW SYNONYMY.

Euphoria (*Isorhipina*) *thelasco*; Casey 1915: 327.

EUPHORIA KERNI

Euphoria Cernii Haldeman 1852: 374. Type locality not given. Type male in MCZ [seen] [unnecessary emendation of patronomic "Kern"].

Euphoria kerni; Bates 1889: 374; Schoch 1895: 122.

Euphoria (*Haplophoria*) *kerni*; Casey 1915: 313.

Euphoria Clarkii LeConte 1853: 441. Type locality Texas. Type female in MCZ [seen]. NEW SYNONYMY.

Euphoria kerni var. *Clarkii*; Horn 1880: 402.

Euphoria texana Schaufuss 1863: 113. Type locality Texas [?]. Type location unknown to me.

Euphoria (*Haplophoria*) *texana*; Casey 1915: 313.

Euphoria kerni var. *texana*; Schenkling 1921: 339.

Euphoria (*Haplophoria*) *wichitana* Casey 1915: 312. Type locality "Kansas." Type female in USNM [seen]. NEW SYNONYMY.

Euphoria (*Haplophoria*) *retusa* Casey 1915: 311. Type locality "Mexico." Type male in USNM [seen]. NEW SYNONYMY.

Euphoria (*Haplophoria*) *connivens* Casey 1915: 312. Type locality "Texas & Arizona." Type in USNM. Lectotype here designated: male specimen with the following labels: 1) Tex [printed]; 2) CASEY/ bequest/ 1925 [printed]; 3) TYPE USNM/ 48671 [handwritten, printed, red]; 4) connivens/ Csy [handwritten]; 5) Euphoria/ connivens/ Casey [handwritten]; 6) LECTOTYPE/ Euphoria/ connivens Csy/ By A. R. Hardy 1978 [handwritten, red]. NEW SYNONYMY.

EUPHORIA DISCICOLLIS, NEW COMBINATION

Stephanucha discicollis Dejean 1837: 192 [nomen nudum].

Stephanucha discicollis Thomson 1878: 28. Type locality "Amer. bor." Type male[?] in Paris [seen].

Stephanucha atrata Dejean 1837: 192 [nomen nudum].

Stephanucha discicollis var. *atrata* Thomson 1878: 28. Type locality "Amer. bor." Type in Paris[?] [not seen]. NEW SYNONYMY.

Euphoria aestuosa Horn 1880: 398, 400. Type locality "Kansas." Type female in MCZ [seen]. NEW SYNONYMY.

Euphoria (*Haplophoria*) *aestuosa*; Casey 1915: 314.

Euphoriaspis aestuosa; Blackwelder 1939: 55.

GEMINATA GROUP

EUPHORIA GEMINATA

Cetonia geminata Chevrolat 1835: 107. Type locality "Tampico." Type male in Leiden [seen]. [There are two examples in the Leiden Museum from the Chevrolat material, one labelled "Vera Cruz," and the other "Tampico." The specimen labelled "Tampico" was considered to be the type.]

Erirhipis geminata; Burmeister 1842: 386.

Euphoria geminata; Bates 1889: 373.

Euphoria (*Rhipiphoria*) *geminata*; Casey 1915: 317.

Cetonia cheniaci Laporte; Burmeister 1842: 386. [Nomen nudum?]. Type locality and location of type not known to me.

EUPHORIA LEPROSA

Euphoria leprosa Burmeister 1842: 379. Type locality "Mexico." Type location unknown to me.

EUPHORIA EXIMA

Euphoria exima Bates 1889: 372. Type locality "Costa Rica." Type in BMNH. Lectotype here designated: male with the following labels: 1) SYN-/TYPE [printed, blue edged disc]; 2) Type [printed, red edged disc, inverted]; 3) Costa Rica [printed]; 4) Salle Coll [printed]; 5) 1340 [printed, green, inverted]; 6) Euphoria/ exima/ Bates [handwritten]; 7) B.C.A., Col., II(2)./ Euphoria [printed, inverted]; 8) LECTOTYPE/ Euphoria/ exima/ Bates=By/ A.R. Hardy '78 [handwritten, red]. The other specimen from the cotypical series not located.

EUPHORIA SCHOTTI

Cetonia vestita Gory & Percheron 1833: 63, 271 (nec Say 1825: 201). Type locality "Mexico" Dejean Collection, Oberthur collection, Paris [seen]. NEW SYNONYMY.

Erirhipis vestita; Burmeister 1842: 387.

Euphoria vestita; Bates 1889: 371.

Cetonia irregularis Gory & Percheron 1833: 63, 272 (nec Olivier 1789: 6, 51, 62). Type locality "Mexique." Type in Hope collection, Oxford [not seen]?

Euphoria schotti LeConte 1853: 441. Type locality "Eagle Pass." Type in MCZ. Lectotype here designated: male with the following labels 1) [red disc]; 2) schotti 3 [handwritten]; 3) Lectotype E. schotti LeC. by A.R. Hardy 1977. 2 paralectotypes.

Euphoria (*Erirhipidia*) *schotti*; Casey 1915: 309, 318.

EUPHORIA AVITA

Euphoria avita Janson 1881: 584. Type locality Guatemala. Type in Leiden Museum [seen].

Euphoria (*Haplophoria*) *longula* Casey 1915: 314. Type locality "Honduras (San Pedro Sula)." Type in USNM [seen]. NEW SYNONYMY.

EUPHORIA FULVEOLA

Euphoria fulveola Bates 1189: 370. Type locality "Mexico, Zacualtipan in Hidalgo, Oaxaca." Type in BMNH. Lectotype here designated, specimen with the following labels: 1) SYN-/TYPE [blue edged disc, press printed]; 2) Oaxaca,/ Mexico./ Hoege. [press printed]; 3) Euphoria/ fulveola/ Bates [handwritten]; 4) B.C.A., Col., II(2)./ Euphoria [press printed, inverted]; 5) LECTOTYPE/ Euphoria/fulveola/Bates=By/A.R. Hardy '78 [red, handwritten]. 2 paralectotypes.

Euphoria nigriventris Bates 1889: 371. Type locality "Mexico, Peras, Etla, Jalapa." Type in BMNH. Lectotype here designated: male with the following labels; 1) SYN /TYPE [blue edged disc, press printed]; 2) Jalapa,/ Mexico./ Hoege [press printed]. 3) B.C.A., Col., II(2)./ Euphoria/nigriventris/Bates [press printed, handwritten]; 4) LECTOTYPE/ Euphoria/nigriventris/Bates=By/A.R. Hardy '78 [red, handwritten]. 3 paralectotypes (4 missing). NEW SYNONYMY.

EUPHORIA QUADRICOLLIS

Euphoria quadricollis Bates 1889: 371. Type locality "Durango City." Type in BMNH. Lectotype here designated, male with the following labels: 1) SYN-/ TYPE [blue edged disc, press printed]; 2) Type [red-edged disc, press printed, inverted]; 3) Durango City/Mexico./Höge. [press printed]; 4) Euphoria/ quadricollis/ Bates ♂ [handwritten]; 5) B.C.A., Col., II(2)./ Euphoria [press printed, inverted]; 6) LECTOTYPE/ Euphoria/quadricollis/Bates=By/A.R. Hardy '78 [red, handwritten]. Second specimen may be lost.

Euphoria arizonica Schaeffer 1907: 15. Type locality "Huachuca Mts., Az." Type in USNM. Lectotype here designated, male with the following labels: 1) Type [red, press printed, genitalia glued on]; 2) Palmerly/Cochise Co./July. Ariz. [handwritten and press printed] 3) BROOKLYN/MUSEUM/COLL, 1929 [press printed]. 4) Catal. No. /1351 [handwritten and press printed]; 5) Cotype/No. 42588/ U.S.N.M. [red, press printed and handwritten]; 6) Euphoria/arizonica/ Schaef. [handwritten]; 7) LECTOTYPE/ Euphoria/arizonica Schf./By A.R. Hardy 1979 [red, handwritten]. NEW SYNONYMY.

EUPHORIA ATRA

Euphoria atra Bates 1889: 371. Type locality "Mexico, Peras, Oaxaca." Type in BMNH. Lectotype here designated, male with the following labels: 1) SYN-/ TYPE [blue edged disc, press printed]; 2) Oaxaca,/ Mexico/ Hoege. [press printed]; 3) B.C.A., Col., II(2)./Euphoria/atra, Bates [press printed and handwritten]; 6) LECTOTYPE/ Euphoria/atra/Bates=By/A.R. Hardy '78 [red, handwritten]. 1 paralectotype, one other BMNH specimen, believed to not be a part of the co-typical series, labelled "Oajaca" Mexico.

Euphoria casselberryi

Euphoria casselberryi Robinson 1937: 163. Type locality "Davis Mountains Texas." Type in USNM.

INCERTAE SEDIS
  subguttata Burmeister
  melancholica (Gory & Percheron) [= lurida or nitens?]
  segmentata Guerin [ms. name?]

South American Species

Of the six species of *Euphoria* (with recognized synonyms) recorded as restricted to South America, one was not present in the material examined (*E. trivittata* Nonfried), and is apparently known only from the type material. I felt that a comprehensive review of the South American fauna should await the accumulation of more material. Several of the species examined (*boliviensis* Blanchard; *lurida* Fabricius; *punicea* Janson), have not been verified by the examination of type material. Some species show close affinities to species treated here. *E. punicea,* as mentioned by Janson (1881: 584), is close to *steinheili,* and I believe may be a synonym of that species. *Euphoria boliviensis* is related to *subtomentosa,* and *lurida* to *sepulchralis*. *Euphoria acerba* Janson (type examined) is a valid species, resembling, as stated by the author, *E. leseuri* Gory & Percheron.

The South American species:
E. abreona Janson 1878: 304; Colombia
E. acerba Janson 1881: 582; Ecuador
E. boliviensis Blanchard 1850: 13; Bolivia
  andina Schein 1950: 273
E. lurida (Fabricius) 1775: 49; Brazil, Argentina
  adspersa (Weber 1801: 71)
  bivittata (Gory & Percheron 1833: 58, 207)
  fasciolata Eschscholtz 1822: 25
  rufescens (Gory & Percheron 1833: 68)
  sordens (Linnaeus 1790: 1573)
E. punicea Janson 1881: 584; Ecuador
E. trivittata Nonfried 1894: 130; Ecuador

Status of Names in Euphoriina

In the history of Euphoriina, there have been many names used in various genera. The following list is presented as an aid to placement of these names.

abronea Janson	valid- S. America
acerba Janson	valid- S. America
adspersa Weber	=*lurida* (in Blackwelder)
aestuosa Horn	=*discicollis* Thomson
andina Schein	=*boliviensis* (in Martinez 1957)
antennata Gory & Percheron	=*herbacea* (Leng)
appalachia Casey	=*sepulchralis sepulchralis*
areata Fabricius	*Stephanucha*
arizonica Schaeffer	=*quadricillis*

atra Bates	valid
avita Janson	valid
barbata Say	=*inda* (in Leng)
basalis Gory & Percheron	valid
belti Sharp	=*candezei*
biguttata Gory & Percheron	valid
binoculata Casey	=*biguttata*
biplagiata Casey	=*biguttata*
bispinis Bates	*Stephanucha*
bivittata Gory & Percheron	=*lurida*
boliviensis Blanchard	valid- S. America
brunnea Gory & Percheron	=*inda*
californica LeConte	=*Oxycetonia jucunda*
candezei Janson	valid
canescens Gory & Percheron	valid
casselberryi Robinson	valid
cerni Haldeman	=*kerni*
chapini Cartwright	*Chlorixanthe*
cheniaci Laporte	=*geminata* (in Casey)
childern Gory & Percheron	=*pulchella*
childreni Gory & Percheron	=*pulchella*
chontalensis Bates	valid
clarki LeConte	=*kerni*
comminuta Casey	=*precaria*
connivens Casey	=*kerni*
crinicauda Casey	=*basalis*
crinitula Casey	=*sepulchralis sepulchralis*
cuprascens Casey	=*sepulchralis sepulchralis*
devulsa Horn	valid
dimidiata Gory & Percheron	valid
discicollis Thomson	valid
exima Bates	valid
fascifera LeConte	valid
fasciolata Escholtz	=*lurida*
ferrugata Gory & Percheron	=*pulchella*
flavoviridis Thomson	*Chlorixanthe*
floridana Casey	=*sepulchralis sepulchralis*
fulgida Fabricius	valid
fulgida var. *schwarzi* AUTHOR	=*fulgida limbalis*
fulveola Bates	valid
fuscocyanea Casey	valid- ssp. *fulgida*
geminata Chevrolat	valid
hera Burmeister	*Euphoriopsis*
herbacea Olivier	valid
hirta Fabricius	=*Tropinota*
hirtella Linnaeus	=*Tropinota*
hirtipes Horn	valid
histrionella Schaeffer	=*sepulchralis rufina*

histrionica Thomson	valid
holochloris Fall	valid- ssp. *fulgida*
humilis Blanchard	valid
inda Linnaeus	valid
insignis Casey	=*Oxythyrea funesta*
iridescens Schaum	valid
irregularis Gory & Percheron	=*schotti*
kansana Casey	=*sepulchralis sepulchralis*
kerni Haldeman	valid
latreillei Gory & Percheron	=*leseuri*
leprosa Burmeister	valid
leseuri Gory & Percheron	valid
leucographa Gory & Percheron	valid- ssp *sepulchralis*
leucopyge Bates	valid
limatula Janson	=*sepulchralis leucographa*
limbalis Fall	valid- ssp. *fulgida*
lineoligera Blanchard	valid
longula Casey	=*avita*
lurida Fabricius	valid
lurida Olivier	=*sepulchralis sepulchralis*
marilandica von Frölich	=*inda*
melancholica Gory & Percheron	=*lurida* or *nitens*
montesuma Gory & Percheron	=*pulchella*
monticola Bates	valid
morosa Janson	=*precaria*
mystica Thomson	valid
nigripennis Klages	=*inda*
nigriventris Bates	=*fulveola*
nitens Casey	valid- ssp. *sepulchralis*
notulata Gory & Percheron	=*leseuri*
occidentalis Knaus	=*herbacea*
oxysternum Casey	=*sepulchralis sepulchralis*
pilipennis Kraatz	*Stephanucha*
precaria Janson	valid
pubera Gyllenhal	=*herbacea*
pulchella Gory & Percheron	valid
punicea Janson	valid- S. America
quadricollis Bates	valid
reichi Gory & Percheron	=*sepulchralis sepulchralis*
retusa Casey	=*kerni*
refescens Gory & Percheron	=*lurida*
rufina Gory & Percheron	valid- ssp. *sepulchralis*
rufobrunnea Casey	=*inda*
scabiosa Casey	=*histrionica*
schotti LeConte	valid
scolopacea Casey	=*sepulchralis sepulchralis*
sepulchralis Fabricius	valid
solidula Casey	=*canescens*

sonorae Bates	=*histrionica*
sordens Linnaeus	=*lurida*
steinheili Janson	valid
subguttata Burmeister	Incertae sedis
submaculosa Gory & Percheron	valid
submetallica Casey	=*sepulchralis leucographa*
subtomentosa Dejean	valid
testacea Casey	=*sepulchralis rufina*
texana Schauf [COMPLETE NAME]	=*kerni*
thelasco Gory & Percheron	=*pulchella*
thoracica Casey	*Stephanucha*
tomentosa mannerheim	=*subtomentosa*
trapezium Casey	valid- ssp. *fascifera*
trivittata Nonfried	valid- S. America
verticalis Horn	*Stephanucha*
vestita Gory & Percheron	=*schotti*
vestita Say	=*Tropinota hirta*
westermanni Gory & Percheron	valid
wichitana Casey	=*kerni*
xanthomelas Thomson	=*lineoligera*
yucateca Bates	=*sepulchralis leucographa*

LITERATURE CITED

Bates, H. W. 1889. *In* Biologia Centrali Americana, Insecta, Coleoptera, Dynastidae, Cetoniidae, suppl. Volume 2, Pt. 2. pp. 337–416, pls. xix–xxiv.

Blackwelder, R. E. 1939. Fourth supplement 1933 to 1938 (inclusive) to the Leng catalogue of Coleoptera of America, north of Mexico. Mount Vernon, New York.

Blackwelder, R. E. 1944. Checklist of the Coleopterous Insects of Mexico, Central America and the West Indies, and South America. Part 2. Bull. Smith. Inst., 185: 189–341.

Blanchard, C. É. 1850. Muséum d'Histoire Naturelle de Paris. Catalogue de la collection entomologique. Classe des insectes. Ordre des coléoptèes, 1: 1–128. Paris.

Brown. 1930. Studies in the Scarabaeidae (IV). Can. Entomol., 42: 2–6.

Burmeister, H. C. C. 1842. Handbuch der entomologie (Coleoptera Lamellicornia Melitophila). Volume 3, 826 pp. Berlin.

Casey, T. L. 1915. A review of the American species of Rutelinae, Dynastinae and Cetoniinae. Memoirs on the Coleoptera, 6: 1–394.

Chevrolat, L. A. A. 1835. Coléoptères de Mexique. [p. 107]. Strasbourg.

Dejean, P. F. M. A. 1837 (1836). Catalogue des coléoptèes de la collection de M. le compte Dejean. Troisième édition, revue, corrigée et augmentée, livr. 1–4: 1–468. Paris.

Eschscholtz, J. F. 1822. Entomographien, Erste Liefrung. 128 pp. Berlin.

Fabricius, J. C. 1775. Systema entomologiae. 30 + 832 pp. Lipsiae.

Fabricius, J. C. 1801. Systema eleutheratorum. 2. 687 pp. Kiliae.

Fall, H. C. 1905. New species of Coleoptera, chiefly from the southwest. Canad. Entomol., 37: 270–276.

von Frölich, J. A. 1792. Bermerkungen über einige seltene Käfer aus der Insecten-Sammlung des Hr. Rudolph in Erlangen. Naturforscher, 26: 68–165.

Gmelin, J. F. 1790. Linne's Systema Naturae . . . edit 13. 1: 1517–2224.

Gory, H. L. & A. R. Percheron. 1833. Monographie des cétoines et genres voisins, format, dans les familles naturelles de Latreille, la division des scarabées mélitophiles. 4 pp., 77 pls. Paris.

Gyllenhal, L. 1817. *In* Schönherr, Appendix ad synonymia insectorum. 1: 1–266.

Haldeman, S. S. 1852. Insects, *In* Stansbury, Exploration and survey of the valley of the Great Salt Lake of Utah . . . pp. 366–378. Washington.

Horn, G. H. 1880. Synopsis of the *Euphoriae* of the United States. Proc. Amer. Philos. Soc., XVIII: 397–408.

Janson, O. E. 1875. Descriptions of three new species of American Cetoniidae. Cist. Entomol., 1: 373–376.

Janson, O. E. 1878. Notices of new or little known Cetoniidae (no. 4). Cist. Entomol., 2: 299–304.

Janson, O. E. 1881. Descriptions of new American Cetoniidae. (Part II). Cist. Entomol., 2: 581–585.

Klages, E. A. 1894. Euphoria inda var. nigripennis. Entomol. News, 5: 198.

Knaus. 1916. A Kansas variety of Euphoria herbacea. Bull. Brooklyn Entomol. Soc., 11: 84.

Landin, B. O. 1956. The Linnean species of Lamellicornia described in "Systema Naturae," Ed. X (1758). (Col.). Entomol. Tidskr., 77: 1–17.

LeConte, J. L. 1853. Descriptions of some new Coleoptera from Texas, cheifly collected by the Mexican Boundary Commission. Proc. Acad. Nat. Sci. Philadelphia, 6: 439–448.

LeConte, J. L. 1861. Notes on the coleopterous fauna of Lower California. Proc. Acad. Nat. Sci. Philadelphia, 13: 335–338.

Linnaeus, C. 1760. Systema naturae . . . ed. 11. Volume 1, 823 pp. Halae Magdeburgicae.

Linnaeus, C. 1790. *See* Gmelin, 1790.

Nonfried, A. F. 1894. Beschreibungen neuer Lamellicorner, Buprestiden und Cerambyciden aus Central- und Süd-Amerika. Entomol. Nachrichten, 20: 129–142.

Olivier, A. G. 1789. Entomologie, ou histoire naturelle des insectes, avec leurscharactères génériques et spécifiques, leur description, leur synonymie, et leur figure enluminée. Coléoptères. Volume 1. [Genera separately paged]. Paris.

Pallas, P. S. 1781. Icones insectorum praesertim Russiae Sibiriaeque peculiarum, quae collegit et descriptionibus illustravit. 1: 1–56. Erlangae.

Robinson, M. 1937. A new Euphoria from Texas (Coleoptera: Scarabaeidae). Entomol. News, 48: 163.

Say, T. 1823. Descriptions of coleopterous insects collected in the late expedition to the Rocky Mountains, performed by order of Mr. Calhoun, Secretary of War, under the command of Major Long. Journ. Acad. Nat. Sci. Philadelphia, 3: 239–282.

Say, T. 1825. Descriptions of new species of coleopterous insects inhabiting the United States. Journ. Acad. Nat. Sci. Philadelphia, 5: 160–204.

Schaeffer, C. F. A. 1907. New Scarabaeidae. Journ. New York Entomol. Soc., 15: 60–75.

Schaufuss, L. W. 1863. Revision und Ergänzungen zu den von mir beschriebenen Käfer-arten I. Sitzungs-Berichte der Naturwissenschaftilichen Gessellschaft Isis zu Dresden. pp. 113–118.

Schaum, H. R. 1841. Analecta entomologica. Halis Saxonum.

Schaum, H. R. 1844. Observations critiques sur la famille des lamellicornes mélitophiles. Ann. Soc. Entomol. France, ser. 2 2: 333–426, illus.

Schaum, H. R. 1849. Observations critiques sur la famille des lamellicornes mélitophiles. (2e partie). Ann. Soc. Entomol. France, ser. 2 7: 241–295.

Schein, H. 1950. Neue Cetoniden (Col.). Entomol. Arbeiten aus dem Museum G. Frey, 1: 273–276.

Schenkling, S. 1921. Coleopterum catalogus, pars 72, Scarabaeidae: Cetoniinae, XXI: 1–431.

Schoch, G. 1895. Die Genera und Species meiner Cetonidensammlung. I. Teil: Trib. Goliathidae, Gymnetidae, Madagassae, Schizorrhinidae. pp. 1–148. Zurich.

Schoch, G. 1897. Nachtrag IV zu Schoch: Genera und Species meiner Cetoniden-Sammlung. Mitth. Schweizerischen Entomol. Ges., 9: 451–477.

Sharp, D. 1877. Description of some new species of beetles (Scarabaeidae) from Central America. Journ. Linn. Soc. Zool., 13: 129–138.

Thomson. 1878. Typi cetonidarum suivis de typi monommidarium et de typi nilionidarum musaei Thomsoniani. pp. 1–37, 3–4, 41–44. Paris.

Voet. 1778. Catalogus systematicus coleopterorum, Volume 2. La Haye.

Weber. 1801. Observations entomologicae, continentes novorum quae condidt generum characteres, et nuper detectarum specierum descriptiones. 116 pp. Kiliae.

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A NEW SPECIES OF *NOSERUS* (COLEOPTERA: ZOPHERIDAE) FROM MEXICO

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Abstract.—A new species of the family Zopheridae, *Noserus doyeni* García-París, Coca-Abia, and Parra-Olea, NEW SPECIES, is described from the State of Nuevo León in México. The species is characterized by the presence of a dense velvety cover of scaliform setae and by its smooth non-prominent elytral tuberculation. The range of the genus *Noserus* extends along two disjunct geographic areas. The first, which includes a group of poorly defined forms allied to *N. plicatus,* is restricted to the Pacific regions of California. The second group includes two species, *N. doyeni,* so far restricted to Cerro Potosí in the uplands of Nuevo León, and *N. emarginatus* from Texas. The external appearance of the three species of *Noserus* is strikingly diverse, and they may represent at least two independent phyletic lineages not necessarily sister to each other.

Key Words.—Insecta, Taxonomy, Coleoptera, Zopheridae, *Noserus doyeni* n. sp., North America, México.

Resumen.—Se describe una especie nueva de la familia Zopheridae, *Noserus doyeni* García-París, Coca-Abia, and Parra-Olea, SPECIES NOVA, del Estado de Nuevo León en México. La especie se caracteriza por el denso recubrimiento aterciopelado de sedas escamosas y por la poca prominencia de los tubérculos elitrales, que sobresalen poco o nada de la superficie elitral. Las especies del género *Noserus* se incluyen en dos grupos con distribución geográfica disjunta. El primer grupo incluye un conjunto de razas poco definidas relacionadas con *N. plicatus,* y se restringe a las regiones del Pacífico de California. En el segundo grupo se incluyen dos especies, *N. doyeni* hasta el momento exclusiva del Cerro Potosí en las montañas de Nuevo León, y *N. emarginatus* de Texas. El aspecto externo de las tres especies de *Noserus* es sorprendentemente diverso, de forma que el género podría incluir al menos dos linajes independientes, no necesariamente hermanos.

The family Zopheridae, first proposed by Böving & Craighead (1931) on the basis of larval characters, is currently integrated by two subfamilies, Usechinae and Zopherinae and a few Australian genera, *Docalis* Pascoe, *Cotulades* Pascoe, and *Latometus* Erichson, of difficult placement within either zopherid subfamily (Doyen & Lawrence 1979, Lawrence 1994, Lawrence & Newton 1995). The content and diagnosis of the zopherid subfamilies Usechinae and Zopherinae have suffered relatively few modifications since Gebien's World catalogues of Tenebrionidae (1910, 1937). Only the addition of new species, the transfer of *Exeniotis* Pascoe to the Tenebrionidae s. str., or the placement of some of Casey's (1907a, b) genera as junior synonyms of *Zopherus* Gray and *Nosoderma* Solier (Triplehorn 1972, Doyen & Lawrence 1979) are significant. The subfamily Zopherinae, a relatively homogeneous group on external appearance, includes 65 species distributed in 8 genera. Keys to genera of New World Zopheridae, and generic synonyms, have been provided by Doyen & Lawrence (1979), and the genus *Zopherus* has been comprehensively revised by Triplehorn (1972), but no other genera of Zopherinae have been critically revised.

The genus *Noserus* LeConte (1862), is characterized within the subfamily Zopherinae by having the two apical segments of the antennae fused, the inner surface of the femora of males with tuberosities, and by the presence of a shallow, but marked short hypomeral groove that does not completely contain the antennae while in repose (Doyen & Lawrence 1979). Until present, the genus included a group of poorly defined species closely related to *Noserus plicatus* (LeConte), 1859, restricted to California (Casey 1907a, b), and *Noserus emarginatus* Horn (1878), a well defined species known from Texas (USA) and Mexico (García-París et al. 2000).

Based on comparisons among specimens of the North American genera *Meralius, Noserus, Nosoderma, Phellopsis, Phloeodes,* and *Zopherus,* and a series of zopherine beetles collected at Cerro Potosí (Nuevo León, México), we believe the latter share more traits with *Noserus* than with any other genera of Zopheridae, including: (1) the presence of a short, shallow hypomeral groove that does not completely contain the antennae while in repose, (2) the two apical segments of the antennae fused, and (3) the presence of a narrow longitudinal area not covered by setae in the ventral mid-line of each tarsal segment, which appear to be grooved. These specimens do not match any known species of zopherine beetle and therefore we include their description in the following paragraphs.

Depository Abbreviations.—The following abbreviations are used to indicate deposition of specimens: CAS (California Academy of Sciences, San Francisco, USA), EM-UCB (Essig Museum of Entomology, University of California at Berkeley, USA), IB-UNAM (Instituto de Biología, Universidad Nacional Autónoma de México, México), MCZ (Museum of Comparative Zoology, Harvard University, Cambridge, USA), and MNCN (Museo Nacional de Ciencias Naturales, CSIC, Madrid, Spain).

Methodology.—Dry mounted specimens were used for descriptions and drawings. External sculpture and pubescence and dissected mouth parts were studied with Scanning Electron Microscopy (SEM). Preparations of male and female genitalia were obtained from alcohol preserved specimens. Aedeagus and median lobe were removed and studied at the dissecting microscope immersed in distilled water, and with SEM. Female genitalia and genital segment were cleared with a hot 5% KOH solution, progressively dehydrated in 70%, 90%, 95% and 100% ethanol, and mounted in Euparal for examination at the dissecting microscope. Drawings of the female genitalia were performed using camera-lucida.

NOSERUS DOYENI GARCÍA-PARÍS, COCA-ABIA & PARRA-OLEA NEW SPECIES

(Figs. 1–30)

Types.—Holotype: MEXICO: NUEVO LEÓN: Cerro Potosí, 2600–3200 m, 23 May 1996, M. García-París and G. Parra-Olea: IB-UNAM. Paratypes (36 specimens): 1–3: same data as holotype; 4: same data as holotype, except: MNCN; 5–33: same data as holotype, except: 10,300 ft., 25 Sep 1975, J. Powell, J. Chemsak, and T. Freilander: EM-UCB; 34–36: same data as holotype, except: 11,000 ft, Galeana, 5 Aug 1938, H. Hoogstraal: CAS.

Diagnosis.—Zopherine beetle distinguished by its smooth, non-prominent dorsal and lateral tuberculation, completely covered by dense scaliform setae. Posterior declivity of the elytra smooth, without tubercles. The two apical segments of the antennae are fused. A shallow but marked short hypomeral groove that does not completely contain the antennae while in repose is present on the ventro-

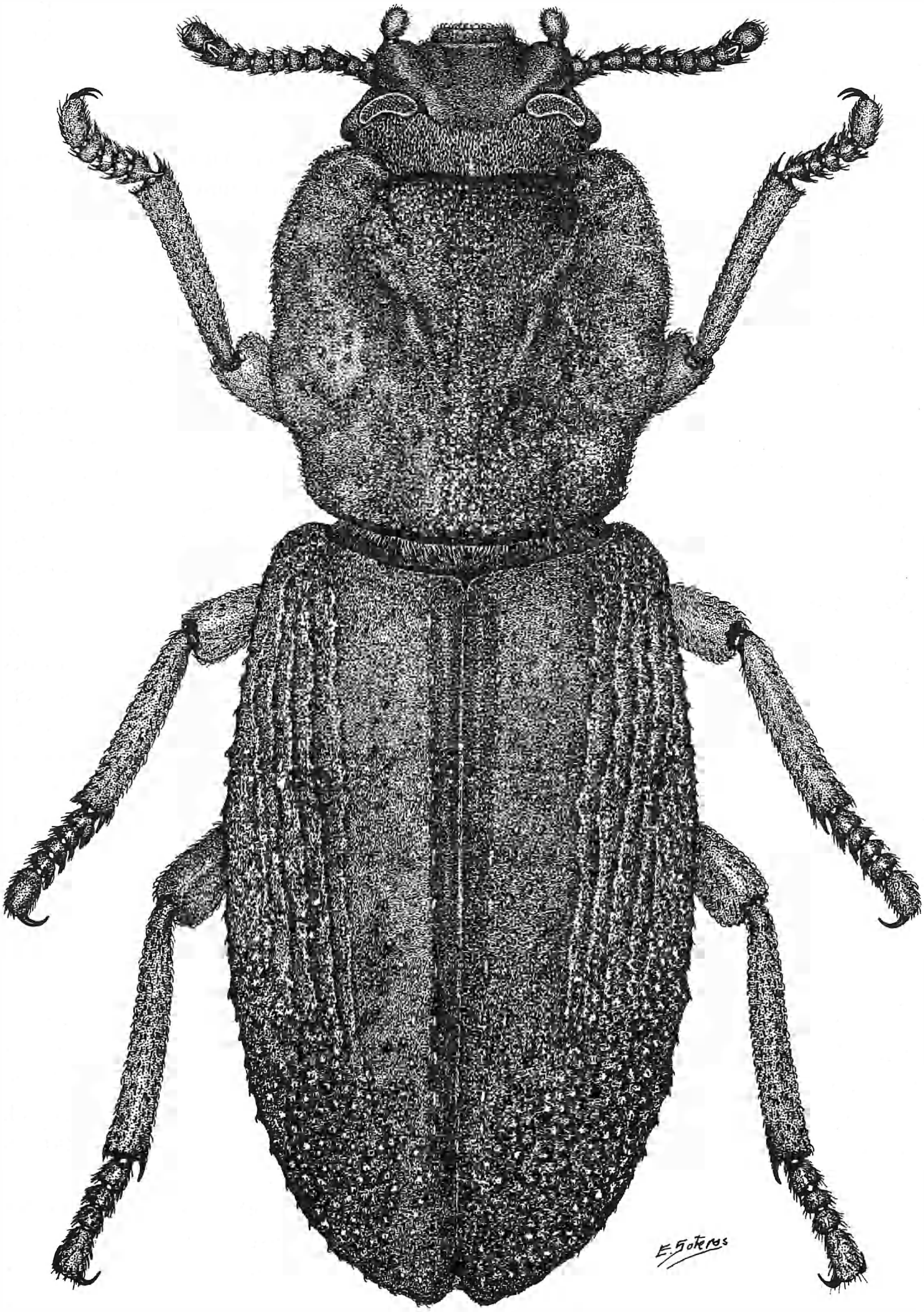
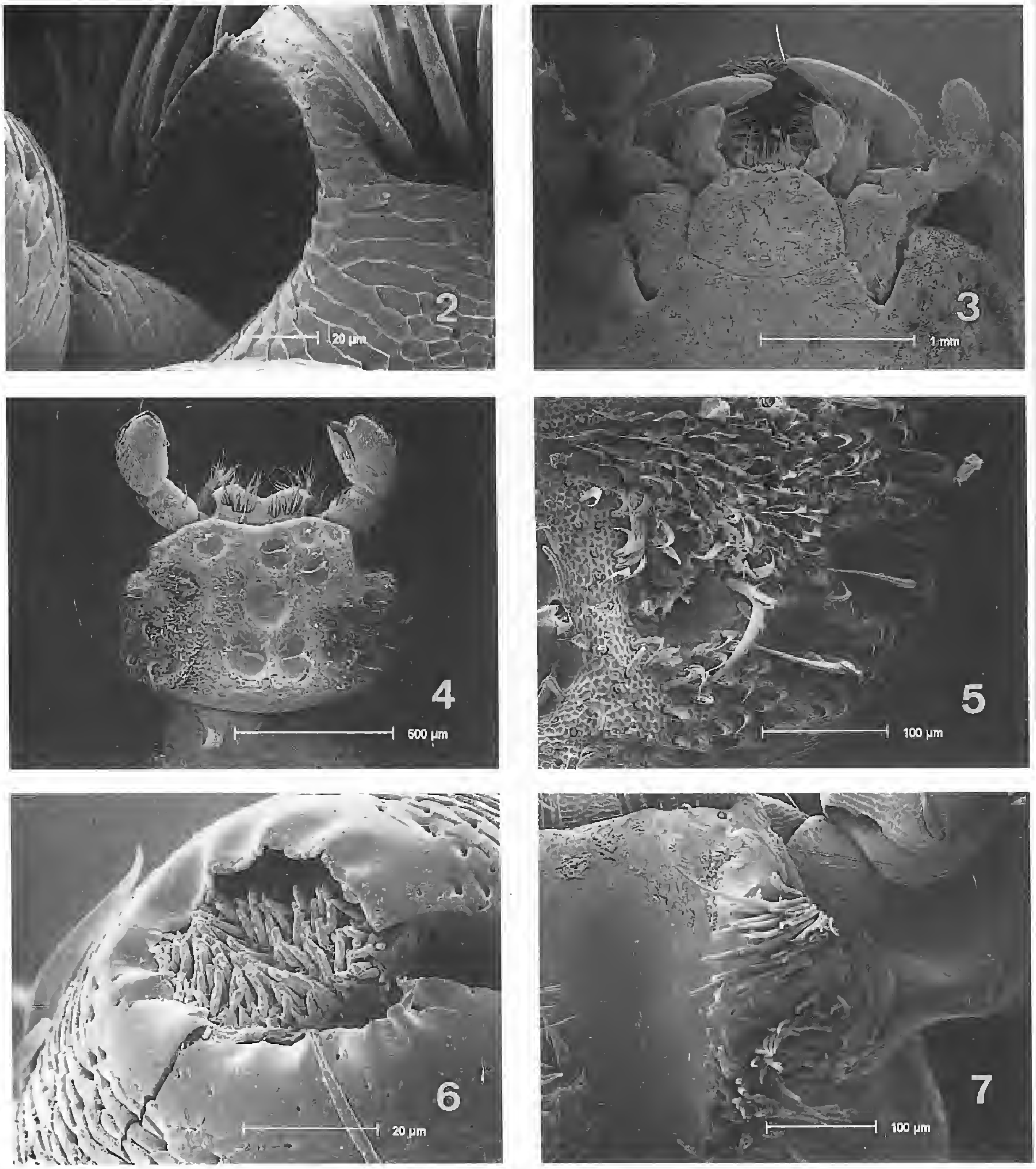


Figure 1. Habitus of *Noserus doyeni* sp. nov. from Cerro Potosí (Nuevo León, México).

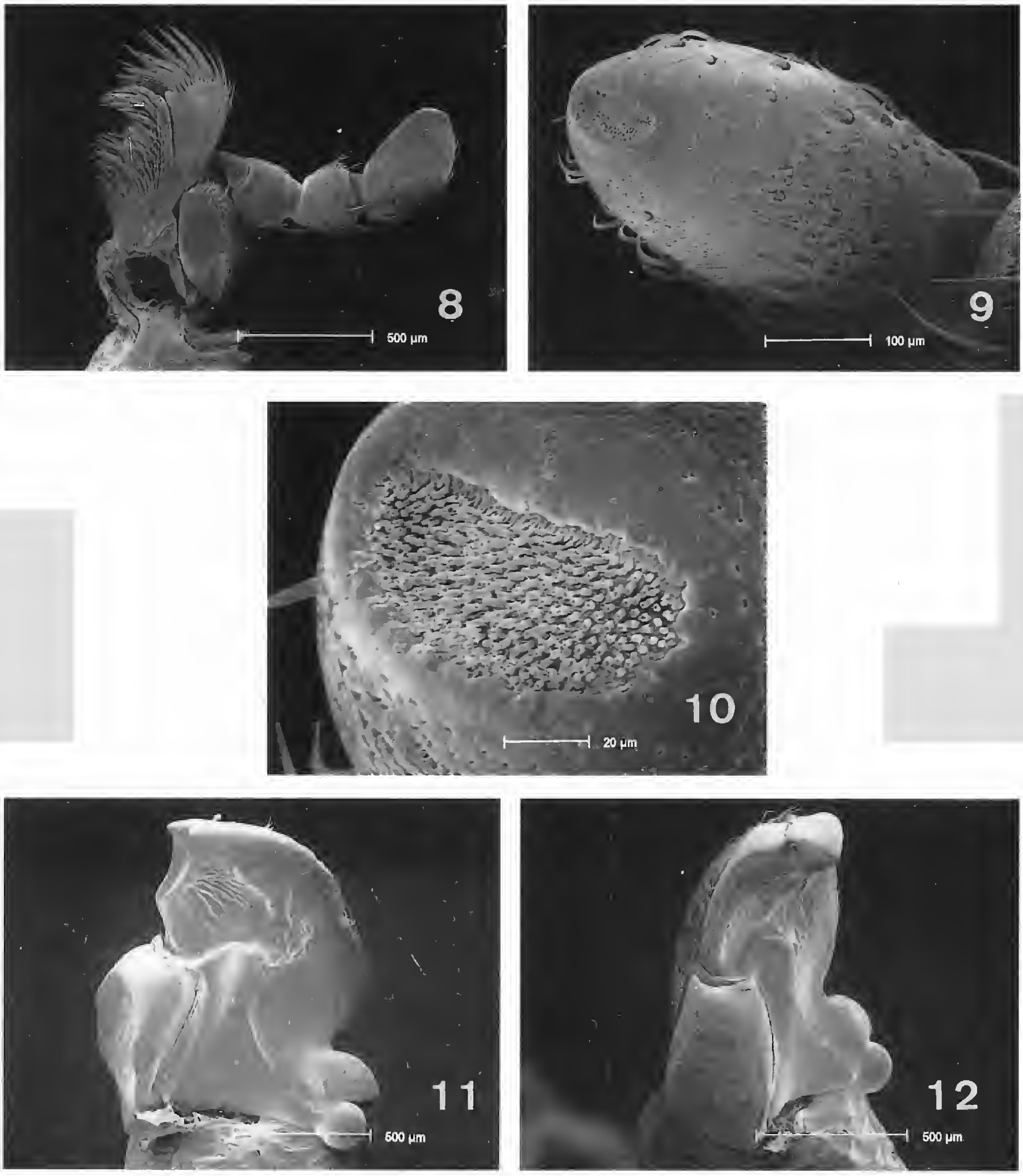


Figures 2–7. Cephalic and bucal morphology of *N. doyeni.* Figure 2. Detail of the tegument at the labial palp insertion region. Note the juxtaposed or slightly imbricate tegulae. Figure 3. Ventral view of the mouth region showing the gular v-shaped incisions which accommodate the maxillary basistipe. Figure 4. Ventral view of the mentum and labial palpi. Figure 5. Dense pubescence at the mental margins. Figure 6. Sensory organs at terminal opening of the labial palp. Figure 7. Dorsal pubescence at the insertions of the labial palp.

lateral surface of the pronotum. Posterolateral corners of the pronotum smoothly rounded, not angular.

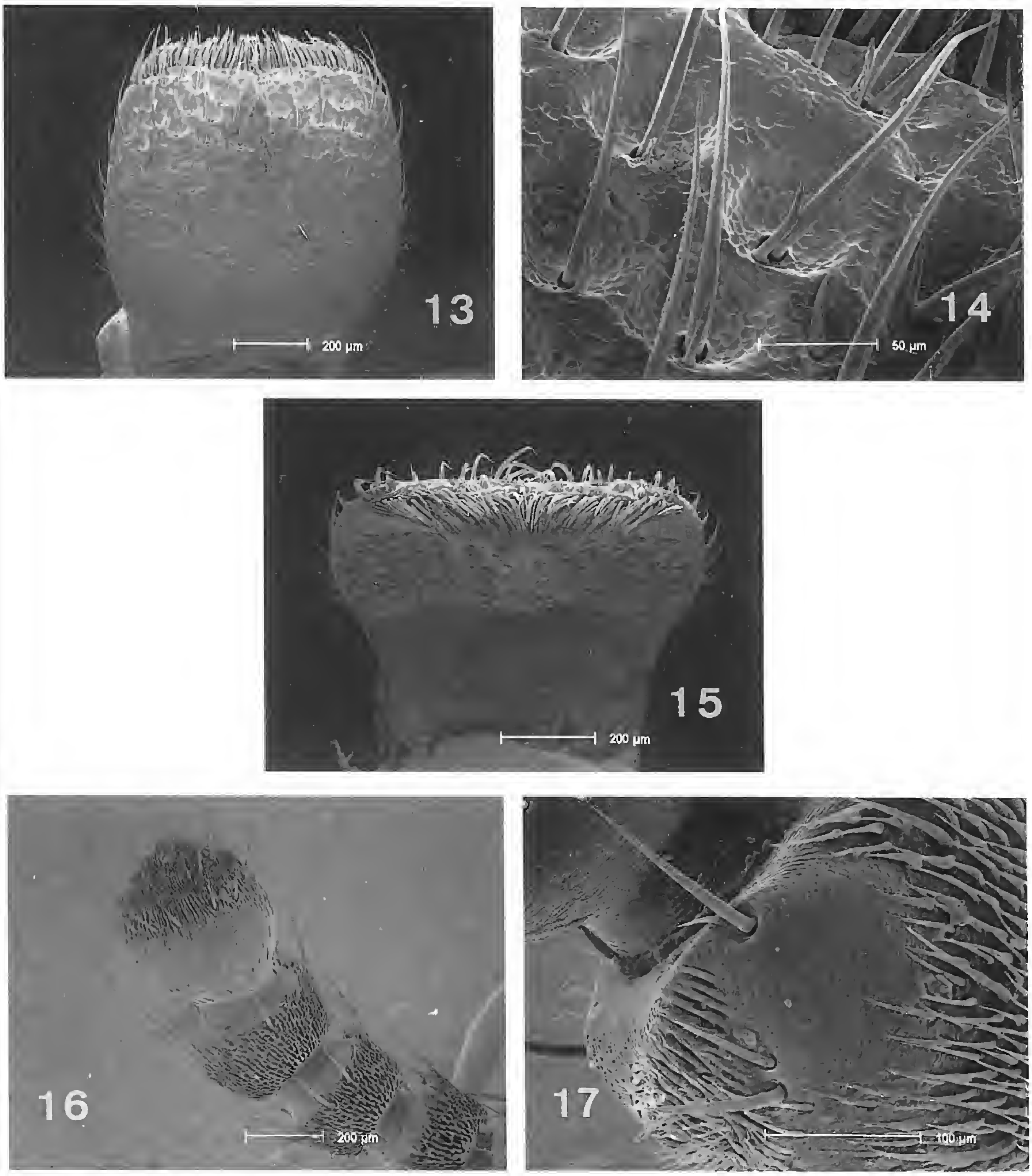
Description.—Habitus as in Fig. 1. Coloration uniformly castaneous, with most of the body closely covered with squamiform, curved, golden to brown setae, with scattered hooked black to brown setae particularly evident at the margin of the prothorax. Live specimens present a velvety, almost furry, aspect. Tegument formed by irregularly shaped tegulae, juxtaposed or partially imbricated (Fig. 2).

Head inserted into the prothorax as far as the antennal insertions while in repose; epistoma medially



Figures 8–12. Buccal morphology of *N. doyeni*. Figure 8. Ventral view of the maxilla. Note the pubescence of the lacinia and galea. Figure 9. Terminal segment of the maxillary palp. Figure 10. Terminal ovate fossa of the maxillary palp with internal sensory papillae. Figure 11. Ventral view of the mandible. Note the shape of the incissor and molar lobes. Figure 12. Lateral view of the mandible.

depressed, laterally inflated, densely covered by squamiform, golden setae. Gular suture arcuate; deep gular v-shaped incisions, broadly opened, which accommodate the maxillary basistipe (Fig. 3). Mentum (prementum) subrectangular with arcuate posterior margin (labial suture), and smoothly emarginate anterior edge (Fig. 4); ventral surface of the mentum setose with shallow broad fossae bearing laterally a single long curved hair; mental margins densely setose (Fig. 5); labial palpi robust with a broad terminal opening, showing the internal, non-protruding, sensory organs (Fig. 6); insertions of the labial palpi with tuffs of dense long setae directed inwards towards the oral cavity (Fig. 7). Maxillae with lacinia and galea densely setose (Fig. 8); maxillary palpi with non-terminal segments short and robust, covered by setae on most of their dorsal surface; terminal segment of the palpi (Fig. 9) elongate,



Figures 13–17. Buccal morphology and antennae of *N. doyeni.* Figure 13. Dorsal view of the labrum. Figure 14. Detail of the setiferous fossae on the dorsal surface of the labrum. Figure 15. Anterior edge of the labrum in ventral view. Figure 16. Antennal segments 7–11. Note the fusion of the terminal segments and the protruding denuded area in segment 9. Figure 17. Detail of the protruding smooth area in the 9th segment of the antenna.

fusiform, with scattered long setae and a terminal ovate fossa with internal sensory papillae (Fig. 10); basistipe well developed, with a marked hump. Mandibles robust and strong, joined to the head by a single point of articulation and several muscles; each mandible has a triangular base, and its mesal surface is differentiated into a very sharp, distal toothed incisor lobe (Fig. 11) and a proximal molar lobe flat and smooth, with poorly defined transversal grooves (Fig. 12). Labrum relatively small (Fig. 13), strongly punctured ventrally, with deep dorsal setiferous fossae (Fig. 14), and small setae at the anterior edge (Fig. 15). Antennae with segments 2 and 4–8 subquadrate, wider than long, densely covered by strong acute setae; segment 3 longer than wide; segment 9 conical, wider than the other segments at its distal portion (Fig. 16), with a well marked smooth denuded area slightly protruding anteriorly (Fig. 17); articles 10 and 11 fused forming a sub-sphaeric terminal segment (Fig. 16).

Prothorax subrectangular in dorsal outline, longer than wide, slightly wider at its first third, with prominent anterior lobed lateral angles that cover genae and eyes; posterolateral corners smoothly rounded, not prominent (Fig. 1); base of thorax arquate; dorsal surface completely covered with squamiform, curved golden-brown setae; ventral surface of the prothorax densely covered by setae, with occasional deep fossae, and a very short but marked hypomeral groove in the anterior portion (Fig. 18). Scutellum hidden under the elytra, small and densely covered by postrate setae, each originating from basal granuli (Fig. 19).

Legs completely pilose except a smooth patch on the internal surface of the femora of males (Fig. 20); the surface of these black ovate tuberosities is smooth with fine pores unevenly dispersed (Fig. 21); ventral surface of tarsus with two rows of divergent setae that give a grooved appearance to the tarsus (Fig. 22); terminal tarsal segment with strong claws (Fig. 23).

Elytra 1.6 to 1.8× longer than wide, with shallow humeral impressions, and faded posterior tuberculation, densely covered by squamiform golden brown setae (Fig. 24); dispersed small setiferous fossae are almost completely obliterated by pilosity (Fig. 25); posterior elytral depressions absent; sutural region depressed; apices rounded, not touching each other (Fig. 1).

Male genitalia including a well developed genital segment which corresponds to the eighth and ninth abdominal sternites. Aedeagus with parameres dorsally fused, their apices pubescent and less sclerotized than the rest (Fig. 26); phallobase ventrally opened and shorter than the parameres (P/Ph ratio about ⅓). Median lobe long and thin (Fig. 27), its apex obliquely truncated and distally opened, with the terminal portion narrowly rounded and with scattered deep fossae (Fig. 29). The endophallus is a membranous sac that seems empty at low magnification.

The female genitalia (Fig. 30) consist of two ovaries, two lateral oviducts converging posteriorly from the ovaries, a median oviduct (oviductus communis) receiving the lateral ducts anteriorly, the gonopore opened to the exterior on the eighth abdominal segment, a spermatheca (receptaculum seminis), two accessory glands, and the vagina, a tubular exit passage from the median oviduct to the genital chamber. The eighth abdominal segment is well developed and it is associated with the genital chamber which is modified in an organ formed of appendicular parts, serving for the deposition of the eggs; this organ is not a real ovipositor but it can be protracted like a tube, having the opening of the egg passage near its distal end; the functional ovipositor is composed of a pair of dorsal and ventral elongate processes or threads, which give stiffness to this part of the female genitalia; the ventral wall is longer than the dorsal and it has a sclerotized median rod in the middle and two distal genital palpi with sensillae.

Length (elytra plus prothorax), 14.5–17.7 mm.

Variability.—Paratypes 5–33 are covered by a dark exudate that obliterates most of the scalation, tuberculation, and fossae. Coloration of these specimens is brown-black with dorsal shiny reflections from the exudate. Some specimens present small dorsal tubercles along the striae, completely covered by golden setae.

Secondary sexual characters.—Males have a large oval black tuberosity completely free of setae on the interior surface of the femora.

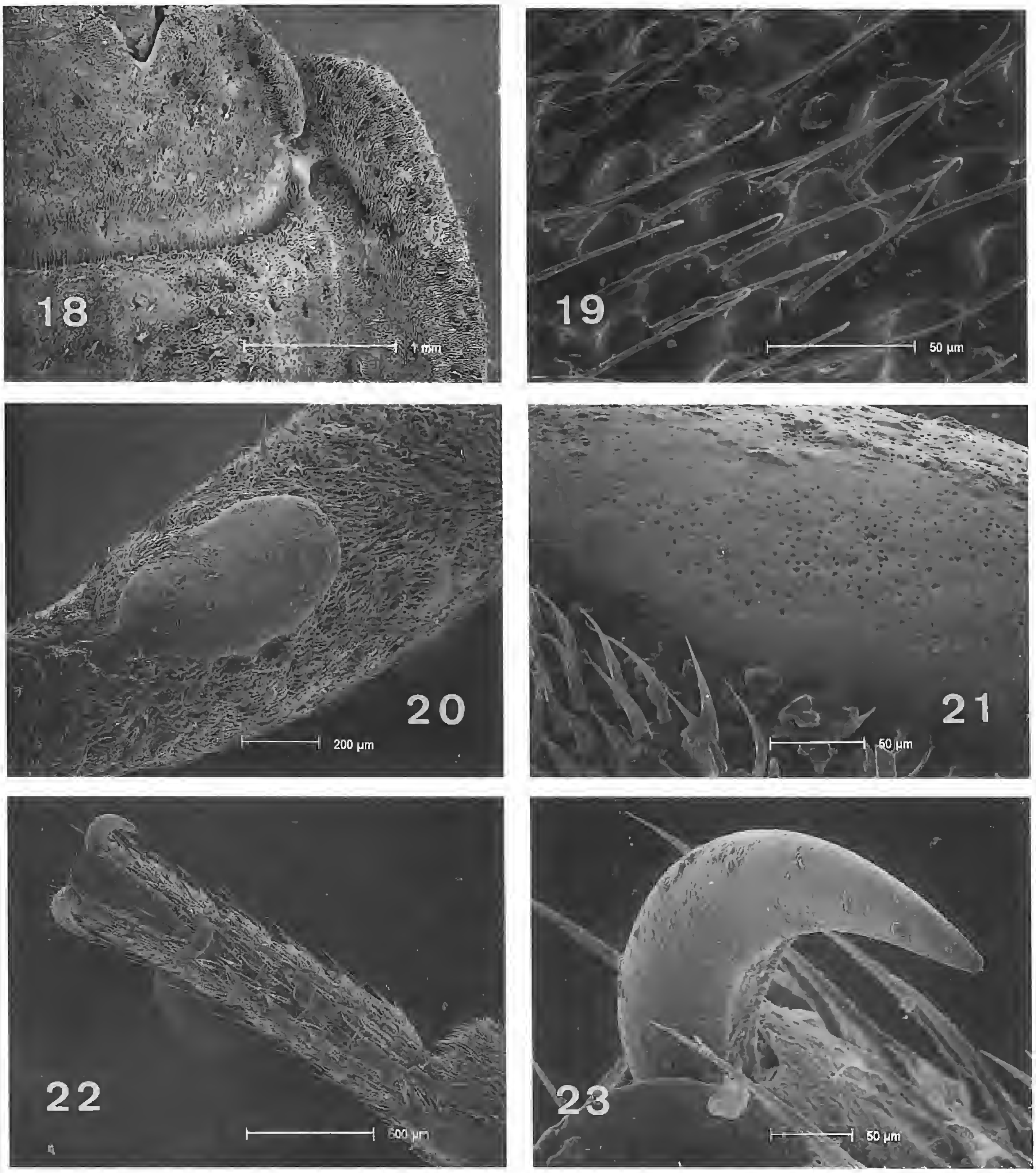
Etymology.—This species is named to honor John T. Doyen whose contributions to the systematics of Neotropical and Neartic tenebrionoids have been substantial to present and future workers on the group, and who kindly provided us with his material for the description of the new species.

Geographic Range.—Known only from the type locality, the Cerro Potosí in Nuevo León, México.

Ecological Remarks.—The species was found under loose bark of dead pine stumps, often in company of the plethodontid salamander *Chiropterotriton priscus* Rabb 1956, at elevations ranging from 2600 to 3200 m.

Material Examined.—37 specimens of *Noserus doyeni*: The type series indicated above plus one additional specimen used for the SEM study, MEXICO: NUEVO LEÓN: Cerro Potosí, 2600–3200 m, 23 May 1996, M. García-París and G. Parra-Olea: 1 specimen (MNCN).

Additional specimens of *N. plicatus* from California (*n* = 11; MNCN), *N. emarginatus* from Texas,

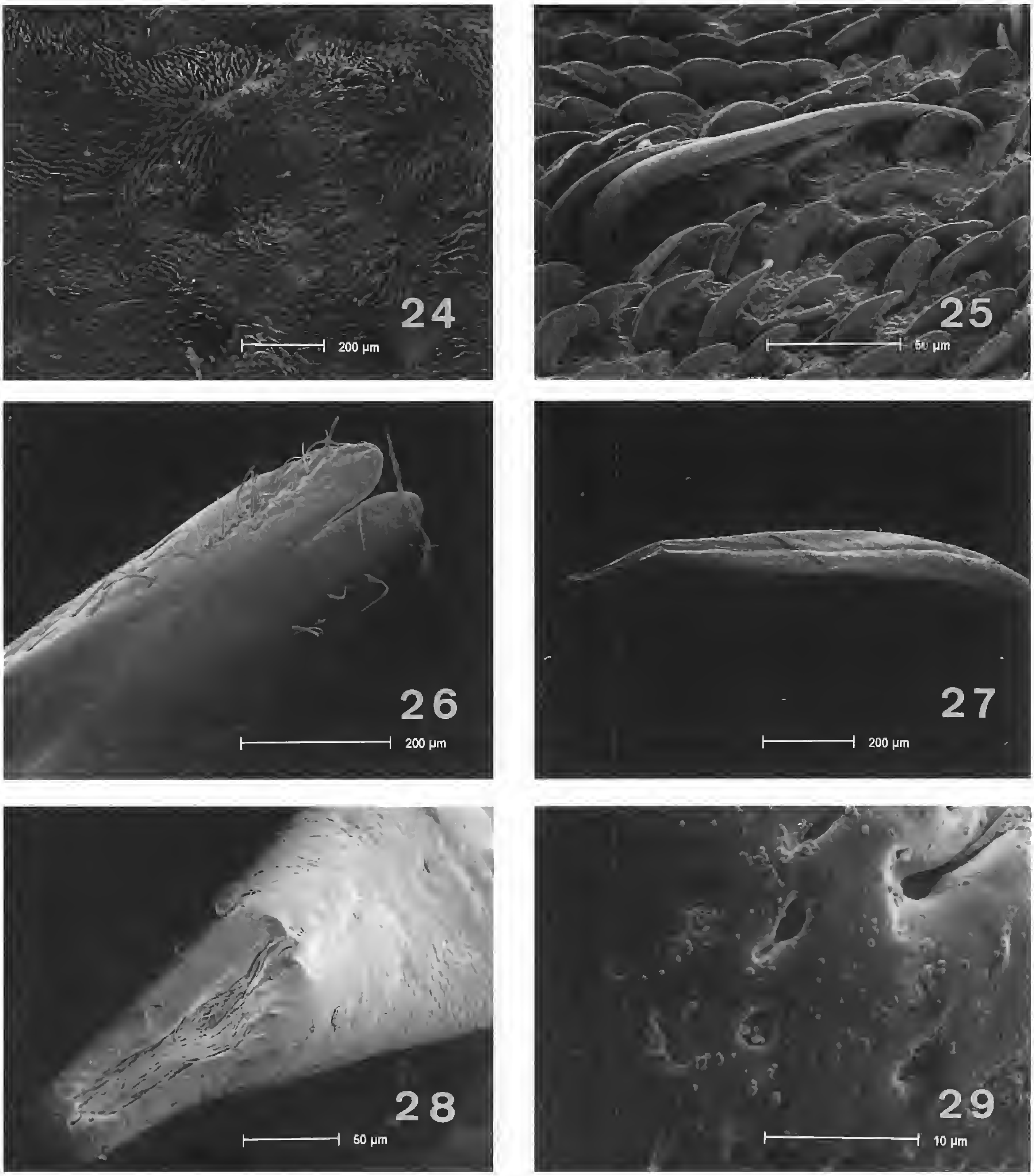


Figures 18–23. Taxonomic characters of *N. doyeni*. Figure 18. Ventral view of the posterior portion of the head and the lateral area of the prothorax. Note the short hypomeral groove and the ventral fossae. Figure 19. Detail of the pubescence on the scutellum. Figure 20. Oval tuberosity on the internal surface of the femora of males. Figure 21. Detail of the surface of the femoral tuberosity, showing the pores and the lack of pubescence. Figure 22. Ventral view of the tarsus. Figure 23. Terminal claw of the tarsus.

including the holotype ($n = 3$; MCZ), and representatives of all the North American genera of Zopherinae: *Phloeodes, Nosoderma, Meralius, Phellopsis* and *Zopherus* (CAS, EM, MNCN) were also examined.

KEYS TO SPECIES OF ADULT NOSERUS

In the following key all the geographic forms restricted to California (Casey 1907a, b) and closely related to *Noserus plicatus* are included under that name.



Figures 24–29. Taxonomic characters of *N. doyeni.* Figure 24. Dorsal view of the elytral pubescence at the disc region. Figure 25. Detail of the elytral pubescence. Note the density of the squamiform setae and the isolated long hair corresponding to the hidden dorsal setiferous foveae. Figure 26. Dorsal view of the parameri of the male genitalia. Note the pubescence on the lateral regions. Figure 27. Lateral view of the median lobe of the male. Note the obliquely truncate apex. Figure 28. Distal opening of the median lobe. Figure 29. Detail of the deep fossae of the distal region of the median lobe.

1. Elytral tuberculation reduced, not prominent to almost obliterate, and completely hidden by dense pilosity. Posterior declivity of elytra smooth .... *N. doyeni*

*. Elytral tuberculation strong, especially prominent at the posterior half.

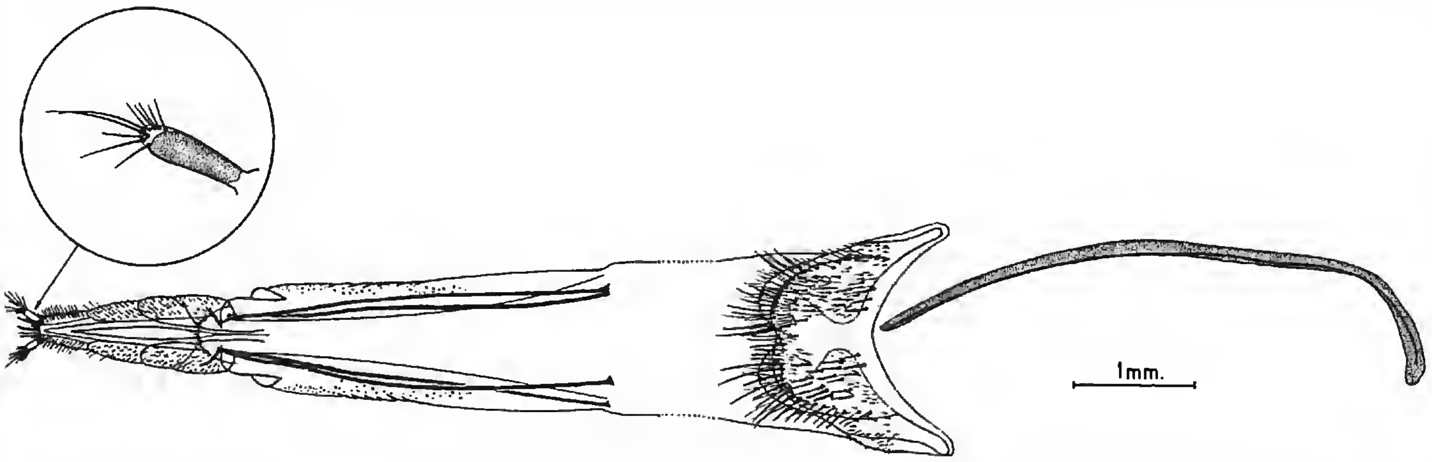


Figure 30. Female genitalia. Broken lines indicate the region is longer than shown.

Dorsal pilosity does not hide the posterior tubercules. Posterior declivity of elytra abrupt 2

2. Apex of the elytra deeply emarginate. Undersurface with obvious fossae and without prominent tubercles, covered by dense squamiform pilosity .... *N. emarginatus*

*. Apex of the elytra not emarginate. Undersurface without large fossae, with dispersed long setae placed at the base of rounded black tubercles .... *N. plicatus*

Discussion.—The range of the genus *Noserus* includes two disjunct geographic areas. The first group is restricted to the Pacific regions of California. It includes a group of poorly defined forms allied to *N. plicatus,* which do not deserve a specific taxonomic status because most of their diagnostic characters are variable features widespread along the geographic range of *N. plicatus.* The second unit is distributed along the Atlantic regions of Texas (USA) and the State of Nuevo León (México) (García-París et al. 2000). This group includes two species, *N. doyeni,* so far restricted to a single mountain, the Cerro Potosí in the uplands of Nuevo León, and *N. emarginatus* from Texas. The Atlantic (Gulf of México) species share a dense dorsal velvety vestiture and the presence of deep setiferous fossae on the undersurface, not present in the Pacific *N. plicatus.*

Noserus doyeni with its furry vestiture and lack of dorsal and posterior elytral tuberculation, is one of the most easily recognized species of the Zopherinae. The single known population of this species may represent a relict of a wider distribution, along the mountains of the Sierra Madre Oriental, that was progresively restricted as a consequence of the Plio-Pleistocene aridification of the uplands of Nuevo León (Braun 1955). The range of *N. emarginatus* covers part of the humid lowlands of southern Texas, and montane forests in northeastern Mexico, but its frequency of capture is very low as inferred from the scarcity of material available in museum collections (García-París et al. 2000).

Casey (1907b) divided the Zopherinae into two tribes, the Zopherini and the Nosodermini. Casey's (1907b) Zopherini included only *Zopherus* sensu Triplehorn (1974), and Nosodermini included a highly heterogeneous assemblage of the remaining genera including *Noserus.* We follow Doyen & Lawrence (1979) and do not consider justifiable to subdivide the Zopherinae at this point, since any possible arrangement probably requires the recognition of many monotypic tribes. *Noserus* is morphologically close to the American genera *Nosoderma, Meralius* and *Phloeodes.* These taxa share the fusion of the two apical segments of the antennae and the presence of tuberosities on the internal surface of the femora of males. The only apparently constant discriminating character among them is the presence of a deep hypomeral groove that completely contains the antennae when in repose in *Phloeoedes,* the complete absence of the hypomeral groove in *Nosoderma* and *Meralius,* and the presence of a shallow, but marked short groove that does not completely contain the antennae in *Noserus* (Doyen & Lawrence 1979). The hypomeral groove in Atlantic *Noserus* is less developed than in the Pacific species, and altogether, *Noserus* seems to be a transitional taxon between *Nosoderma* and *Phloeodes.* The relevance of the hypomeral groove as a discriminant character within Zopherinae is undisputable, however its phylogenetic relevance is less clear because it is likely subjected to adaptive pressures, and it seems to have evolved two or three times within the family, because it also occurs in the American *Zopherus* Gray, and the Australian *Zopherosis* White, genera apparently not closely related to each other nor to *Phloeodes* or *Noserus* (Doyen & Lawrence 1979).

The external appearance of the three known species of *Noserus* is strikingly diverse, and they may represent two independent phyletic lineages, the Pacific and the Atlantic groups, rendering the genus *Noserus* possibly paraphyletic. The presence of dense dorsal velvety vestiture, deep setiferous fossae on the undersurface, and poorly defined tarsal grooves in Atlantic *Noserus* is shared by species of *Nosoderma.* However *Nosoderma* is not a morphologically homogeneous taxon (Casey 1907b, Doyen & Lawrence 1979), and any re-evaluation of the status of *Noserus* must wait for the revision, currently in progress, of this diverse genus.

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We are grateful to J. T. Doyen for kindly allowing the examination of his material deposited at the Essig Museum, and to C. B. Barr (Essig Museum), D. H. Kavanaugh and R. Brett (California Academy of Sciences), C. Martín (Museo Nacional de Ciencias Naturales) and P. Perkins (Museum of Comparative Zoology) who helped us during the revision or provided invaluable material for study; C. A. Triplehorn who also had recognized this species for his comments and suggestions, F. Flores (México) who kindly helped us during field work, J. Bedoya and E. Soteras (Museo Nacional de Ciencias Naturales) for the Scanning Electron Microscopy services, and the excellent drawings that illustrate this work. We are especially grateful to D. B. Wake who provided support during field trips, and B. Sanchiz and A. Navas who provided facilities for the study of the material at the Museo Nacional de Ciencias Naturales in Madrid. During part of this research MG-P was supported with a postdoctoral fellowship of the Comunidad Autónoma de Madrid (Spain) and GP-O with a fellowship of the CONACyT (México).

Literature Cited

Böving, A. G. & F. C. Craighead. 1931. An illustrated synopsis of the principal larval forms of the Order Coleoptera. Entomol. Amer. (n.s.), 11: 1–351.

Braun, E. L. 1955. The phytogeography of unglaciated eastern United States and its interpretation. Bot. Rev., 21: 297–375.

Casey, T. L. 1907a. Notes on *Chalcolepidius* and the Zopherini. Can. Entomol., 39: 29–46.

Casey, T. L. 1907b. A revision of the American components of the tenebrionid subfamily Tentyriinae. Proc. Wash. Acad. Sci., 9: 275–522.

Doyen, J. T. & J. F. Lawrence. 1979. Relationships and higher classification of some Tenebrionidae and Zopheridae (Coleoptera). System. Entom., 4: 333–377.

García-París, M., G. Parra-Olea & M. Coca-Abia. 2000. First records of the genus *Noserus* LeConte (Coleoptera: Zopheridae) in Mexico. Proc. Entomol. Soc. Wash., 102: 473–474.

Gebien, H. 1910. Tenebrionidae, XVIII, (I) pp. 1–166. *In* Junk, W. & S. Schenkling (eds.). Coleopterorum Catalogus, pars 15. W. Junk, Berlin.

Gebien, H. 1937. Katalog der Tenebrioniden (Col.: Heteromera). Teil I. Publicazioni del Museo Entomologico "Pietro Rossi", 2: 505–883.

Horn, G. H. 1878. Contributions to the Coleopterology of the United States, No. 2. Trans. Amer. Entomol. Soc., 7: 51–60.

Lawrence, J. F. & A. F. Newton, Jr. 1995. Families and subfamilies of Coleoptera (with selected genera, notes, references and data on family-group names). pp. 779–1006. *In* Pakaluk, J. & S. A. Slipinski (eds.). Biology, phylogeny, and classification of Coleoptera: papers celebrating the 80th birthday of Roy A. Crowson. Muzeum i Instytut Zoologii PAN, Warszawa.

Lawrence, J. F. 1994. The larva of *Sirrhas variegatus*, sp. nov. with notes on the Perimylopidae, Ulodidae (stat. nov.), Zopheridae and Chalcodryidae (Coleoptera: Tenebrinoidea). Invert. Taxon., 8: 329–349.

LeConte, J. L. 1859. Catalogue of the Coleoptera of Fort Tejón, California. Proc. Acad. Nat. Hist. Phil., 11: 69–90.

LeConte, J. L. 1862. Classification of the Coleoptera of North America. Smithsonian Misc. Coll., 136: 209–286.

Triplehorn, C. A. 1972. A review of the genus *Zopherus* of the World (Coleoptera: Tenebrionidae). Smithsonian Cont. Zool., 108: 1–24.

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POLYTRICHAPHIS (HOMOPTERA: APHIDIDAE), A NEWLY RECORDED GENUS FROM CHINA, AND DESCRIPTION OF A NEW SPECIES

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Abstract.—The aphid genus, *Polytrichaphis* Miyazaki, is newly recorded from China. A new species, *Polytrichaphis illicius* Qiao and Zhang, is described. The type is deposited in the Zoological Museum, Institute of Zoology, the Chinese Academy of Sciences, Beijing, China.

Key Words.—Insecta, Aphididae, Macrosiphinae, *Polytrichaphis,* New Species, New Record, China.

Some aphids infesting *Illicium verum* on young leaves of the tree were collected in Beiliu County, Guangxi Autonomous Region, P.R. China. Blackman and Eastop (1984, 1994) listed no aphids on *Illicium verum.* Miyazaki (1971) described one new genus, *Polytrichaphis* collected from *Illicium anisatum* in Japan, which belongs to the member of Macrosiphinae. Careful examination revealed that the present specimens belong to a new species, *Polytrichaphis illicius.* Because the tree, *Illicium verum* is economically important in Guangxi Autonomous Region, biological studies on the aphid will have important effects on agricultural production of the tree.

To morphological characters, the genus *Polytrichaphis* Miyazaki is originally described in the Macrosiphini because of the absence of lateral abdominal tubercles and the presence of moderately developed antennal tubercles (Miyazaki 1971, Remaudière & Remaudière 1997). However, Eastop (1979) thought that the genus may even belong to the subtribe Aphidina but it seems more useful to include than to exclude it. Therefore, regarding the systematic status of *Polytrichaphis* much work needs to be done in the future. In this paper, the genus will be regarded as a member of Macrosiphinae, because the distance between stigmal pori on 2nd and 3rd abdominal segments is at least 3.10 times as long as the distance between stigmal pori on 1st and 2nd abdominal segments (Eastop 1979).

The specimens were collected from Guangxi Autonomous Region (Beiliu City 130 m) by Jinyi Huang. All specimens were deposited in the Zoological Museum, Institute of Zoology, the Chinese Academy of Sciences, Beijing, China.

The terminologies and descriptions follow that of Miyazaki (1971). The unit of measurements is in millimeters (mm).

POLYTRICHAPHIS MIYAZAKI, 1971 NEW RECORD IN CHINA

Polytrichaphis Miyazaki, 1971, Ins. Mats., 34(2): 166.

Polytrichaphis Miyazaki: Eastop VF, 1979, Syst. Ent. 4: 386; Remaudière G and M Remaudière, 1997, Catalogue of the world's Aphididae. Homoptera: Aphidoidea, 139.

Type Species.—Polytrichaphis fragilis Miyazaki, 1971, by original description.

Diagnosis.—Body oval or elliptical. Median front slightly developed; frontal tubercles distinct, Antenna 6-segmented, longer than body; without secondary rhinaria in apterous viviparous female; in alate viviparous females with round, variable in size secondary rhinaria on 3rd–5th segments. Mesosternal furca with arms separated from each other. All first tarsal segments bearing 2 setae which are much removed from apex of the segment. Media vein of fore wing 2-branched, hind wing with two oblique veins; wing veins bordered with black bands. Siphunculus sub-cylindrical, weakly imbricated, with slightly spinulose shorter stripes and distinct flange at apex. Cauda elongated tongue-shaped, non-constricted.

Host Plants.—Aphids in this genus feed on plants in the Illiciaceae.

Distribution.—China, Japan.

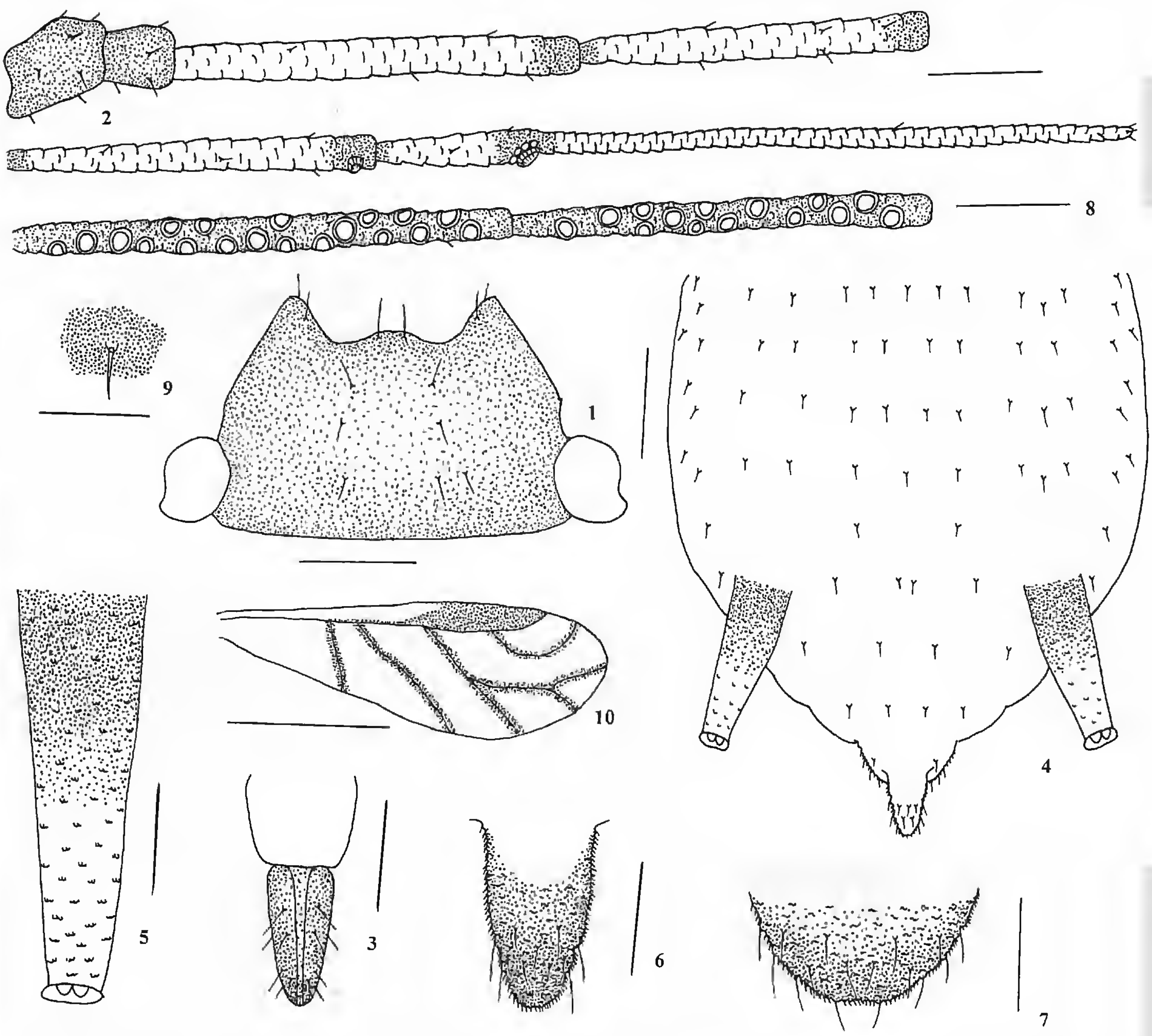
The genus is represented by two species as follow: *Polytrichaphis fragilis.* Miyazaki, and new species *P. illicius* Qiao and Zhang. The genus is newly recorded in China, and there is one new species described from China in this genus.

POLYTRICHAPHIS ILLICIUS, NEW SPECIES
(Figs. 1–10)

Types.—Holotype, apterous viviparous female (Figs. 1–7), deposited in Zoological Museum, Institute of Zoology, the Chinese Academy of Sciences, P.R. China, data: CHINA, GUANGXI AUTONOMOUS REGION, BEILIU *Co.*: 110.3° E, 22.7° N, 130 m, 27 Mar 1997, on *Illicium verum,* by Jinyi Huang (No. Y8243-1-5-2); paratypes: 14 apterous viviparous females and 18 alate viviparous females, other data same as holotype.

Description of Apterous Viviparous Females.—Body oval, black in life, 1.63–1.81 mm long, 0.93–1.13 mm wide. In mounted specimens: distal of 3rd antennal segment, tip and base of 4th–5th segments, basal of 6th segment darkly brown; basal ½–⅓ of siphunculi darkly brown, others pale brown.

Frontal tubercle slightly developed, antennal tubercles distinct, inner margins slightly diverging (Fig. 1). Dorsal hairs of body fewer, slightly thick and sharp. Head with 1 pair of cephalic hairs, 2 pairs of antennal tubercular hairs and 6 or 7 dorsal hairs (Fig. 1). Length of cephalic hairs 0.05–0.07 mm, 1.85×–2.4× as long as widest diameter of 3rd antennal segment. Antennae 6-segmented (Fig. 2), slender, 1.51–1.97 mm long, 0.88×–1.15× as long as body; 3rd–6th segments with weak imbrications. Proportion of 1st–6th segments: 26:17:100:91:97:40+157; processus terminalis 3.33×–4× as long as basal part. Antennal hairs short and sharp, 1st–6th segments each with 5 or 6, 4, 4–7, 2–5, 3-5, 2+0 or 1 hairs, respectively; apex of processus terminal with 2 or 3 hairs; length of hairs on 3rd antennal segment 0.02 mm, 0.63× as long as widest diameter of this segment. Primary rhinaria small rounded, ciliated. Rostrum reaching mid-coxae; ultimate rostral segment wedge-shaped (Fig. 3), 1.71×–2.18× as long as its basal diameter, 1.7× as long as 2nd segment of hind tarsi, with 4–6 accessory hairs among them. Thorax tergum membranous. Pronotum with 2 or 3 spinal, 1 pair of pleural and 1 pair of marginal hairs; mesonotum with 2–3 pairs of spinal, 1 pair of pleural and 2 pairs of marginal hairs; metanotum with 2 pairs of spinal, 1 pair of pleural and 2 pairs of marginal hairs. Hind femur 0.59–0.71 mm long, 1.68×–2× as long as 3rd antennal segment. Hind tibia 1.03–1.24 mm long, 0.6×–0.72× as long as body. Hairs on legs sparse, short and sharp; length of hairs on hind tibia 0.03–0.05 mm, 0.92×–1.38× as long as middle diameter of the segment. First tarsal chaetotaxy: 2, 2, 2. Mesosternal furca with two arms separated, length of single arm, 0.08–0.11 mm, 1.33×–1.83× as long as 2nd antennal segment. Abdomen tergum membrane (Fig. 4); dorsal hairs on abdominal tergites sparse and sharp; 1st–5th abdominal tergites each with 3–5, 3 or 4, 2–4, 2 or 3 and 1–3 spinal hairs, respectively; 1st–4th abdominal tergites each with 2–5, 4 or 5, 3–5, and 4–6 pleural hairs, respectively; 5th tergite without pleural hairs; 1st–5th tergites each with 1 pair of marginal hairs, 6th tergite with 2 pairs of spino-pleural and 1 pair of marginal hairs; 7th tergite with 1 pair of pleural and 1 pair of marginal hairs; 8th tergite with 4 or 5 hairs. Length of marginal hairs on 1st tergite and dorsal hairs on 8th tergite 0.05–0.06 mm, 0.05–0.07 mm, 1.85×–2.22× and 1.85×–2.41× as long as widest diameter of 3rd antennal segment, respectively. Spiracles round and open, spiracular plates long oval,



Figures 1–7. Apterous viviparous females of *Polytrichaphis illicius*.
Figure 1. Dorsal view of head.
Figure 2. Antenna.
Figure 3. Ultimate rostral segment.
Figure 4. Dorsal view of abdomen.
Figure 5. Siphunculus.
Figure 6. Cauda.
Figure 7. Anal plate.
Figures 8–10. Alate viviparous females of *Polytrichaphis illicius*.
Figure 8. Third and fourth antennal segments.
Figure 9. Dorsal hair on abdominal tergites and hair-bearing sclerite.
Figure 10. Fore wing.
Scale bar: Figs. 1–8, 10 = 0.1 mm, Fig. 9 = 0.05 mm.

brown. Siphunculi sub-cylindrical (Fig. 5), with weakly spinulose short imbrications; 0.34–0.37 mm in length, distal diameter 0.06 mm, length 3×–4.13× as long as its basal width, 2×–2.12× as long as cauda, 0.2×–0.22× as long as body. Cauda elongated tongue-shaped (Fig. 6), non-constricted, with spinulose short imbrications, 0.16–0.18 mm in length, 1.42×–1.6× as long as its basal diameter, with 7–11 hairs. Anal plate circular at apex (Fig. 7), with spinulose short imbrications and 15–20 hairs. Genital plate with weakly spinulose transverse imbrications and 12 or 13 hairs, 4 anterior hairs among them. Gonapophyses three, each with 4 or 5 short sharp hairs.

Description of Alate Viviparous Females.—Body long elliptical, black in life, 1.43–1.88 mm long, 0.53–0.95 mm wide. In mounted specimens: Head, thorax, 1st antennal segment, apex of rostrum,

Table 1. Measurements of apterous viviparous females (mm).

No.	Body length	Body width	Hind femur	Hind tibia	Ant. III	Ant. IV	Ant. V	Ant. VI	Siphunculi	Cauda
1	1.70	1.05	0.64	1.09	0.36	0.31	0.33	0.14 + 0.52	0.35	0.16
2	1.81	1.13	0.65	1.13	0.36	0.33	0.35	0.15 + 0.58	0.36	0.18
3	1.75	1.06	0.67	1.24	0.36	0.32	0.35	0.14 + 0.59	0.34	0.16
4	1.78	1.03	0.66	1.14	0.35	0.37	0.38	0.15 + 0.59	0.37	0.16
5	1.63	0.95	0.59	103	0.30	0.26	0.27	0.12 + 0.41	0.35	0.16
6	1.70	0.96	0.66	1.13	0.38	0.33	0.36	0.15 + 0.56	0.36	0.18
7	1.73	0.93	0.66	1.14	0.36	0.31	0.33	0.14 + 0.55	036	0.18
8	1.70	1.00	0.66	1.08	0.38	0.30	0.36	0.15 + 0.57	0.36	0.16
9	1.75	1.03	0.71	1.19	0.38	0.32	0.37	0.15 + 0.60	0.36	0.18
10	1.63	0.98	0.61	1.03	0.31	0.30	0.31	0.15 + 0.54	0.34	0.16
Average	1.71	1.01	0.65	1.12	0.35	0.32	0.34	0.14 + 0.55	0.36	1.68

coxae, trochanters, basal ⅓ of siphunculi and veins dark brown, 7th–8th abdominal tergites with cross bands across the segment; others pale brown.

Frontal tubercle slightly developed, antennal tubercles distinct, inner margins slightly diverging. Head with 1 pair of cephalic hairs, 2 pairs of antennal tubercular hairs and 6 or 7 dorsal hairs; Antennae 6-segmented, 1.74–2.15 mm long, 1×–1.25× as long as body, 1st antennal segment dark brown; 3rd–6th segments with weak imbrications (Fig. 8); proportion of 1st–6th segments: 21: 18: 100: 80: 85: 34+139; processus terminalis 3.53×–4.46× as long as its basal part. Antennal hairs much short and sharp, 1st–5th segments each with 5 or 6, 4, 3–6, 2–4, 3–6 hairs, respectively; base of 6th segment with 1 or 2 hairs, processus terminalis each with 0 or 1 hair; apex of processus terminalis with 3 hairs. Length of hairs on 3rd segment 0.01–0.02 mm, ⅓×–½× as long as widest diameter of this segment. Secondary rhinaria rounded, variable in size, 3rd segment with 23–31 rhinaria and 4th segment with 10–19 rhinaria along their whole length, 5th segment with 0 or 1 rhinarium. Rostrum reaching mesothorax, ultimate rostral segment wedge-shaped, 0.1–0.12 mm long, 1.57×–2.2× as long as its basal width, 1.43×–1.71× as long as 2nd segment of hind tarsi, with 2–3 pairs of accessory hairs. Pronotum each with 1 pair of spinal, pleural, and marginal hairs. Hind femur 0.52–0.67 mm long, 1.27×–1.63× times as long as 3rd antennal segment. Hind tibia 0.98–1.19 mm long, 0.57×–0.69× as long as body. Hairs on legs sparse, short sharp. Length of hairs on hind tibia 0.02–0.03mm, as long as middle width of the segment. First tarsal chaetotaxy: 2, 2, 2. Fore wing 2.25–2.85mm long, 1.31×–1.66× as long as body (Fig. 10). Media vein 2-branched; hind wing with two oblique veins. Wing veins bordered with black bands. 7th–8th abdominal tergites with spinulose short imbrications. Dorsal hairs of body sparse, slightly short sharp, which on abdominal tergites with distinct hair-bearing sclerites (Fig. 9); 1st–7th abdominal tergites each with 4, 2, 2 or 3, 2 or 3, 2, 1 or 2 and 2 or 3 spinal hairs, respectively; 1st–4th tergites each with 2–4, 3–6, 4, and 5 or 6 pleural hairs, respectively, 6th tergite with 2 pleural hairs, 5th and 7th tergites without pleural hairs; 1st–7th tergites each with 1 pair of marginal hairs; 8th tergite with 4 or 5 hairs. Length of marginal hairs on abdominal 1st tergite and dorsal hairs on 8th tergite 0.03–0.05 mm, 0.05–0.06 mm, 1×–1.67× and 1.67×–2× as long as widest diameter of 3rd antennal segment, respectively. Siphunculi with weakly spinulose imbrications; 0.26–0.31 mm long, 3.16–3.76× as long as its basal diameter, 1.86×–2.21× as long as its basal width. Cauda 0.13–0.15 mm long, with spinulose short imbrications and 7–9 hairs. Anal plate with spinulose short imbrications and 16–18 hairs. Genital plate with weakly spinulose imbrications and 13 or 14 hairs, 4 anterior hairs among them. Other data same as apterous viviparous females.

Diagnosis.—The new species is near to *Polytrichaphis fragilis* Miyazaki, but differs from it as follow: basal ⅓–½ of siphunculi dark (the latter: dark brown in wholly length); black in life (the latter: yellow to pale yellowish green in life); 8th tergite with 4 or 5 hairs (the latter: 9–13 hairs); genital plate with 4 anterior hairs (the latter: 2); dorsal hairs on body shorter and fewer (the latter: tergum abounding with long flagellate hairs) (Miyazaki 1971).

Etymology.—The new species is named for its infesting on *Illicium verum*.

Table 2. Measurements of alate viviparous females (mm).

No.	Body length	Body width	Fore wing	Hind femur	Hind tibia	Ant. III	Ant. IV	Ant. V	Ant. VI	Siphuncu-li	Cauda
1	1.70	0.70	2.25	0.61	1.10	0.38	0.34	0.35	0.15 + 0.56	0.31	0.13
2	1.88	0.73	2.53	0.64	1.19	0.44	0.41	0.37	0.15 + 0.59	0.30	0.14
3	1.43	0.53	2.50	0.52	0.98	0.36	0.27	0.31	0.12 + 0.53	0.28	0.13
4	1.85	0.95	2.85	0.67	1.13	0.43	0.39	0.37	0.15 + 0.55	0.29	0.14
5	1.83	0.75	2.78	0.65	1.15	0.47	0.39	0.37	0.15 + 0.60	0.30	0.15
6	1.80	0.78	2.65	0.62	1.15	0.45	0.40	0.38	0.14 + 0.62	0.31	0.15
7	1.65	0.65	2.40	0.57	1.01	0.39	0.31	0.31	0.14 + 0.54	0.26	0.13
8	1.71	0.78	2.50	0.62	1.12	0.37	0.36	0.37	0.13 + 0.60	0.28	0.15
9	1.70	0.75	2.55	0.64	1.11	0.40	0.33	0.35	0.14 + 0.53	0.26	0.14
10	1.63	0.75	2.45	0.62	1.13	0.36	0.38	0.36	0.14 + 0.59	0.30	0.14
Average	1.72	0.74	2.55	0.62	1.11	0.41	0.33	0.35	0.14 + 0.57	0.29	1.14

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LITERATURE CITED

Blackman, R. L. & V. F. Eastop. 1984. Aphids on the world's crops. An identification guide. The Pitman Press, Ltd., Bath, Avon. John Wiley & Sons, VII: 466 pp.

Blackman, R. L. & V. F. Eastop. 1994. Aphids on the world's trees. An identification and information guide. University Press, Cambridge, Center for Agriculture and Biosciences International VIII: 1024 pp.

Eastop, V. F. 1979. Key to the genera of the subtribe Aphidina (Homoptera). Syst. Ent., 4: 379–388.

Heie, O. E. 1992. The Aphidoidea (Hemiptera) of Fennoscandia and Denmark. IV. Scandinavian Science Press Ltd., Denmark, Fauna Ent. Scand., 25: 1–189.

Miyazaki, M. 1971. A revision of the tribe Macrosiphini of Japan (Homoptera: Aphididae: Aphidinae). Ins. Mats., 34: 1–247.

Remaudière, G. & M. Remaudière. 1997. Catalogue of the world's Aphididae. Homoptera: Aphidoidea. Paris, Institut Natural de la Recherche Agronomique, 473 pp. (in French.)

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ABUNDANCE AND MATING BEHAVIOR OF ORIENTAL FRUIT FLIES (DIPTERA: TEPHRITIDAE) NEAR METHYLEUGENOL-BAITED TRAPS

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Abstract.—Methyleugenol-baited traps are used for Oriental fruit fly control through male annihilation, as well as for detection and monitoring of fly populations. However, if the males which come to these traps emit sex pheromones, attract females from the surrounding vegetation, and mate with them before being killed, then using such traps might in fact increase levels of fruit infestation. In the present study, we monitored fly abundance in an experimental orchard before, during, and after methyleugenol-baited trap deployment. We also recorded the numbers of flies recruited to the trees with and without traps, and quantified their sexual activity. The males attracted by methyleugenol in our experiments fed on the poisoned baits almost immediately upon their arrival, and did not attempt to emit pheromones or attempt copulations before entering the traps. No changes in female abundance in the vicinity of deployed traps were recorded. Because of their high specificity, low cost, and environmental safety, methyleugenol-baited traps might be a valuable tool for integrated management of Oriental fruit fly populations.

Key Words.—Insecta, *Bactrocera dorsalis,* behavioral control, methyleugenol, mating, parapheromone.

Oriental fruit fly, *Bactrocera dorsalis* (Hendel), is one of the most important insect pests of tropical horticulture, which causes direct damage to more than 150 species of fruits and vegetables (Christenson & Foote 1960, Haramoto & Bess 1970). Male (but not female) Oriental fruit flies are strongly attracted to methyleugenol (4-allyl-1,2-dimethoxybenzene) (Steiner 1952). Feeding on this compound significantly increases male mating success (Shelly & Dewire 1994). Methyleugenol-baited traps have been widely used for Oriental fruit fly control through male annihilation, as well as for detection and monitoring of fly populations (Cunningham 1989). Male annihilation using methyleugenol has been successful in eradicating Oriental fruit fly from several isolated geographic areas, including the Marianas Islands (Steiner et al. 1965), the Amami Islands (Ushio et al. 1982), and the Okinawa Islands (Koyama et al. 1984). It has also been used to uproot the small "bridgehead" populations of the papaya fruit fly, *Bactrocera papayae* Drew and Hancock, which invaded Queensland, Australia in 1995 (Lloyd et al. 1998, Meats 1998, Hadwen et al. 1998). However, eradication of the Oriental fruit fly in Hawaii is hindered by the existence of large well-established fly populations, often in hard-to-reach natural areas (Vargas et al. 1989, 1990). Because of the high economic and environmental costs of fruit fly eradication, the goals of fruit fly control programs in Hawaii are beginning to shift from complete annihilation towards suppression of fly populations below economic thresholds in selected fruit-growing areas (Mitchell & Saul 1990, Vargas et al. 2000).

With a more targeted approach to the Oriental fruit fly management, we should

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anticipate an increased use of methyleugenol-baited traps for smaller-scale fly control within individual orchards. Cunningham & Suda (1986) achieved a 48% reduction in fruit infestation within a 63 ha papaya orchard by using only 9 small fiberboard blocks saturated with a mixture of methyleugenol and malathion per 1 ha of orchard area. However, using methyleugenol-baited traps within even smaller orchards (e.g., several ha) presents a potential danger. Male Oriental fruit flies attract females by secreting airborne sex pheromones (Kobayashi et al. 1978). They also display specialized courtship behaviors, expressed as rapid wing fanning and rear leg movements over abdomen, probably in an attempt to facilitate pheromone dispersal in the air (Arakaki et al. 1984, Shelly & Kaneshiro 1991). Therefore, if males which come to traps emit sex pheromones, attract females from surrounding vegetation, and mate with them before being killed, the use of methyleugenol traps might in fact increase levels of fruit infestation in localized areas. In the present study, we performed a series of experiments to investigate the possibility of this occurring in small orchards in Hawaii.

METHODS AND MATERIALS

Experimental Sites.—The study was conducted between 28 Apr. and 13 Jun., 1999 at two sites on the Kauai Agricultural Research Center (Kapaa, island of Kauai, Hawaii). The two sites were isolated from each other by approximately 700 m of predominantly non-host vegetation. Site 1 was a small orchard of 75 grapefruit (*Citrus paradisi* Macf.) and eight mandarin (*C. nobilis* Lour.) trees, and Site 2 was a cluster of two shaddock (*C. grandis* (L.)), two grapefruit, and one mandarin trees adjacent to a coffee grove. The grapefruit trees at Site 1 were fruiting throughout the study, while no fruit was observed on any of the trees at Site 2 after 15 May.

Trap Design.—The methyleugenol-baited traps used in our experiments consisted of white plastic buckets (20 cm high, 20 cm in diameter) with 4 entry holes (2.5 cm in diameter) each. A single cotton wick (15.5 cm in length, 1 cm in diameter) was soaked in 10 ml of methyleugenol and 5 ml of a 10% water suspension of malathion and hung by wire from the inner side of each bucket's lid. Buckets were hung on the trees approximately 1.6 m above the ground.

Experiment 1.—The objective of our first experiment was to determine if deploying methyleugenol-baited traps leads to an increase in fly numbers in the immediate surrounding area. Twelve 22.5 by 13.75 cm yellow plastic rectangles (Trécé Inc., Salinas, California) covered with Tanglefoot were placed on trees at random locations within Site 1 (1 rectangle per tree). On the 7th day after rectangle deployment, 1 methyleugenol-baited trap was placed on a tree in the middle of the orchard for another 6 days, and then removed and taken to the laboratory for examination. The rectangles were replaced and checked for flies every 2 days for 18 consecutive days (6 days before placing the methyleugenol-baited trap in the orchard, 6 days during which the trap was deployed, and 6 days after the trap was removed). The numbers of captured male and female flies were recorded. The location of each replacement rectangle was selected at random. The experiment was repeated three times. Since the data did not follow a normal distribution (Wilk-Shapiro test, $n = 216$, $W = 0.5538$, $P < 0.05$ for the number of males, and $W = 0.8680$, $P < 0.05$ for the number of females), they were transformed using rank transformations (Conover & Iman 1981). Transformed data were analyzed using a two-way ANOVA (Analytical Software 1996), with the period during which the flies were captured (e.g., before, during, or after trap deployment) and replicates treated as main effects. When interaction terms were statistically significant, we also analyzed treatment effects separately within each replicate using one-way ANOVA.

Experiment 2.—In our second experiment, we investigated if there was any increase in courtship or mating activity of Oriental fruit flies in the areas immediately adjacent to methyleugenol-baited traps. One such trap was placed on a tree within one of the two sites. The other site was used as a control. The number of male and female flies, number of calling males, and number of mating pairs were recorded on the tree with a trap, as well as on the 4 trees immediately surrounding it. Observations began approximately 1 hour before sunset and continued for 40 minutes, thus covering the period of peak mating activity reported for the Oriental fruit fly (Arakaki et al. 1984, Shelly & Kaneshiro 1991). Observations were repeated 10 times. Each site was used five times as a treatment, and five times as a control. The numbers of flies recruited to the sites with and without a trap were compared using two-sample Student *t*-tests. One-tailed Fisher exact test (Zar 1999) was used to test the null hypothesis that the sex ratio of flies encountered around the trap was not skewed towards males. Two-tailed Fisher exact tests were used to test the null hypotheses that the sex ratio of flies observed in the control site was not different from 1:1 (Analytical Software 1996).

Experiment 3.—The goal of the third experiment was to determine if Oriental fruit fly males responding to methyleugenol arrive directly to the source of its odor. Two neighboring fruit trees were selected at random for observations. The distance between the trees was approximately 6.18 m (SE = 0.74). The number of flies on these trees was visually observed immediately before the beginning of the experiment, and their number was recorded. A methyleugenol-baited trap was then placed on one tree. The number of flies on the trees with and without the trap was then counted every 15 min for 1 h. Flies located on the outer or inner trap walls were not included in the count. The experiment was repeated five times at each of the two sites. Since the data did not follow a normal distribution (Wilk-Shapiro test, $n = 100$, $W = 0.8301$, $P < 0.05$), they were transformed using rank transformations (Conover & Iman 1981). Transformed data were analyzed using a three-way ANOVA (Analytical Software 1996), with site, time since trap placement, and presence of the trap treated as main effects. Means and standard errors were calculated from the non-transformed data only.

We also estimated the period of time between male arrival in the vicinity of a methyleugenol-baited trap and subsequent entry into the trap. Since all the trees within sites 1 and 2 had large canopies, preventing us from following the movements of individual flies, a methyleugenol-baited trap was placed on a potted guava tree (1.75 m tall) located approximately 10 m from Site 2. Time between fly landing on the guava tree and its entering the trap was recorded for 10 flies. The observations were repeated 4 times, with the behavior of a total of 40 flies observed.

RESULTS

Experiment 1.—Experimental results and ANOVA statistics are presented in Table 1. Placing a methyleugenol-baited trap in the orchard significantly reduced

Table 1. Abundance of male and female Oriental fruit flies within Site 1 before, during, and after deploying of a methyleugenol-baited trap.

	Mean no. of males				Mean no. of females			
	Replicate 1	Replicate 2	Replicate 3	Overall	Replicate 1	Replicate 2	Replicate 3	Overall
Before trap placement	17.13	11.96	3.79	10.96	5.96	6.83	7.79	6.86
	(2.48)	(1.71)	(0.48)	(1.20)	(0.83)	(0.98)	(1.11)	(0.56)
During trap placement	14.29	4.46	2.17	6.97	5.50	10.79	5.88	7.39
	(1.51)	(0.53)	(0.33)	(0.82)	(0.81)	(1.52)	(0.85)	(0.69)
After trap placement	15.33	4.88	3.46	7.89	3.88	8.63	7.13	6.54
	(5.44)	(0.73)	(0.45)	(1.91)	(0.75)	(1.19)	(1.13)	(0.63)
ANOVA								
D.f.	2, 69	2, 69	2, 69	2, 207	2, 69	2, 69	2, 69	2, 207
F	2.93	12.86	4.91	10.64	2.62	2.81	0.98	0.89
P	0.0584	0.0001	0.0102	0.0001	0.0782	0.0653	0.3809	0.4148

the number of Oriental fruit fly males captured by yellow rectangles. There was substantial variation in the extent of this influence as indicated by a highly significant interaction term (ANOVA, df = 4, 207, $F = 4.49$, $P = 0.0018$). However, the general trend towards a reduction in male numbers due to trap deployment remained consistent within each replication. However, when the male population in the orchard was the highest (Replicate 1), the difference in the number of males caught before, during, and after trap deployment was not statistically different.

Unlike the numbers of captured males, female captures were not affected by trap presence. There was a significant interaction between treatment and replication (ANOVA, df = 4, 207, $F = 2.74$, $P = 0.0294$), indicating different fluctuation patterns in the numbers of females captured during each of the replications. However, separate analysis of treatment effects within each replication still did not reveal any significant influence of deploying the methyleugenol-baited trap on the number of females captured by yellow rectangles.

Experiment 2.—On average, 5.0 flies (SE = 0.98) encountered around methyleugenol-baited traps were identified as males, and 2.6 flies (SE = 1.01) encountered around the traps were identified as females. At the control sites, approximately 3.0 flies (SE = 1.22) were identified as males, and approximately 2.7 flies (SE = 1.04) were identified as females. Sex ratio was significantly skewed towards predominance of males in the presence of the trap (Fisher exact test, $\chi^2 = 3.89$, df = 1, $P = 0.0352$), but did not differ from 1:1 in the absence of the trap (Fisher exact test, $\chi^2 = 0.08$, df = 1, $P = 0.8515$).

Calling behavior was recorded for an average of 1.6 males (SE = 0.43) within the treatment sites, and an average of 1.4 males (SE = 0.64) within the control sites. The difference between the treatment and control sites was not statistically significant (Student t-test, $t = -0.26$, df = 18, $P = 0.7970$). Only 4 mating pairs were recorded during the entire study, with three of them being observed on a single day. All the observed mating took place within the treatment sites. However, when we included both mating and calling males in our analysis, the difference between the treatment and the control sites still remained statistically insignificant (Student t-test, $t = -0.69$, df = 18, $P = 0.5001$). No statistically significant difference in the number of recruited females was recorded between the treatment and the control sites (Student t-test, $t = 0.07$, df = 18, $P = 0.9460$).

Experiment 3.—Experimental results are shown in Fig. 1. Overall, significantly more flies were encountered at Site 2 than at Site 1 (ANOVA, df = 1, 80, $F = 32.21$, $P = 0.0001$), with the number of flies being significantly affected both by the presence of a trap (ANOVA, df = 1, 80, $F = 210.56$, $P = 0.0001$), as well as by the time since trap placement on a tree (ANOVA, df = 4, 80, $F = 11.20$, $P = 0.0001$). Time trends were similar at both sites, as indicated by the absence of a statistically significant interaction between the site and the time (ANOVA, df = 4, 80, $F = 0.94$, $P = 0.4451$). At the same time, the interaction between the time and the trap was highly significant (ANOVA, df = 4, 80, $F = 12.07$, $P = 0.0001$), with a rapid increase in the fly numbers on the trees with a trap soon after trap placement, and virtually no change on the trees without a trap (Fig. 1). A three-way interaction among site, trap, and the time since the trap placement was not statistically significant (ANOVA, df = 4, 80, $F = 1.23$, $P = 0.3057$). On average, flies spent 66.37 seconds (SE = 10.05) on the tree before entering the trap.

DISCUSSION

Results of the present study once again demonstrate that methyleugenol-baited traps are highly attractive to Oriental fruit fly males. However, we did not find any increase in fly sexual activity in the vicinity of the deployed traps. It appears that the majority of males which are attracted to the odor of methyleugenol approach directly the source of the odor. Arrival rate curves observed in the present study for the flies landing on the tree containing a trap are similar to the curves reported by Nishida & Vargas (1990) for flies landing on their methyleugenol-baited traps. The recruited males feed on methyleugenol almost immediately upon their arrival and do not attempt to attract females and copulate before entering the trap. Such behavior is not unexpected, since male Oriental fruit flies incorporate methyleugenol metabolites into their sex pheromone (Nishida et al. 1988), and mating success of males fed on methyleugenol is significantly higher than mating success of males deprived of this compound (Shelly & Dewire 1994). Therefore, it is probably adaptive for males to ingest methyleugenol before trying to attract a mate. Actually, 40–50% of males respond to methyleugenol baits even before reaching full sexual maturity (Wong et al. 1989). Since there was no significant increase in male calling around the traps, and by itself methyleugenol is not very attractive to females (Steiner 1952), it is not surprising that we also did not detect any changes in female numbers following the deployment of methyleugenol-baited traps.

From a pest management perspective, it appears that using male lures on small farms will not attract additional Oriental fruit fly females from the surrounding vegetation, nor will it facilitate mating among the resident flies. Therefore, our original concern that the use of methyleugenol traps might in fact increase the level of fruit infestation appears to be unjustified. Still, it is unlikely that male annihilation alone can provide a satisfactory level of Oriental fruit fly control on small farms. This species is highly polygamous (Cunningham 1989). Therefore, even very few surviving males will be able to fertilize a substantial number of females, and each female can produce over 1000 eggs (Vargas et al. 1984). How-

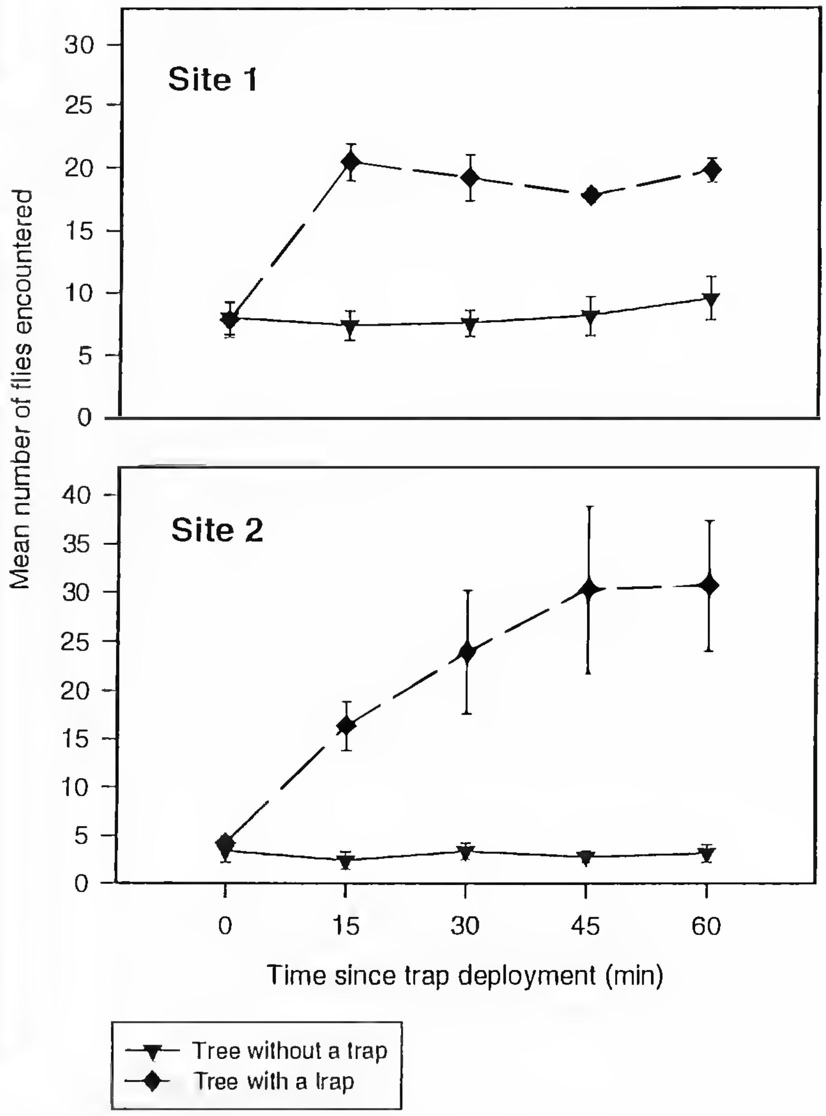

Figure 1. Effect of methyleugenol-baited traps on recruitment of Oriental fruit flies to fruit trees. The methyleugenol-baited trap consisted of a white plastic bucket with 4 entry holes and a single cotton wick soaked in methyleugenol-malathion mixture and hung by wire from the inner side of the bucket's lid. Error bars represent standard errors of measurement among 5 replications.

ever, low cost, high specificity, and environmental safety of methyleugenol-baited traps make them highly compatible with other management techniques, such as sterile male releases, biological control, bait sprays of environmentally friendly insecticides (e.g. spinosad), or visual lure-and-kill traps. Therefore, even though male lures alone are unlikely to solve the Oriental fruit fly problem, they might still be a valuable component of the future IPM systems.

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LITERATURE CITED

Analytical Software. 1996. Statistix for Windows, version 1.0. Analytical Software, Tallahassee, Florida.

Arakaki, N., H. Kuba & H. Soemori. 1984. Mating behavior of the Oriental fruit fly, *Dacus dorsalis* Hendel (Diptera: Tephritidae). Appl. Ent. Zool., 19: 42–51.

Christenson, L. C. & B. H. Foote. 1960. Biology of fruit flies. Annu. Rev. Entomol., 5: 171–192.

Conover, W. J. & R. L. Iman. 1981. Rank transformations as a bridge between parametric and nonparametric statistics. Am. Stat., 35: 124–129.

Cunningham, R. T. 1989. Male annihilation. pp. 345-351. *In* Robinson, A. S. & G. Hooper (eds.). Fruit flies: their biology, natural enemies, and control. V. 3B. Elsevier, Amsterdam.

Cunningham, R. T. & D. Y. Suda. 1986. Male annihilation through mass-trapping of male flies with methyleugenol to reduce infestation of Oriental fruit fly (Diptera: Tephritidae) larvae in papaya. J. Econ. Entomol., 79: 1580–1582.

Hadwen, W. L., A. Small, R. L. Kitching & R. A. I. Drew. 1998. Potential suitability of North Queensland rain forest sites as habitat for the Asian papaya fruit fly, Bactrocera papayae Drew and Hancock (Diptera: Tephritidae). Austr. J. Entomol., 37: 219–227.

Haramoto, F. H. & H. A. Bess. 1970. Recent studies on the abundance of the oriental and Mediterreanean fruit flies and the status of their parasites. Proc. Hawaiian Entomol. Soc., 20: 551–566.

Kobayashi, R. M., K. Ohinata, D. L. Chamber & M. S. Fujimoto. 1978. Sex pheromones of the oriental fruit fly and melon fly: mating behavior, bioassay method, and attraction of females by live males and by suspected pheromone glands of males. Environ. Entomol., 7: 107–112.

Koyama, J., T. Teruya & K. Tanaka. 1984. Eradication of the Oriental fruit fly (Diptera: Tephritidae) from the Okinawa islands by a male annihilation method. J. Econ. Entomol., 77: 468–472.

Lloyd, A., P. Leach & R. Kopittke. 1998. Effects of exposure on chemical content and efficacy of male annihilation blocks used in the eradication of Bactrocera papayae in North Queensland. Gen. Appl. Entomol., 28: 1–8.

Meats, A. 1998. Cartesian methods of locating spot infestations of the papaya fruit fly Bactrocera papayae Drew and Hancock within the trapping grid at Mareeba, Queensland, Australia. Gen. Appl. Entomol., 28: 1–8.

Mitchell, W. C. & S. H. Saul. 1990. Current control methods for Mediterranean fruit fly, Ceratitis capitata, and their application in the USA. Rev. Agric. Entomol., 78: 923–940.

Nishida, R., K. H. Tan, M. Serit, N. H. Lajis, A. M. Sukari, S. Takahashi & H. Kukami. 1988. Accumulation of phenylpropanoids in the rectal glands of males of the Oriental fruit fly, *Dacus dorsalis*. Experientia, 44: 534–536.

Nishida, T. & R. I. Vargas. 1990. Arrival rates of the Oriental fruit fly, Dacus dorsalis Hendel (Diptera: Tephritidae) to methyl eugenol. Proc. Hawaiian Entomol. Soc., 30: 105–112.

Shelly, T. E. & K. Y. Kaneshiro. 1991. Lek behavior of the Oriental fruit fly, *Dacus dorsalis*, in Hawaii (Diptera: Tephritidae). J. Insect Behav., 4: 235–241.

Shelly, T. E. & A.-L. M. Dewire. 1994. Chemically mediated mating success in male Oriental fruit flies (Diptera: Tephritidae). Ann. Entomol. Soc. Am., 87: 375–382.

Steiner, L. F. 1952. Methyl eugenol as an attractant for Oriental fruit fly. J. Econ. Entomol., 45: 241–248.

Steiner, L. F., W. C. Mitchell, E. J. Harris, T. T. Kozuma & M. S. Fujimoto. 1965. Oriental fruit fly eradication by male annihilation. J. Econ. Entomol., 58: 961–964.

Ushio, S., K. Yoshioka, K. Nakasu & K. Waki. 1982. Eradication of the Oriental fruit fly from Amami Islands by male annihilation. Jpn. J. Appl. Entomol. Zool., 26:1–9.

Vargas, R. I., O. Miyashita & T. Nishida. 1984. Life history and demographic parameters of three laboratory-reared tephritids (Diptera: Tephritidae). Ann. Entomol. Soc. Am., 77: 651–656.

Vargas, R. I., J. D. Stark & T. Nishida. 1989. Abundance, distribution, and dispersion indices of the oriental fruit fly and melon fly (Diptera: Tephritidae) on Kauai, Hawaiian Islands. J. Econ. Entomol., 82: 1609–1615.

Vargas, R. I., J. D. Stark & T. Nishida. 1990. Population dynamics, habitat preference, and seasonal distribution patterns of oriental fruit fly and melon fly in an agricultural areas. Environ. Entomol., 19: 1820–1828.

Vargas, R. I., J. D. Stark, M. H. Kido, H. M. Ketter & L. C. Whitehead. 2000. Methyl eugenol and cue-lure traps for suppression of male Oriental fruit flies and melon flies (Diptera: Tephritidae) in Hawaii: effects of lure mixtures and weathering. J. Econ. Entomol., 93: 81–87.

Wong, T. T. W., D. O. McInnis & J. I. Nishimoto. 1989. Relationship of sexual maturation rate to response of Oriental fruit fly strains to methyl eugenol. J. Chem Ecol., 15: 1399–1495.

Zar, J. H. 1999. Biostatistical Analysis (4th ed.). Prentice Hall, Upper Saddle River, New Jersey.

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NEW AND RARE SPECIES OF *PHYLLOPHAGA* (*S. STR.*) FROM MEXICO (COLEOPTERA: MELOLONTHIDAE, MELOLONTHINAE)

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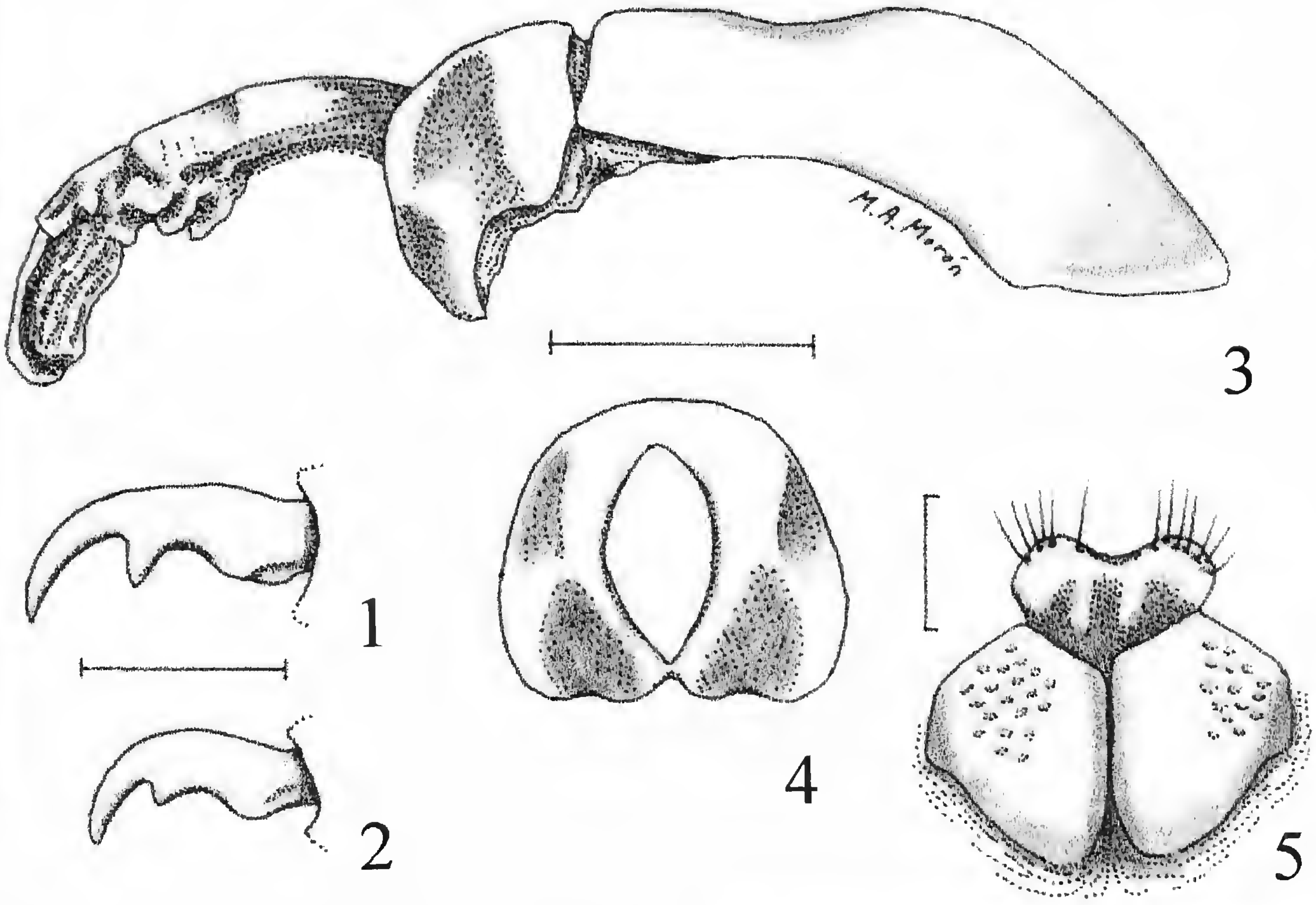
Abstract.—Seven new species of *Phyllophaga* (*s.str.*) are described from Mexican localities as follows: *P. cahitana* NEW SPECIES, from subtropical lowlands of northern Sinaloa; *P. quetzala* NEW SPECIES and *P. regiomontana* NEW SPECIES from pine-oak forests of Nuevo León and Tamaulipas; *P. quetzaloides* NEW SPECIES from temperate montane forests of northwestern San Luis Potosí; *P. stzotzilana* NEW SPECIES from deciduous tropical forests of northwestern Chiapas; *P. tsajumiana* NEW SPECIES and *P. papaloana* NEW SPECIES from pine-oak forests of northern Oaxaca. *Phyllophaga pilula* (Moser) and *P. nisuens* Saylor, previously known only by unique type specimens are redescribed with specimens collected in Chiapas and Oaxaca, respectively. Drawings of male genital capsules, and tarsal claws are provided.

Key Words.—Insecta, May beetles, *Phyllophaga,* taxonomy, Mexico.

Resúmen.—Se describen siete especies nuevas de *Phyllophaga* (*s. str.*) procedentes de seis localidades mexicanas: *P. cahitana* NUEVA ESPECIE de las tierras bajas del norte de Sinaloa, *P. quetzala* NUEVA ESPECIE y *P. regiomontana* NUEVA ESPECIE de los bosques de pino-encino del oeste de Nuevo León y Tamaulipas; *P. quetzaloides* NUEVA ESPECIE de los bosques de montaña al noroeste de San Luis Potosí; *P. stzotzilana* NUEVA ESPECIE del bosque tropical caducifolio del noroeste de Chiapas; *P. tsajumiana* NUEVA ESPECIE y *P. papaloana* NUEVA ESPECIE de los bosques de pino y encino del norte de Oaxaca. Con base en ejemplares recolectados en Chiapas y Oaxaca se redescriben *Phyllophaga pilula* (Moser) y *P. nisuens* Saylor, previamente solo conocidas por ejemplares tipo únicos. Se incluyen ilustraciones de las cápsulas genitales masculinas y de las uñas tarsales de todas las especies citadas.

Curatorial work of *Phyllophaga* specimens from Mexico, deposited in Canadian or United States collections, as well as from recent collection trips to poorly known localities in northwestern and southeastern regions of that country, provided specimens of many undescribed or little known species. Many of these possess diagnostic sets of external characters and male genital capsules that are very different from the known groups of species proposed by Morón (1986). Some of these may be arranged in future new groups of species, but others remain isolated, with uncertain position in the subgenus *Phyllophaga* (*s. str.*). Because many of these species are rare or scarce, it seems more appropriate to describe the new species, and redescribe the rare species while the new groups are configured. This paper gives descriptions of males and some females of seven new species of *Phyllophaga* (*s. str.*), and redescriptions and distributions of two species previously known only by unique type specimens. The characters and terms used in the descriptions are those of Sanderson (1958) and Morón (1986). Drawings were made with the aid of a camera lucida and Leica stereomicroscope and measurements were obtained with ocular micrometer or caliper.

Depository Abbreviations.—American Museum of Natural History, New York (AMNH); California Academy of Sciences, San Francisco (CASC); Canadian National Collection, Ottawa (CNC); Colegio de la Frontera Sur, San Cristóbal de Las Casas, Chiapas, México (ECOSUR); Instituto de Ecología, Xalapa, México



Figures 1–5. *Phyllophaga* (*s.str.*) *cahitana* Morón.
Figure 1. Male protarsal claw.
Figure 2. Female protarsal claw.
Figure 3. Male genital capsule, lateral view.
Figure 4. Paramera, distal view.
Figure 5. Female genital plates, ventral view. Scale lines: Figs. 1–2, 5 = 0.5 mm; Figs. 3–4 = 1 mm.

(IEXA); Los Angeles County Museum of Natural History, California (LACM); The Natural History Museum, London (BMNH); University of Nebraska State Museum, Lincoln, Nebraska (UNSM); Zoologisches Museum, Humboldt Universität zu Berlin, Germany (ZMHU); H. & A. Howden/Canadian Museum of Nature, Ottawa (HAHC); G. Nogueira, Guadalajara, México (GNGC) and M.A. Morón, Xalapa, México (MXAL).

Phyllophaga (*Phyllophaga*) *cahitana* Morón, NEW SPECIES
(Figs. 1–5)

Types.—(Described from 6 males and 5 females). Holotype, male; MEXICO. SINALOA: Los Mochis, 19 July 1960, W.W. Gibson; deposited: Canadian National Collection, Ottawa. Allotype, female; same data as holotype deposited: M.A. Morón collection, Xalapa. Paratypes: same data as holotype (4 females) (CNC); Sinaloa, Los Mochis, 29 August 1997, G. Nogueira (2 males) (MXAL); Sonora: Ciudad Obregón, 14 July 1960, W.W. Gibson (1 male) (HAHC); Obregón, 29 July 1952, C. & P. Vaurie (1 male) (AMNH); same data except 3 August 1952 (1 male) (AMNH).

Holotype.—Male. Head reddish brown, pronotum, elytra, sterna, pygidium and legs yellowish brown, with silky luster. Clypeus wider than long (3.1:1), anterior border widely sinuated with margins moderately elevated, surface slightly convex, with many shallow, circular punctures, without setae. Fronto-clypeal suture clearly sinuated and finely impressed. Frons wider than long (1.7:1) convex, densely punctate, without setae. Antenna 10 segmented, with 3 segmented club; lamellae 1.3× longer than the six preceding segments combined, segments 4° or 5° as long as segment 3, segments 6° and 7° wider than long, with acute process directed forward. Frons 4.4× wider than each eye dorsal diameter. Canthus narrowed, curved and rounded, with 6 short setae. Labrum deeply bilobed, with scattered setae on the borders. Mentum widely concave, polished, with scarce setae, anterior border briefly notched. Pronotum wider than long (1.6:1) and 2.3× wider than frons. Pronotal disk with round, shallow punctures regularly dispersed, separated by 1–3 diameters, without setae; lateral borders widely angulated, marginal bead fine and irregularly crenulate, with scarce, short setae; anterior angles obtuse, slightly pointed out; posterior angles obtuse, pointed out. Scutellum 1.4× wider than long, with 10 shallow, small punctures. Elytron 2.2× longer than wide, densely punctate, without macroscopic setae; epipleural border narrowed, extended along the complete margin, with scattered, minute setae; humeral calla rounded, prominent; apical calla rounded, diffuse. Metathoracic wings completely developed. Propygidium with silky luster, fine and sparcely punctate, without setae. Pygidium slightly convex, with silky luster, sparce and shallowly punctate, glabrous; apical margin with 10 short setae; basal margin effaced from side to side. Pterosternum with scarce, short, yellowish vestiture. Visible abdominal sternites 2° to 4° convex at the midline with scattered, short setae, sternite 5° convex, with some short setae at the middline; anal plate shortened, slightly convex, with some, small punctures, and anterior border slightly thickened, with 6 scattered setae near the posterior border. Protibiae shorter than protarsi (0.8:1), with two big teeth and one small tooth on external border, preapical spur long, straight, acute, shorter than 2° protarsomerus. Mesotibiae with one oblique, strong, setiferous, transverse carina across external side, and one point with 2 short spines along dorsal border; upper apical spur nearly straight, narrow, 1.2× longer than lower spur. Metatibiae nearly as long as metatarsi (0.9: 1), with one oblique, strong setiferous transverse carina across external side, and one point with 2 short spines along dorsal border; apical spurs articulated with border, upper spur curved, with rounded apex, slightly shorter than 2° metatarsomerus, and 1.1× longer than lower spur. Tarsomeres semicylindrical, elongated, with enlarged apex, some setae around the apex and two irregular lines of some setae ventrally. Tarsal claws symmetrical, similar on all legs, with short teeth located near the middle of ventral border (Fig. 1).

Genital capsule with short, wide paramera, fused at their basis, distal half widened and slightly compressed, with apex briefly sinuated and nearly fused toward mid-line. Tectum convex. Aedeagus long, with sclerotized narrow, tube-like support (Figs. 3–4). Length of genital capsule from the apex of parameres to the border of basal piece: 2.6 mm. Total body length: 7.2 mm. Humeral width: 4.8 mm.

Allotype.—Female. Similar to the male except as follows: antennal club as long as the preceding five segments; distal half of elytra more rounded; pygidial shape more triangular, disk less convex; visible abdominal sternite 5° convex, with scattered setiferous punctures; anal plate convex, shallowly punctate, with 8 short setae near the posterior border. All tarsi shorter than tibiae. Apical spurs of metatibiae more wide and curvated than in male, with rounded apex. Tarsal claws with small teeth located before the middle of ventral border (Fig. 2). Ventral genital plates strongly sclerotized, nearly symmetrical, convex, with shallow punctures toward the sides, without setae; dorsal genital plates fused, with wide, rounded distal borders provided with 6–7 setae on each side (Fig. 5). Total body length: 11.2 mm. Humeral width: 5.1 mm.

Type Locality.—Between Los Mochis, state of Sinaloa and Ciudad Obregón, state of Sonora, México (25°47′–27°29′ N; 109°0′–109°57′ W).

Variation.—Male paratypes are similar to the holotype except as follows: body color dark reddish brown to light yellowish brown; pronotal lateral borders more or less rounded; pygidium with more punctures; total body length: 7.2–13.5 mm, humeral width: 4.6–6.0 mm. Female paratypes are similar to the allotype except by total body length: 7.0–14.6 mm; humeral width: 5.2–6.0 mm.

Biological Data.—Specimens of *P. cahitana* were collected at lights in open deciduous tropical forest, thorn forest and xeric shrubs located from 10 to 50 m of altitude, with 25–26° C mean annual temperature and 307–320 mm total annual rainfall, where *Prosopis juliflora* (Swartz) DC, *Acacia cymbispina* Spregue et Riley, *Cercidium torreyanum* (Wats.) Sarg. and *Pithecollobium sonorae* Wats

(Caesalpinaceae) are the most common trees. Phenology: July (8), August (3). The other species of *Phyllophaga* flying at the same time and places were *P.* (*s.str.*) *fucata* (Horn), and one undescribed species of *P.* (*Listrochelus*).

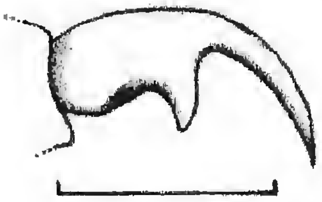
Remarks.—*Phyllophaga cahitana* resembles some species in the species group *fucata* (*sensu* Morón 1986), by the external characters, as well as the shape of clypeus, pronotum and elytra, style of punctuation, reduced vestiture, shape of male tarsal claws and female dorsal genital plates, however, the compressed shape of parameres is quite different from the short tube-like parameres of *P. fucata* or *P. opaca* (Moser). Also, the tooth of the tarsal claws in female *P. cahitana* are smaller than in *P. fucata,* and the female tarsi of the latter are longer than in *P. cahitana.*

Etymology.—Derived from the indigenous people named "*Cahita*" that actually live in some localities of Sonora and Sinaloa, speaking the language "*cahita*" (Tarahumara-Cahita subgroup of Sonoran languages), also known as "Yaqui" or "Mayo" (Manrique 1988).

PHYLLOPHAGA (*PHYLLOPHAGA*) *QUETZALA* MORÓN, NEW SPECIES
(Figs. 6–14)

Types.—(Described from 26 males and 49 females). Holotype, male; MEXICO. NUEVO LEÓN, Monterrey, Mesa Chipinque, 26–29 August 1960, H. F. Howden; deposited Canadian National Collection, Ottawa. Allotype female; same data as holotype; deposited A. & H. Howden/Canadian Museum of Nature, Ottawa. Paratypes: same data as holotype, except "on walnut" (7 males, 19 females) (CNC; MXAL); Mesa Chipinque, nr. Monterrey, 8 July 1963, light, A. T. Howden (1 male) (HAHC); same data except 30 July 1963 (1 male, 1 female) (HAHC); near Monterrey, Mesa Chipinque, 5400′, 30 July 1963, H. Howden (6 females) (CNC); 6 mi S Monterrey, 17 July 1963, H. & A. Howden (1 male) (CNC); Chipinque, 22 June 1971, H.F. Howden (1 male, 1 female) (HAHC); 10 km S Chipinque, 4500′, 2 June 1983, UV, K. Kaulbars & R. Anderson (9 males, 20 females) (HAHC; MXAL); TAMAULIPAS, Gómez Farías, 29 June 1969, deciduous forest, S. & J. Peck, (1 female) (HAHC); Ciudad Victoria, Rancho La Reja, 30 July / 1 August 1981, 6000–8000′ B. C. Ratcliffe & C. L. Messenger (6 males, 1 female) (UNSM; MXAL).

Holotype.—Male. Head and pronotum, shiny dark brown, elytra, pygidium, sterna and legs shiny reddish brown, slightly pruinose, with iridescent luster. Clypeus bilobed, wider than long (4:1), anterior border deeply sinuated with margins slightly elevated (Fig. 11), disk surface convex, with dense, round punctures, and erect, short setae. Fronto-clypeal suture slightly curved, clearly impressed. Frons wider than long (3:1) convex, rugo-punctate, with medium size, whitish, slender setae. Antenna 10 segmented, with 3 segmented club; lamellae as long as the length of the six preceding segments combined, segments 4° or 5° as long as segment 3°, segments 6° and 7° wider than long, each one with large, acute process directed forward. Frons 6× wider than each eye dorsal diameter. Canthus curved and rounded, with 9 setae. Labrum bilobed, deeply notched, with curved slender, long setae on borders. Mentum wide and shallowly concave, polished, with lateral slender setae, anterior border briefly sinuate. Pronotum wider than long (1.7:1) and 2.2× wider than frons. Pronotal disk with dense, round punctures uniformly distributed, separated by a distance of 1–2 diameters, with erect, whitish medium size setae; lateral borders strongly angulated, marginal bead crenulate, with long, slender setae; anterior angles right, prominent; posterior angles slightly obtuse, prominent. Scutellum 1.9× wider than long, with 48 round, shallow setiferous punctures. Elytron 2.5× longer than wide, densely punctate, with dense, erect, whitish, medium size setae, uniformly distributed; epipleural border extended along the complete margin, narrowed toward the apex and provided with a fringe of short setae; humeral calla



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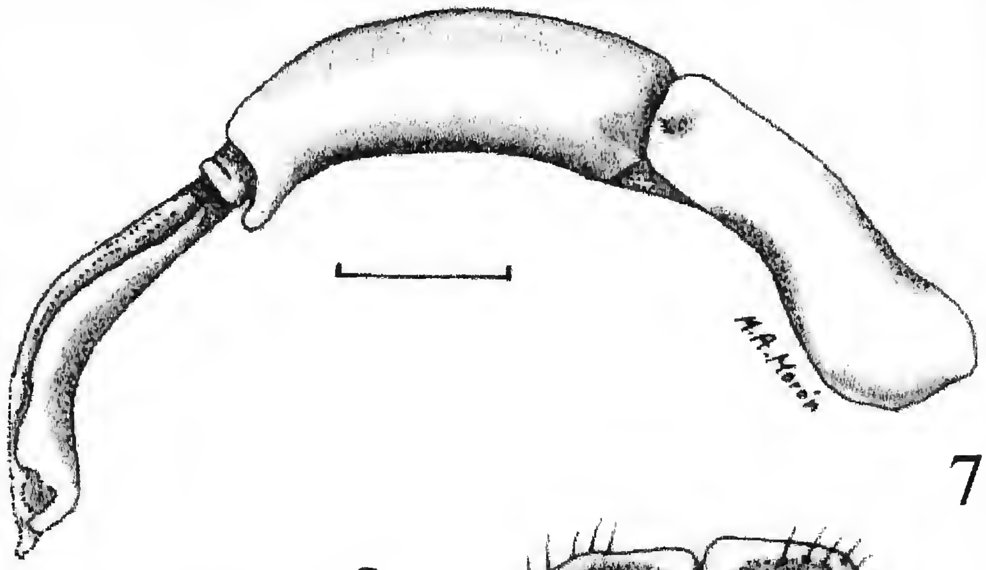

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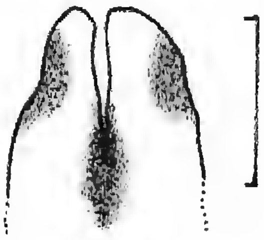

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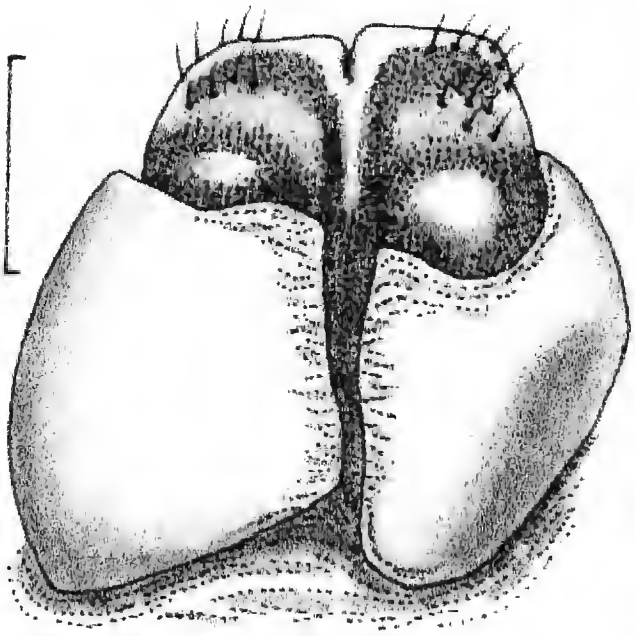

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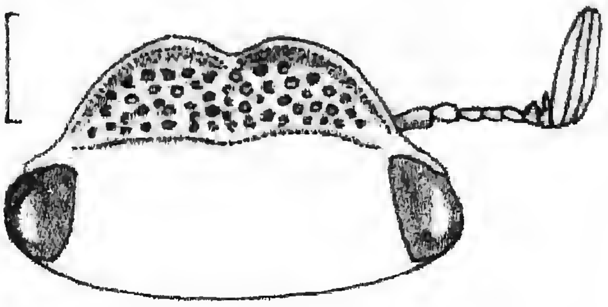

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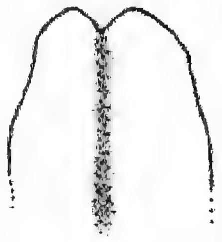

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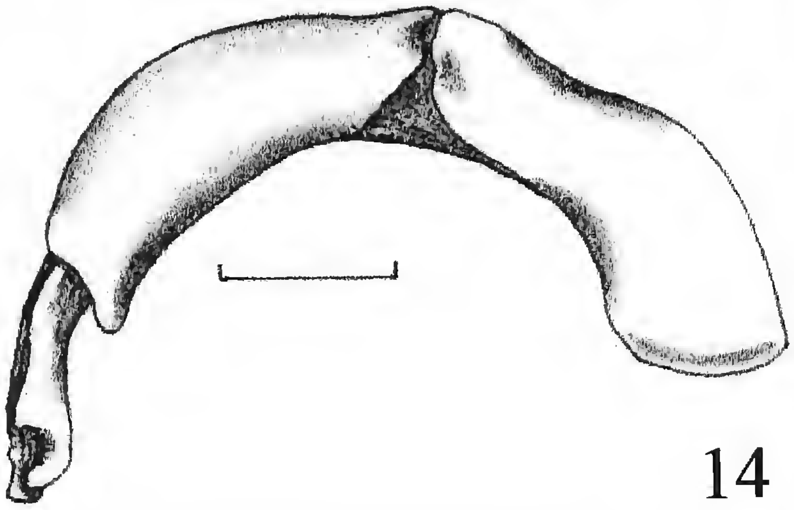

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Figures 6–14. *Phyllophaga* (*s.str.*) *quetzala* Morón.
Figure 6. Male protarsal claw.
Figure 7. Holotype genital capsule, lateral view.
Figure 8. Paramera and aedeagus of holotype, dorsal view.
Figure 9. Apex of paramera of holotype, dorsal view.
Figure 10. Allotype genital plates, ventral view.
Figure 11. Paratype head, dorsal view.
Figure 12. Apex of paramera of paratype, dorsal view.

rounded, prominent; apical calla rounded. Metathoracic wings completely developed. Propygidium shiny, densely punctate, covered with many whitish, short setae. Pygidium shiny, slightly convex, densely punctate and covered with many whitish, short setae; apical margin with 14 slender setae; basal margin effaced at the middle. Pterosternum with long, dense, whitish setae. Visible abdominal sternites 2° to 4° convex at the midline, densely covered with whitish, short setae on all surface; sternite 5° convex, prominent, with vague patch of granules at the middle, densely covered with whitish, short setae; anal plate shallowly concave, granulose-punctate, with some erect, slender setae, anterior border with vague bead and posterior border moderately thickened. Protibiae nearly as long as protarsi (0.9:1), with two big, rounded teeth toward the apex and one small tooth near the middle on external border, preapical spur long, straight, acute, slightly longer than 2° protarsomerus (0.8:1). Mesotibiae with one oblique, strong, setiferous, transverse carina, and setiferous point on external side; upper apical spur nearly straight, narrowed, 1.3× longer than the lower spur. Metatibiae shorter than metatarsi (0.8:1), with one oblique, strong setiferous transverse carina and setiferous point on the external side; apical spurs articulated with the border, upper spur, straight, narrow, with acute apex, shorter than 2° metatarsomerus, and 1.5 longer than the lower spur. Tarsomeres semicylindrical, elongated, with enlarged apex, some setae around the apex and scattered setae ventrally; metatarsomeres 1°–4° ventrally with one row of short, stout setae. Tarsal claws symmetrical, similar on all legs, with large, curved tooth near the middle of ventral border (Fig. 6). Genital capsule with long, curved, tube-like paramera, fused at their basis, apex dorsally deep cleft, ventrally narrowly cleft. Tectum convex. Basal piece slightly shorter than paramera (1:1.1). Aedeagus long, with sclerotized, sinuose, narrow support (Figs. 7–9). Length of genital capsule from the apex of parameres to the border of basal piece: 4.5 mm. Total body length: 15.5 mm. Humeral width: 6.6 mm.

Allotype.—Female. Similar to holotype except as follows: antennal club as long as the 5 preceding segments; disk of pygidium less convex, with apical fifth slightly upturned; 5° sternite convex, without granules at the middle; apical spurs of metatibiae widened, lanceolate; anal plate convex, with scattered erect whitish setae. Ventral genital plates strongly sclerotized, slightly asymmetrical, convex, with microscopic punctures toward borders, without setae; dorsal genital plates fused, with wide, truncated distal borders provided with 10–12 setae on each side, and rounded prominences near the middle proximal surface (Fig. 10). Total body length: 16.0 mm. Humeral width: 6.9 mm.

Type Locality.—Mesa de Chipinque, west of Monterrey city, state of Nuevo León, México (approx. 25°36′ N; 100°38′35″ W).

Variation.—Male paratypes from 10 km S Chipinque are similar to the holotype except in the length and width of tube-like paramera, degree of dorsal and ventral curves of paramera, and deep and width of apical notch of paramera (Figs. 12–14). Male paratypes from Rancho La Reja, Ciudad Victoria, Tamaulipas have long, erect, slender setae mixed with short setae on the elytra, but the shape of paramera is similar to the specimens from 10 km S Chipinque. Total body length: 15.2–18.2 mm, humeral width: 6.1–8.0 mm. Female paratypes from Nuevo León localities are similar to the allotype except by total body length: 15.2–16.3 mm; humeral width: 6.4–7.0 mm. Female paratype from Rancho La Reja, have long, erect setae mixed with short setae on the elytra, the ventral genital plates with distal border widely notched, and the prominences near the middle proximal surface of dorsal genital plates are less rounded.

Biological Data.—Specimens of *P. quetzala* was collected at lights or on walnut trees (*Juglans mollis* Engelm.) in temperate mixed forests with *Quercus monterreyenensis*, *Q. polymorpha* Schl. et Cham., *Q. clivicola* (Fagaceae), *Carya myristiciformis* (Michx.) (Juglandaceae), and *Pinus teocote* Schl. et Cham. (Pinaceae), located at 1400–2600 m of altitude. Phenology: June (32), July (17), August (26). The other species of *Phyllophaga* flying at the same time and place was *P.* (*s.str.*) *rolbakeri* Saylor.

Remarks.—*Phyllophaga quetzala* is similar to *P. opacita* Reinhardt from south-

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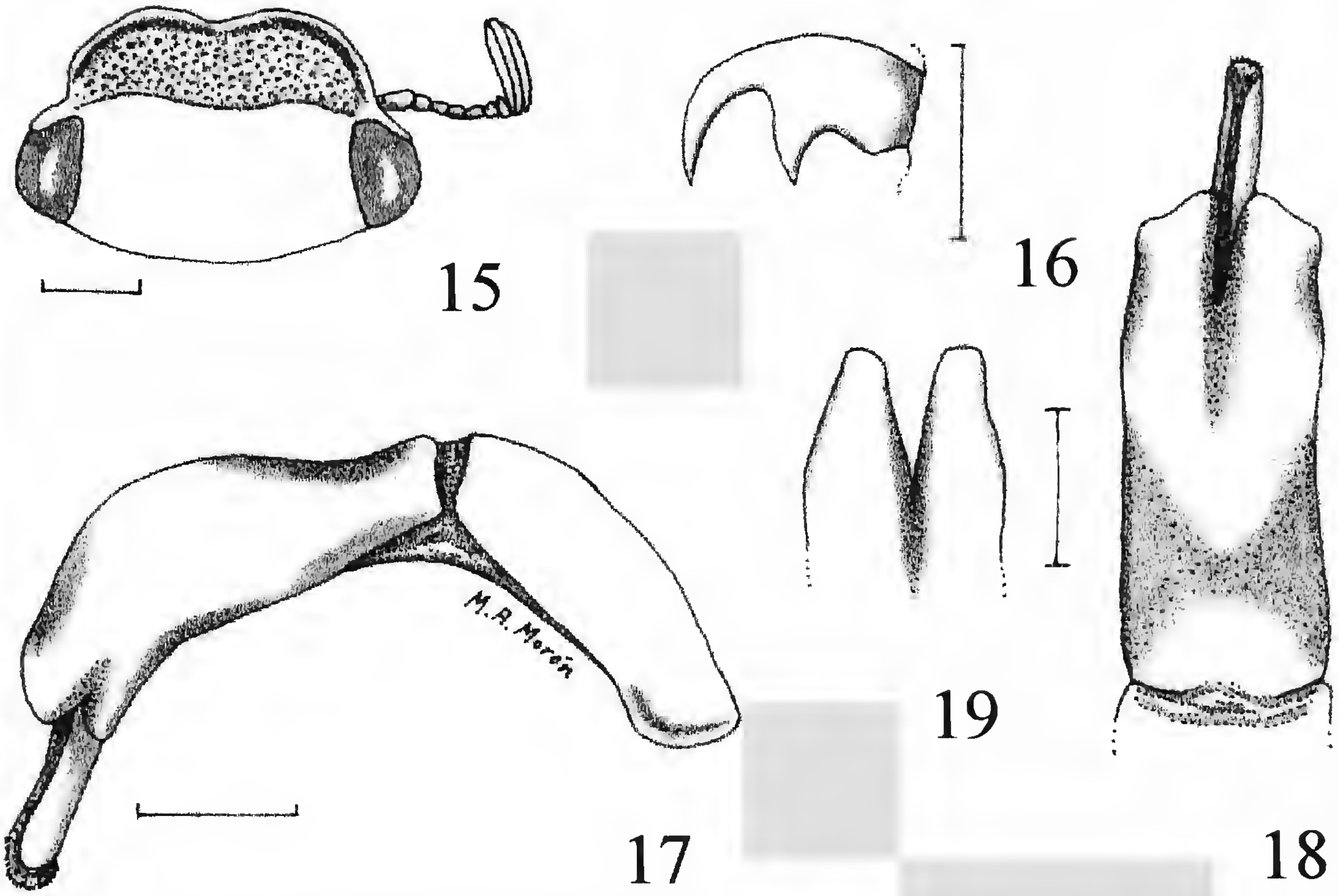
Figure 13. Apex of paramera of paratype, ventral view.

Figure 14. Paratype genital capsule, lateral view. Scale lines: Figs. 6, 10 = 0.5 mm; Figs. 7–9, 11–14 = 1 mm.



Figures 15–19. *Phyllophaga* (*s.str.*) *quetzaloides* Morón.
Figure 15. Holotype head, dorsal view.
Figure 16. Male protarsal claw.
Figure 17. Holotype genital capsule, lateral view.
Figure 18. Paramera and aedeagus, dorsal view.
Figure 19. Apex of paramera, ventral view. Scale lines: Figs. 16 = 0.5 mm; Figs. 15, 17–19 = 1 mm.

ern Texas in general body shape, form of clypeus, kind of body vestiture, form of tarsal claws, and basic structure of paramera, but the tube-like paramera of the new species are much longer with the ventro-apical border much shorter, and the apex of the aedeagus does not have sclerotized spines; male of *P. opacita* have the middle of 5° sternite clearly granulose, and the dorsal punctuation much finer. Also, *P. quetzala* is closely related to *P. quetzaloides* n.sp., as described below.

Etymology.—Derived from old Nahuatl language "*quetzalli*", meaning "something beautiful, pretty, or special" (Simeón 1975), because this species have a nice presence with the combination of abundant whitish setae and iridescent luster of tegument.

PHYLLOPHAGA (*PHYLLOPHAGA*) *QUETZALOIDES* MORÓN, NEW SPECIES
(Figs. 15–19)

Types.—(Described from 2 males). Holotype, male; MEXICO. SAN LUIS POTOSÍ, 6.8 mi W Chupaderos, 11 July 1973, 3400′, R.R. Snelling & T.W. Taylor; deposited: Los Angeles County Museum, California. Paratype: Same data as holotype (1 male) (MXAL).

Holotype—Male. Head and pronotum, shiny dark brown, elytra, pygidium, sterna and legs shiny reddish brown, slightly pruinose, with vague iridescence. Clypeus bilobed, wider than long (3.7:1), anterior border deeply sinuated with margins moderately elevated (Fig. 15), disk surface concave, densely rugo-punctate, with erect, short setae. Fronto-clypeal suture slightly curved, clearly impressed.

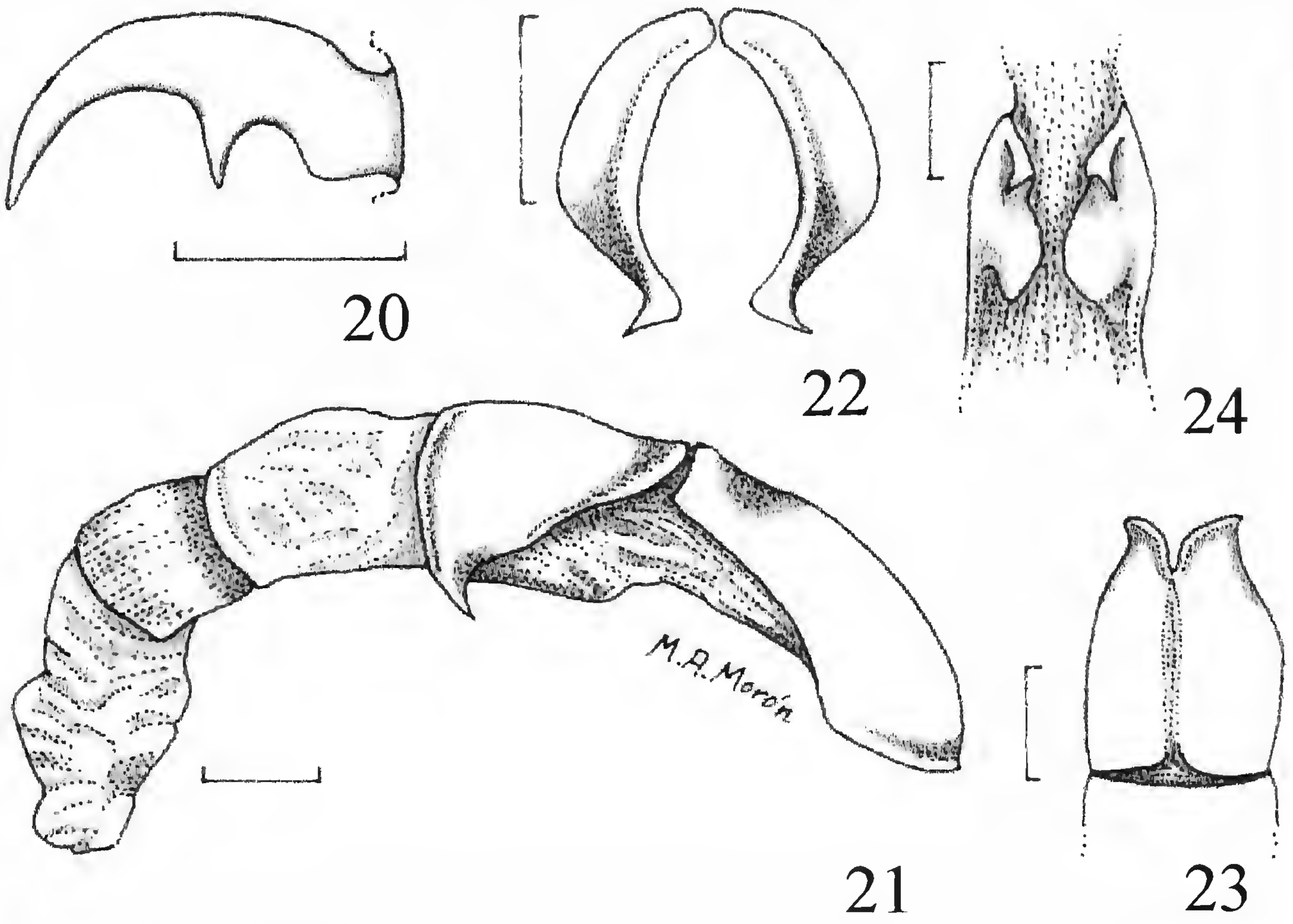
Frons wider than long (3:1) convex, rugo-punctate, with medium size, whitish, erect, slender setae. Antenna 10 segmented, with 3 segmented club; lamellae as long as the length of the six preceding segments combined, segments 4° or 5° as long as segment 3°, segments 6° and 7° wider than long, each one with acute process directed forward. Frons 4.2× wider than each eye dorsal diameter. Canthus curved and rounded, with 10 setae. Labrum bilobed, deeply notched, with curved slender, long setae on borders. Mentum wide and shallowly concave, polished, with lateral slender setae, anterior border notched. Pronotum wider than long (1.6:1) and 2.4× wider than frons. Pronotal disk with dense, round punctures uniformly distributed, separated by a distance of 1 diameter, or less, with erect, whitish medium size setae; lateral borders strongly angulated, marginal bead deeply crenulate, with long, slender setae; anterior angles right, prominent; posterior angles slightly obtuse, slightly prominent. Scutellum 1.7× wider than long, with 65 round, shallow, setiferous punctures. Elytron 2.4× longer than wide, densely punctate, with dense, erect, whitish, medium size setae, uniformly distributed; epipleural border extended along the complete margin, narrowed toward the apex and provided with dense fringe of short setae; humeral calla rounded, prominent; apical calla rounded. Metathoracic wings completely developed. Propygidium shiny, densely punctate with many whitish, short setae on all surface. Pygidium shiny, moderately convex, densely punctate with many whitish, short setae on all surface; apical margin with 18 slender setae; basal margin effaced at the middle. Pterosternum with long, dense, whitish setae. Visible abdominal sternites 2° to 4° convex at the midline, densely covered with whitish, short setae on all surface; sternite 5° convex, prominent, with vague patch of granules at the middle, densely covered with whitish, short setae; anal plate shallowly concave, granulose-punctate, with some erect, slender setae, anterior border with vague bead and posterior border moderately thickened. Protibiae slightly shorter than protarsi (0.7:1), with two big, rounded teeth toward the apex and one small tooth near the middle on external border, preapical spur long, straight, acute, as long as 2° protarsomerus. Mesotibiae with one oblique, strong, wide, setiferous, transverse carina, at middle of external side, and other short transverse, setiferous carina toward basal articulation; upper apical spur nearly straight, narrowed, 1.2× longer than the lower spur. Metatibiae shorter than metatarsi (0.7:1), with one oblique, strong, wide, setiferous transverse carina near the middle of external side and other, short, setiferous carina toward the basal articulation; apical spurs articulated with the border, upper spur, straight, narrow, with acute apex, shorter than 2° metatarsomerus, and 1.3× longer than lower spur. Tarsomeres semicylindrical, elongated, with enlarged apex, some setae around the apex and scattered setae ventrally; metatarsomeres 1°–4° ventrally with one row of short, stout setae. Tarsal claws symmetrical, similar on all legs, with wide, curved tooth near the middle of ventral border (Fig. 16). Genital capsule with long, curved, tube-like paramera, fused at their basis, apex dorsally deep cleft, ventrally notched. Tectum convex. Basal piece shorter than paramera (1:1.4). Aedeagus long, with sclerotized, straight, narrow support (Figs. 17–19). Length of genital capsule from the apex of parameres to the border of basal piece: 4.3 mm. Total body length: 17.1 mm. Humeral width: 6.9 mm. *Female.* Unknown.

Type Locality.—Sierra de Charcas, Charcas, state of San Luis Potosí, México (approx. 23°9′ N; 101°15′ W).

Variation.—Male paratype is similar to the holotype except in body color reddish brown and total body length: 17.4 mm, humeral width: 7.0 mm.

Biological Data.—Specimens of *P. quetzaloides* were collected at lights in oak forest with *Quercus crassifolia* H. & B. and *Q. microphylla* Née (Fagaceae), located at 1100 m of altitude. Phenology: July (2). Sierra de Charcas, San Luis Potosí is approximately 280 km from Mesa de Chipinque, Nuevo León, and 200 km from Sierra Peña Nevada, Tamaulipas, where *P. quetzala* Morón occurs; these montane subsystems probably were connected in the recent past by way of Sierra de Catorce, S.L.P. and Sierra de Potosi, Nuevo León. The other species of *Phyllophaga* flying at the same time and place was *P. (s.str.) rugipennis* (Schauffus).

Remarks.—*Phyllophaga quetzaloides* is similar to *P. quetzala* Morón in its body shape, kind of body vestiture, and tube-like structure of the paramera, but dorsally the apices of the paramera in *P. quetzaloides* are longer and wider than in *P. quetzala,* and ventrally the apices in *P. quetzaloides* are longer and more separated than in *P. quetzala.* Externally, the former species are much densely



Figures 20–24. *Phyllophaga* (*s.str.*) *regiomontana* Morón.
Figure 20. Male protarsal claw.
Figure 21. Holotype genital capsule, lateral view.
Figure 22. Paramera, distal view.
Figure 23. Paramera, dorsal view.
Figure 24. Paramera, ventral view. Scale lines: Fig. 20 = 0.5 mm; Figs. 21–24 = 1 mm.

punctate, with anterior border of clypeus widely bilobed, 7° antennal segment without acute anterior projection, pygidium more convex, and tarsal claws slightly shorter and wider than in *P. quetzala.* It is very possible that *P. opacita*, *P. arcta* (Horn), *P. quetzala* and *P. quetzaloides* are part of a group of species distributed from Alabama and Texas to the northwestern mountains of Mexico, but is necessary to obtain more samples from montane localities in Coahuila, Nuevo León, Tamaulipas and San Luis Potosí, before describing the new group. According with Luginbill & Painter (1953) *P. opacita* and *P. arcta* also are not common species.

Etymology.—Derived from old Nahuatl language "*quetzalli*", and Greek suffix "*oeidos*", Neolatin "*oides*", denoting likeness of form (Jaeger 1978) because this species is very similar to *P. quetzala* Morón.

Phyllophaga (*Phyllophaga*) *Regiomontana* Morón, NEW SPECIES
(Figs. 20–24)

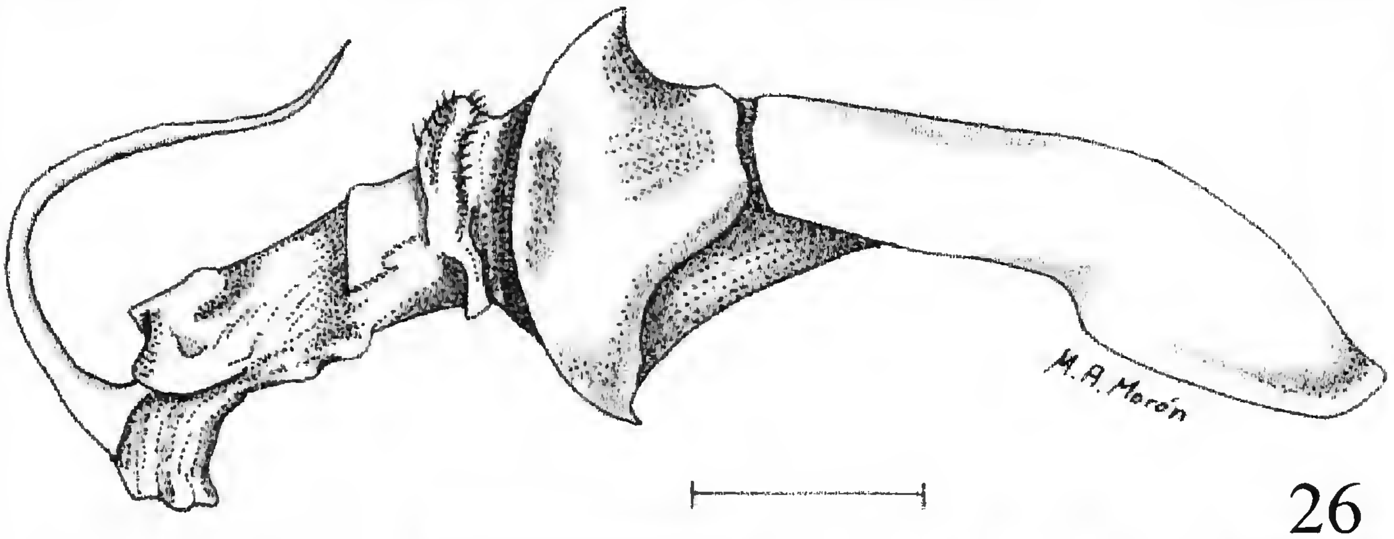
Types.—(Described from 3 males). Holotype, male; MEXICO: NUEVO LEÓN, Monterrey, Mesa Chipinque, 26 June 1974, B.C. Ratcliffe; deposited: University of Nebraska State Museum, Lincoln. Paratypes: Same data as holotype (2 males) (UNSM; MXAL).

Holotype.—Male. Head shiny dark brown, pronotum, elytra, pygidium, sterna and legs shiny reddish brown; each elytron with interstriae slightly pruinose, whitish dull. Clypeus bilobed, wider than long (3.3:1), anterior border deeply sinuated with margins moderately elevated, disk surface convex, coarsely rugo-punctate, with erect, long setae. Fronto-clypeal suture vaguely sinuate, partially covered by rugose punctures. Frons wider than long (2.5:1) convex, irregularly rugo-punctate, with yellowish, long, erect setae. Antenna 10 segmented, with 3 segmented club; lamellae slightly longer than the length of the five preceding segments combined (1.2:1), segments 4° or 5° nearly as long as segment 3°, segments 6° and 7° wider than long, each one with acute process directed forward. Frons 5.5× wider than each eye dorsal diameter. Canthus narrow, curved and rounded, with 11 setae. Labrum bilobed, deeply notched, with curved slender, long setae on borders. Mentum wide and shallowly concave, polished, with transverse narrow sulcus near the middle and lateral slender setae, anterior border widely notched. Pronotum wider than long (1.8:1) and 2.0× wider than frons. Pronotal disk with deep, round punctures, densely grouped toward anterior border and irregularly scattered toward the sides and posterior border; with many erect, yellowish, very long setae near the anterior margin; basal bead with deep punctures and long, erect setae; lateral borders strongly angulated, lateral bead deeply crenulate, with long, erect setae; anterior angles nearly right, clearly prominent; posterior angles slightly obtuse, poorly prominent. Scutellum 1.7× wider than long, with 22 round, shallow, scattered punctures with minute setae. Elytron 3× longer than wide, with dense, irregular, deep, round punctures, and scattered, short setae on the disk; some erect, long setae near midline and near lateral borders; epipleural border extended along the complete margin, narrowed toward the apex and provided with fringe of long setae; humeral calla rounded, prominent; apical calla rounded. Metathoracic wings completely developed. Propygidium dull, densely punctate with many short setae mainly toward posterior border. Pygidium slightly dull, moderately convex, with high number of shallow, round punctures and mixture of short and medium size setae on disk; apical margin with 2 slender setae; basal margin effaced at middle. Pterosternum with long, dense, yellowish setae. Visible abdominal sternites 2° to 4° convex at the midline, finely punctate with scattered, short setae; sternite 5° convex, prominent, slightly rugo-punctate at middle, with scattered short setae toward posterior border; anal plate very short, transversely sulcated, punctate, with some setae on sides and middle of posterior border; anterior border clearly elevated toward sides. Protibiae slightly shorter than protarsi (0.9:1), with two big, rounded teeth toward the apex and one small tooth near the middle on external border, preapical spur long, straight, acute, as long as 2° protarsomerus. Mesotibiae with one oblique, strong, wide, setiferous, transverse carina, at middle of external side, and other short transverse, setiferous carina toward basal articulation; upper apical spur nearly straight, narrowed, 1.2× longer than the lower spur. Metatibiae shorter than metatarsi (0.7:1), with one oblique, strong, wide, setiferous transverse carina near the middle of external side and one acute, short, setiferous tubercle toward basal articulation; apical spurs articulated with border, upper spur, straight, narrow, with rounded apex, shorter than 2° metatarsomerus, and 1.2× longer than lower spur. Tarsomeres semicylindrical, elongated, with enlarged apex, some setae around the apex and scattered setae ventrally; metatarsomeres 1°–4° ventrally with 1 or 2 rows of short, stout setae. Tarsal claws symmetrical, similar on all legs, with short, acute tooth after the middle of ventral border (Fig. 20). Genital capsule with moderately long, wide paramera, not fused at their basis, apex ventrally with acute spine. Tectum slightly concave. Basal piece longer than paramera (1.5:1). Aedeagus long, wide, with slightly sclerotized, preapical ring, without macroscopic spines or other sclerotized plates (Figs. 21–24). Length of genital capsule from the apex of parameres to the border of basal piece: 5.8 mm. Total body length: 17.9 mm. Humeral width: 7.2 mm. *Female.* Unknown.

Type Locality.—Mesa de Chipinque, west of Monterrey city, state of Nuevo León, México (approx. 25°36′ N;100°38′ 35″ W).

Variation.—Male paratypes are similar to the holotype except in number of erect long setae around the pronotum, and along the elytra; extension of whitish pruinosity on sternites and sides of elytra; total body length: 17.2–17.4 mm, humeral width: 7.0–7.1 mm.

Biological Data.—Specimens of *P. regiomontana* were collected at lights in mixed temperate forest located at an altitude of 1000 m, formed by *Quercus clivicola*, *Q. canbyi* Trel. (Fagaceae), *Juglans mollis* Engelm., *Carya myristiciformis* (Michx.) (Juglandaceae) and *Pinus pseudostrobus* Lindl. (Pinaceae). Phenology: June (3). No other species of *Phyllophaga* were recorded flying at the same time and place.



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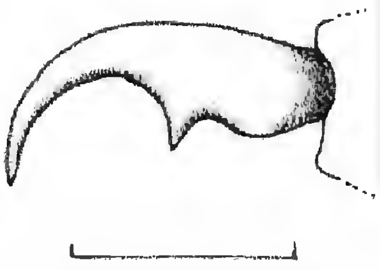

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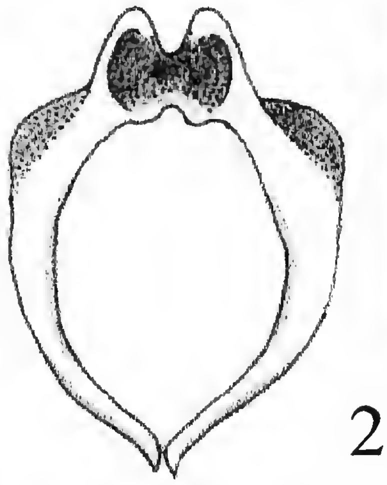

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Figures 25–27. *Phyllophaga* (*s.str.*) *stzotzilana* Morón.
Figure 25. Male protarsal claw.
Figure 26. Paratype genital capsule, lateral view.
Figure 27. Paramera, distal view. Scale lines: Fig. 25 = 0.5 mm; Figs. 26–27 = 1 mm.

Remarks.—*Phyllophaga regiomontana* is not related to any known Mexican species. Basic structure of the paramera is similar to *P. dispar* (Burmeister) from the southeastern United States, but the spine-like apex of paramera of latter are longer and turned to the midline ventrally, the antenna is composed of 9 segments, the anterior border of clypeus is entire and the abdominal sternites are flattened mesially.

Etymology.—Derived from Spanish name "*regiomontano (a)*" given to the people and things from the Monterrey city and surrounding areas; meaning "from the mountain of the king".

Phyllophaga (*Phyllophaga*) *stzotzilana* Morón, NEW SPECIES
(Figs. 25–27)

Types.—Described from 2 males. Holotype, male; MEXICO: CHIAPAS, Cañón del Sumidero, (17 km N Tuxtla Gutiérrez), Mirador La Coyota, 20 May 1979, 1340 m, R. Terrón; deposited: M.A. Morón collection, Xalapa. Paratype: Chiapas, Ocozocuautla, El Ocote, Ejido Nueva Providencia, 16 May 1996, O. Gómez (1 male) (ECOSUR).

Holotype.—Male. Head and pronotum shiny dark reddish brown, elytra, pygidium, and sterna reddish brown with whitish dull, pruinose vestiture, legs shiny reddish brown. Clypeus rounded, wider than long (3.6:1), anterior border nearly straight with margins noticeably elevated, disk surface deep concave, coarsely rugo-punctate, with erect, slender setae. Fronto-clypeal suture deeply sinuate, partially covered by rugose punctures. Frons wider than long (1.7:1) convex, coarsely rugo-punctate, with yellowish, long, erect setae. Antenna 10 segmented, with 3 segmented club; lamellae 1.6× longer than the length of the five preceding segments combined, segments 4° or 5° nearly as long as segment 3°, segments 6° and 7° wider than long, each one with acute process directed forward. Frons 3.6× wider than each eye dorsal diameter. Canthus wide, curved and rounded, with 12 setae. Labrum bilobed, widely sinuated, with curved slender, long setae on borders. Mentum wide and shallowly concave, polished, with lateral slender setae, anterior border nearly straight. Pronotum wider than long (1.6:1) 2.5× wider than frons. Pronotal disk with deep, round punctures and many erect, yellowish, long, slender setae uniformly distributed on all disk, punctures separated by 1–1.5 diameters; lateral borders strongly angulated, lateral bead deep and irregularly crenulate, crenulations progressively narrower from anterior angle to posterior angle, with long, erect setae; anterior angles nearly right, clearly projected; posterior angles slightly obtuse, slightly prominent toward ventral area. Scutellum 1.3× wider than long, with 42 shallow, irregular punctures with short setae. Elytron 2.7× longer than wide, with dense, regularly distributed, shallow, round punctures, and abundant, short setae on all surface; epipleural border extended along the complete margin, narrowed toward the apex and provided with dense fringe of short setae; humeral calla rounded, prominent; apical calla rounded. Metathoracic wings completely developed. Propygidium slightly shiny, densely punctate with many short setae. Pygidium slightly dull, uniformly convex, with dense round punctures and short setae on disk, with some medium size, erect setae toward apex; apical margin with 16 slender setae; basal margin effaced at middle. Pterosternum with long, dense, yellowish setae. Visible abdominal sternites 2° to 4° slightly depressed at midline, slightly pruinose with scattered, short setae; sternite 5° convex, slightly rugo-punctate at middle, with scattered short setae; anal plate transversely concave, punctate, with scattered setae on all surface; posterior and anterior borders clearly elevated. Protibiae slightly shorter than protarsi (0.9:1), with two big, rounded teeth toward the apex and one small, rounded tooth near the middle of external border, preapical spur long, straight, acute, shorter than 2° protarsomerus. Mesotibiae with one oblique, strong, wide, setiferous, transverse carina, at middle of external side, and 3–4 short spines on dorsal border; upper apical spur nearly straight, narrowed, as long as lower spur. Metatibiae shorter than metatarsi (0.8:1), with one oblique, strong, wide, setiferous transverse carina near the middle of external side, and 3–4 short spines on dorsal border; apical spurs articulated with border, upper spur, slightly curved, narrow, with rounded apex, much shorter than 2° metatarsomerus, and 1.3× longer than lanceolate, lower spur. Tarsomeres semicylindrical, elongated, with enlarged apex, some setae around the apex and scattered setae ventrally; metatarsomeres 1°–4° ventrally with 2 rows of short, stout setae. Tarsal claws symmetrical, similar on all legs, with short, acute tooth after the middle of ventral border (Fig. 25). Genital capsule with short, wide paramera, fused at their dorsal basis, with excavated acute projections, apex progresivelly narrowed. Tectum convex. Basal piece much longer than paramera (2.5:1). Aedeagus long, wide, dorsally with strongly sclerotized, preapical very long and sinuose bar, with some short setae on the basis (Figs. 26–27). Length of genital capsule from apex of parameres to border of basal piece: 4.1 mm. Total body length: 17.1 mm. Humeral width: 7.0 mm. *Female.* Unknown.

Type Locality.—Mesa de Ocozocuautla, Ocozocuautla municipality, state of Chiapas, México (approx. 16°52′ N; 93°22′ W).

Variation.—Male paratype is similar to holotype except as follows: punctures on the pronotal disk slightly wider; crenulation on the lateral border of pronotum more irregular; apex of dorso-basal process of paramera slightly rounded; preapical sinuose bar of aedeagus without setae on basis; elytra dark reddish brown; total body length: 15.8 mm, humeral width: 6.6 mm.

Biological Data.—Specimens of *P. stzotzilana* were collected at lights in tropical deciduous forest, located at an altitude of 1000–1340 m, formed by *Heliocarpus reticulatus* Rose (Tiliaceae), *Bursera simaruba* Sarg. (Burseraceae), *Swietenia humilis* Zucc. (Meliaceae), *Alvaradoa amorphoides* Liebm. (Simarubaceae), *Lonchocarpus longipedicellatus* Pitt. (Caesalpinaceae) and many other tropical trees. Phenology: May (2). Other species of *Phyllophaga* flying at same time and place were *P. (s.str.) spaethi* (Nonfried), *P. (s.str.) testaceipennis* (Blanchard), *P. (s.str.) tenuipilis* (Bates), *P. (Chlaenobia) latipes* (Bates), *P. (Phytalus) cometes* (Bates) and *P. (Ph.) obsoleta* (Blanchard).

Remarks.—*Phyllophaga stzotzilana* is not related to any known Mexican or

Central American species. The dense vestiture of short setae, shape of tarsal claws and paramera, with the unique form of the sclerotized accessory "spine" on the aedeagus will aid in the recognition of this new species.

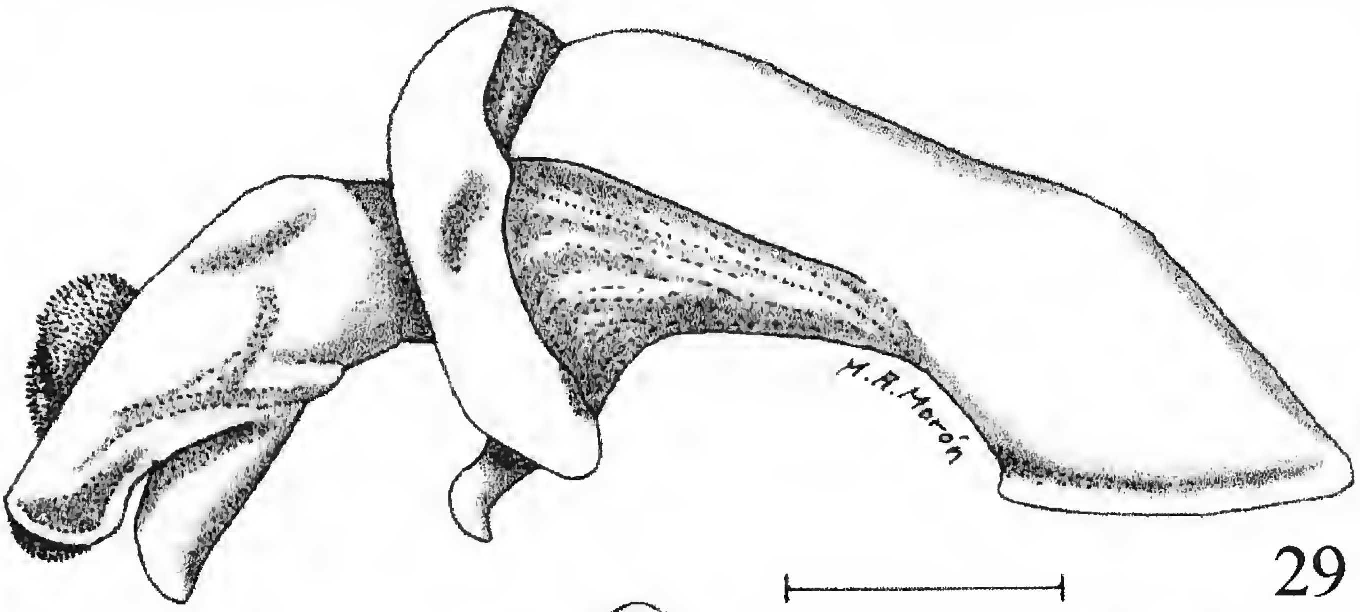
Etymology.—Derived from Maya Tzeltal language, *stzotzil,* meaning "hairy" (M. Girón, personal communication)

PHYLLOPHAGA (PHYLLOPHAGA) PILULA (Moser, 1921)
Deutsche Ent. Zeit. 3: 250
(Figs. 28–33)

Studied Specimens.—(2 males). Type, male; "Mexiko" (ZMHU). MEXICO: CHIAPAS, 8 mi NE San Cristóbal de las Casas, 9-V-1969, H. F. Howden (1 male) (HAHC).

Redescription.—Male. Head, pronotum, elytra and pygidium shiny reddish dark brown (mahogany), sterna and legs shiny reddish brown. Clypeus bilobed, wider than long (3.3:1), anterior border widely sinuated with margins scarcely elevated, surface slightly convex, dense and deeply rugo-punctate, with long, slender setae. Fronto-clypeal suture slightly sinuated, obscured by the dense punctuation. Frons wider than long (2:1) convex, coarsely rugo-punctate, with long, slender setae. Antenna 10 segmented, with 3 segmented club; lamellae as long as the length of the six preceding segments combined, segment 4° longer than segment 3, segments 6° and 7° wider than long, each one with large, acute process directed forward. Frons 4.3× wider than each eye dorsal diameter. Canthus curved and rounded, with 9 setae. Labrum bilobed, with curvated slender setae on the borders. Mentum nearly flat, polished, with lateral slender setae, anterior border notched. Pronotum wider than long (1.8:1) and 2.5× wider than frons. Pronotal disk with round, deep punctures uniformly distributed, separated by a distance of 1–2 diameters, with long, slender setae; lateral borders strongly angulated, marginal bead crenulate, with long slender setae; anterior angles obtuse, rounded, not prominent; posterior angles slightly obtuse, prominent. Scutellum 1.7× wider than long, with 26 rounded, shallow punctures. Elytron 2.5× longer than wide, densely rugo-punctate, with scattered erect, long setae, progressively shorter toward the apex; epipleural border extended along the complete margin, narrowed toward the apex and provided with a fringe of long setae; humeral calla rounded, prominent; apical calla rounded. Metathoracic wings completely developed. Propygidium shiny, finely punctate with short setae near the basis and some scattered setae toward the apex. Pygidium shiny, slightly convex, nearly flat at the center of disk, irregularly rugose with some shallow punctures and scattered setae of different length; apical margin with 18 slender setae; basal margin effaced at the middle. Pterosternum with long, dense, yellowish vestiture. Visible abdominal sternites 2° to 4° convex at the midline, with scattered setae; sternite 5° convex, prominent, with some punctures and sparse setae; anal plate widely concave, granulose, with some erect, slender setae, anterior border with narrowed bead and posterior border thickened. Protibiae nearly as long as protarsi (0.9:1), with two big teeth and one small tooth on external border, preapical spur long, straight, acute, slightly longer than 2° protarsomerus. Mesotibiae with one oblique, strong, setiferous, transverse carina; upper apical spur nearly straight, narrowed, 0.3× shorter than the lower spur. Metatibiae shorter than metatarsi (0.9:1), with one oblique, strong setiferous transverse carina on the external side and some granules along the dorsal border; apical spurs articulated with the border, upper spur wide with rounded apex, slightly curved, shorter than 2° metatarsomerus, and 1.4× longer than the lower spur. Tarsomeres semicylindrical, elongated, with enlarged apex, some setae around the apex and two lines of setae ventrally. Tarsal claws symmetrical, similar on all legs, with large tooth before middle of ventral border near the apex (Fig. 28). Genital capsule with long and sinuose paramera, fused at their dorsal basis, apex narrowed, right angled turned, slightly compressed, and curved downward. Tectum convex. Aedeagus long and wide, with sclerotized preapical tube and membranous apex densely covered with microscopic spines (Figs. 29–33). Length of genital capsule from the apex of parameres to the border of basal piece: 3.2–3.8 mm. Total body length: 14–16.8 mm. Humeral width: 6.8–7.1 mm. *Female*: Unknown

Biological Data.—Label on the type specimen gives no specific information about a precise locality or habitat from which the specimen was collected. One specimen of *P. pilula* was taken at lights in pine and oak forest formed mainly



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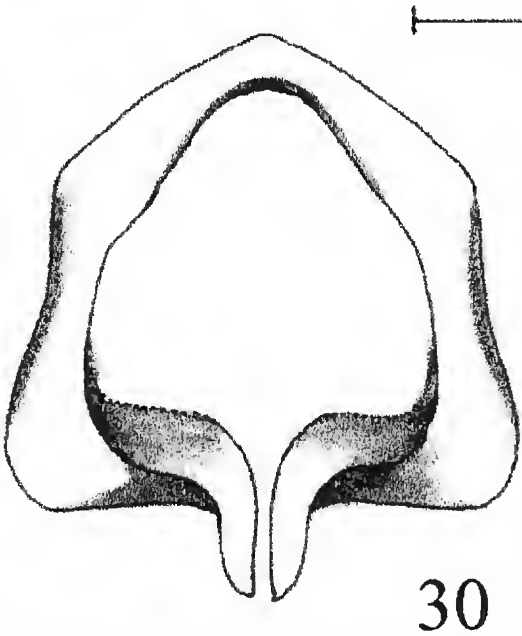

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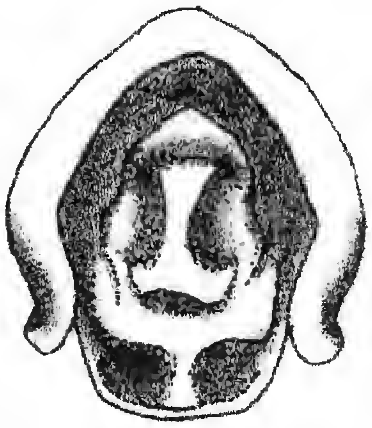

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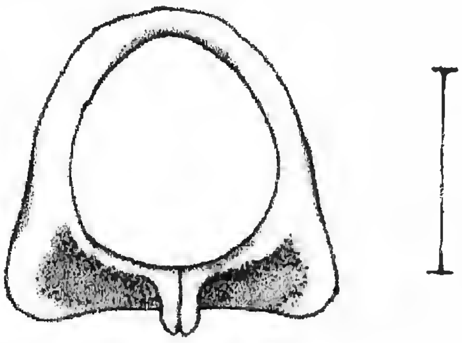

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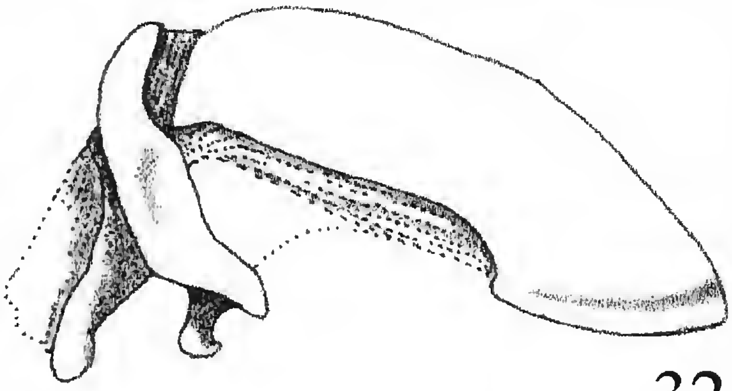

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Figures 28–33. *Phyllophaga* (*s.str.*) *pilula* (Moser).
Figure 28. Male protarsal claw.
Figure 29. Genital capsule, lateral view (specimen from San Cristóbal de Las Casas, Chiapas).
Figure 30. Paramera, distal view.
Figure 31. Apex of aedeagus, distal view.
Figure 32. Type genital capsule, lateral view.
Figure 33. Paramera, distal view. Scale lines = 1 mm.

by *Pinus oocarpa* Schiede, *P. montezumae* Lamb. (Pinaceae), *Quercus peduncularis* Née, *Q. brachystachys* Benth. and *Q. oleoides* Cham. et Schl. (Fagaceae). located at 2400 m of altitude, near volcano Tzontehuitz (approx. 16°44′12″ N; 92°38′18″ W). Phenology: May (1). Other species of *Phyllophaga* flying at the same time were *P. (Phytalus) senicula* (Bates), *P. (Ph.) lineatoides* Morón and *P. (s.str.) jovelana* Morón.

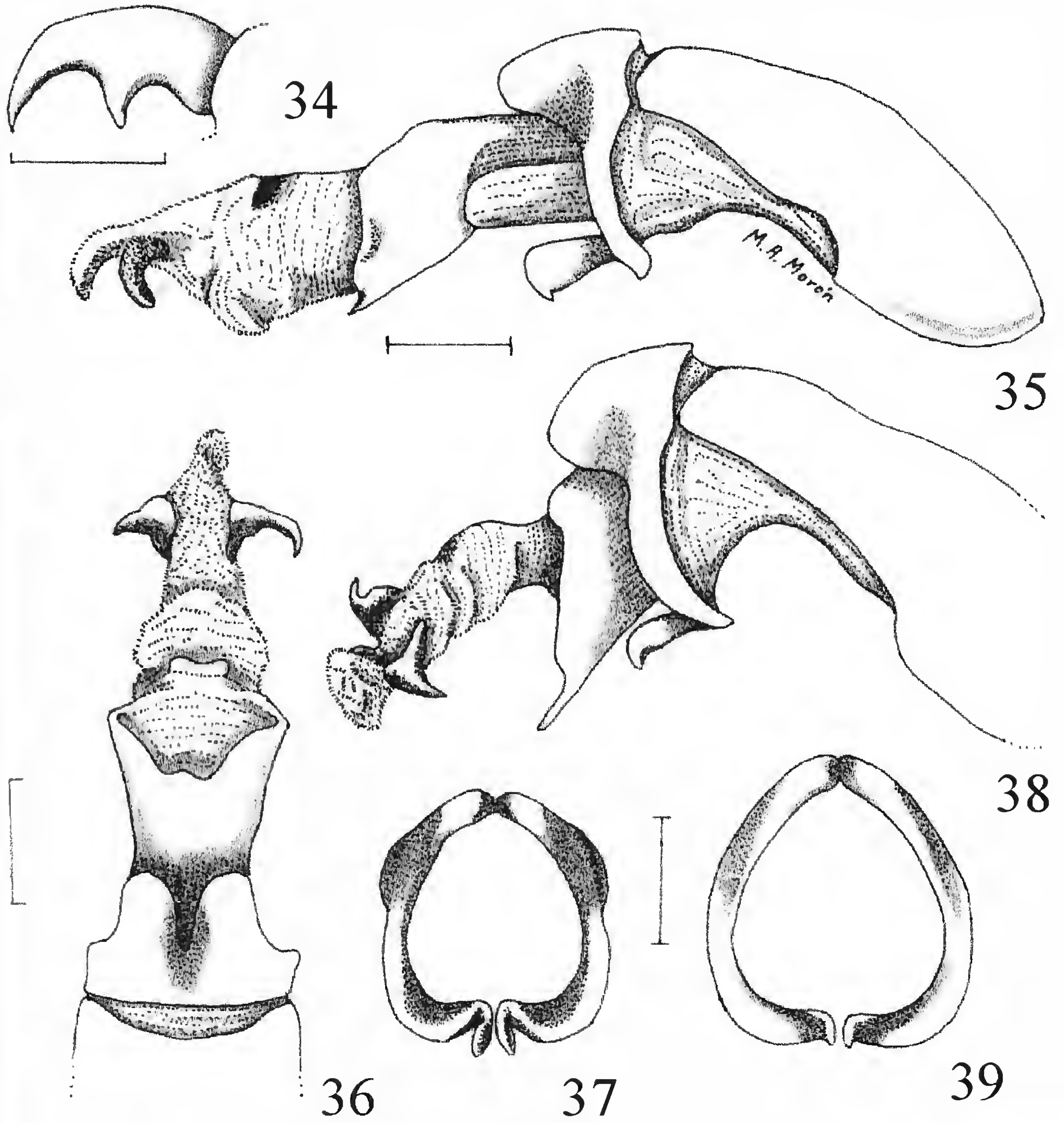
Remarks.—The type specimen shows some slight differences from the specimen from San Cristóbal de Las Casas, Chiapas, mainly in smaller body size, the antennal club is shorter, the elytra have fewer setae, and shape of paramera (Figs. 29–33). *Phyllophaga pilula* (Moser) is not closely related to any other Mexican species, but probably will be placed between the species groups *blanchardi* and *schizorhina* (*sensu* Morón 1986). Shape of the pronotum and last abdominal segments, form of the tarsal claws, general structure of the paramera, dorsal vestiture and punctuation suggest some relation with species in the complex "*pubicauda*", but details and proportions of the genital capsule, and the pronotal and elytral sculpture are different. The basic design of the paramera also show some relationship to *P. nisuens* Saylor, but shape of the tarsal claws and the aedeagus are much different.

Etymology.—Derived from the Latin *pilula*, diminutive of *pila*, meaning "bullet" (Jaeger 1978), in reference to the ovate body shape of this species.

Phyllophaga (*Phyllophaga*) *nisuens* Saylor, 1937
Proc. R. Ent. Soc. London (B) 6: 32–33
(Figs. 34–39)

Studied Specimens.—(6 males). Type, male; MEXICO: Parada (BMNH); MEXICO: OAXACA: 18 km N Guelatao, 28 August 1991, 2630 m, pino-encino, P. Rojas (2 males) (MXAL); Oaxaca, Concepción Papalo, 11 July 1997, 2500 m, G. Nogueira (3 males) (IEXA, MXAL).

Redescription.—Male. Head and pronotum, shiny dark reddish brown, elytra, pygidium, sterna and legs shiny reddish brown. Clypeus rounded, slightly bilobed, wider than long (3.7:1), anterior border briefly sinuated with margins scarcely elevated, surface convex, coarsely rugo-punctate, with scarce, short setae. Fronto-clypeal suture nearly straight, clearly impressed. Frons wider than long (2.1:1) convex, coarse and irregularly rugo-punctate, with some long, slender setae near the eyes. Antenna 10 segmented, with 3 segmented club; lamellae 1.5× longer than the length of five preceding segments combined, segment 4° longer than segment 3, segments 6° and 7° wider than long, each one with acute process directed forward. Frons 6× wider than each eye dorsal diameter. Canthus curved and rounded, with 9 setae. Labrum bilobed, deeply cleft, with curved slender setae on the borders. Mentum concave, polished, with transverse suture at middle and lateral slender setae, anterior border widely sinuate. Pronotum wider than long (1.8:1) and 2× wider than frons. Pronotal disk with round, deep punctures irregularly distributed, separated by a distance of 1-6 diameters, without setae; lateral borders strongly angulated, marginal bead shallowly crenulate, with long, slender setae; anterior angles obtuse, rounded, not prominent; posterior angles widely obtuse, not prominent. Scutellum 1.6× wider than long, without punctures. Elytron 2.6× longer than wide, densely rugo-punctate, without setae; epipleural border extended along complete margin, narrowed toward the apex and provided with some long setae on it basal fourth; humeral calla rounded, prominent; apical calla rounded. Metathoracic wings completely developed. Propygidium shiny, finely rugo-punctate with scattered, short setae. Pygidium shiny, widely convex, with scattered, shallow punctures and some minute setae; apical margin with 28 slender setae; basal margin narrow but complete at the middle, preceded by transverse sulcus. Pterosternum with long, dense, yellowish vestiture. Visible abdominal sternites 2° to 4° nearly convex at midline, shiny, with scattered fine punctures; sternite 5° convex, prominent, with patch of granulose punctures and scarce setae at middle; anal plate widely concave, granulose, with some erect, slender



Figures 34–39. *Phyllophaga* (*s.str.*) *nisuens* Saylor.
Figure 34. Male protarsal claw.
Figure 35. Genital capsule, lateral view (specimen from Guelatao, Oaxaca).
Figure 36. Same, dorsal view of distal half.
Figure 37. Same, distal view of paramera.
Figure 38. Genital capsule, lateral view (specimen from Concepción Papalo, Oaxaca).
Figure 39. Same, distal view of paramera. Scale lines: Fig. 34 = 0.5 mm; Figs. 35–39 = 1 mm.

setae, posterior border slightly thickened at sides and vaguely excavated at middle. Protibiae slightly shorter than protarsi (0.8:1), with two big teeth and one small tooth on external border, preapical spur long, straight, acute, longer than 2° protarsomerus. Mesotibiae with one oblique, strong, setiferous, transverse carina and short, setiferous tubercle toward proximal articulation on external side; upper apical spur straight, narrowed, 0.2 longer than lower spur. Metatibiae shorter than metatarsi (0.8:1), with one oblique, strong setiferous transverse carina and setiferous tubercle toward proximal articulation on external side; apical spurs articulated with the border, upper spur wide with rounded apex, shorter than 2° metatarsomerus, and 1.2 longer than the lower spur. Tarsomeres semicylindrical, elongated, with enlarged apex, some setae around the apex and some setae ventrally; metatarsomeres 2°–4° ventrally with two lines of stout setae. Tarsal claws symmetrical, similar on all legs, with large, acute tooth at middle of ventral border (Figs. 34). Genital capsule with long and sinuose paramera, fused at their expanded, dorsal basis, apex narrowed, right angled turned, slightly compressed. Tectum convex. Aedeagus long and wide, with sclerotized tubular support, membranous apex densely covered with microscopic spines and claw-like, curved sclerotized structure at each side (Figs. 35–39). Length of genital capsule from apex of parameres to the border of basal piece: 4.5–5.2 mm. Total body length: 16.0–18.1 mm. Humeral width: 6.8–7.5 mm. *Female*: Unknown.

Biological Data.—Specimens of *P. nisuens* were collected at lights in pine and oak forests formed mainly by *Pinus pseudostrobus* Lindl., *P. leiophylla* Schl. et Cham. (Pinaceae), *Quercus urbani* Trel., *Q. conspersa* Benth., and *Q. castanea* Née (Fagaceae), located at an altitude of 2500–2630 m. Phenology: July (3), August (2). The other species of *Phyllophaga* flying at the same time and place was *P. (s.str.) papaloana* n.sp.

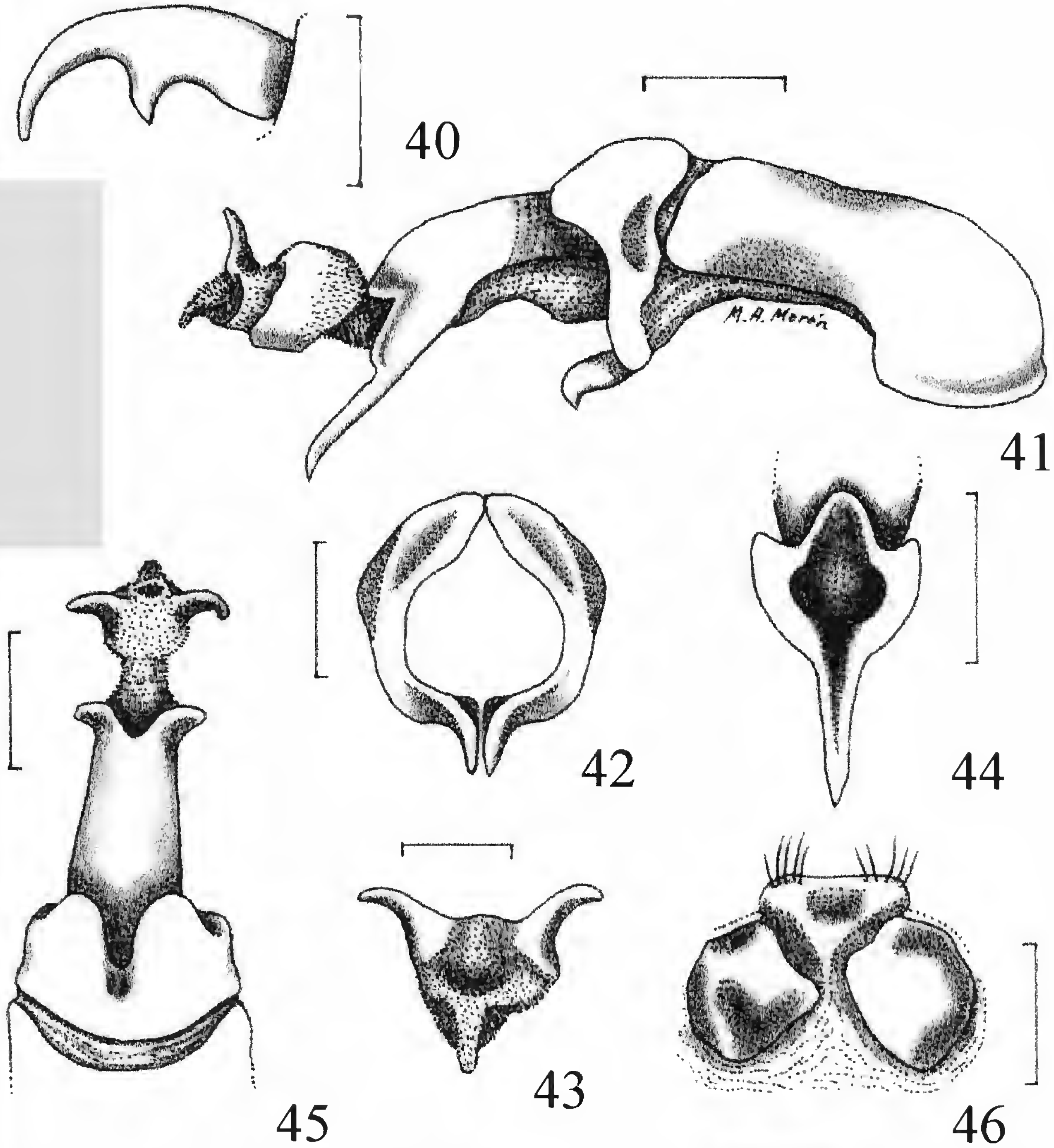
Remarks.—Type locality probably is "La Parada", Oaxaca, located on the northern slope of mountains west of Cerro San Felipe, 2630 m, north of the city of Oaxaca (Selander & Vaurie 1962). Specimens from Guelatao (near 20 km NE of La Parada) are very similar to the type specimen, except by minor differences on ventral border of the apex of the paramera, which do not have the indentation seen in the type. Specimens from Concepción Papalo (near 40 km NNW of Guelatao) show some differences in the shape of dorsal projections at the base of the paramera, length of the ventral spine of the sclerotized support of aedeagus and width of apical projection of the paramera (Figs. 35–39). The localities cited above are placed around the Ixtlan upper valley (approx. 17°10′–17°25′ N, 96°30′–96°45′ W). Although there are minor differences in genitalia among type series, externally the specimens appear to be identical. *Phyllophaga nisuens* Saylor is not closely related to any described Mexican species, but probably will be included in a new group of species, placed near the group *blanchardi* (*sensu* Morón 1986). Shape of the clypeus, pronotal punctuation, form of last abdominal sternites and general structure of paramera suggest some relationship with species in the "*pubicauda*" complex, but the details and proportions of the aedeagus, form of tarsal claws and pygidial sculpture are quite different.

Etymology.—Derived from the Latin *nisus, nisuens,* meaning "striving" (Jaeger 1978).

PHYLLOPHAGA (*PHYLLOPHAGA*) *TSAJUMIANA* MORÓN, NEW SPECIES
(Figs. 40–46)

Types.—(Described from 13 males and 8 females). Holotype, male; MEXICO. Oaxaca, Concepción Papalo, 1 July 1998, 2375 m, G. Nogueira; deposited: M.A. Morón collection, Xalapa. Allotype, female, same data as holotype; deposited: M.A. Morón collection, Xalapa. Paratypes: same data as holotype (3 males, 2 females) (MXAL, IEXA); same data except, 9 July 1997, 2475 m (1 male, 2 females) (IEXA, CAS); same data except, 10 July 1997, 2275 m (3 males) (IEXA); same data except, 22 June 1998, 2300 m (1 female) (IEXA); same data except, 2 July 1998, 2330 m, (5 males, 2 females) (ZMHU, AHHC, MXAL, GNGC).

Holotype.—Male. Head, sterna and legs shiny reddish brown; pronotum, elytra, and pygidium dull reddish brown. Clypeus rounded, slightly bilobed, wider than long (3.5:1), anterior border shallowly and widely sinuated with margins scarcely elevated, surface convex, densely rugo-punctate, with scarce, short setae. Fronto-clypeal suture slightly sinuate, clearly impressed. Frons wider than long (2.3:1) convex, irregularly rugo-punctate, with some scattered, slender setae on all disk. Antenna 10



Figures 40–46. *Phyllophaga* (*s.str.*) *tsajumiana* Morón.
Figure 40. Male protarsal claw.
Figure 41. Holotype genital capsule, lateral view.
Figure 42. Paramera, distal view.
Figure 43. Apex of edeagus, distal view.
Figure 44. Apex of sclerotized support of aedeagus, dorso-distal view.
Figure 45. Genital capsule, dorsal view of distal half.
Figure 46. Female genital plates. Scale lines: Figs. 40, 43 = 0.5 mm; Figs. 41–42, 44–46 = 1 mm.

segmented, with 3 segmented club; lamellae 2× longer than the length of five preceding segments combined, segment 4° longer than segment 3, segments 6° and 7° wider than long, each one with acute process directed forward. Frons 5.1× wider than each eye dorsal diameter. Canthus curved and rounded, with 12-14 setae. Labium bilobed, widely sinuate, with curved slender setae on borders. Mentum concave, polished, with transverse suture at middle and lateral slender setae, anterior border widely sinuate. Pronotum wider than long (1.7:1) and 2× wider than frons. Pronotal disk with small, round, shallow punctures irregularly distributed, separated by a distance of 2–6 diameters, pruinose iridescent, without setae; lateral borders strongly angulated, marginal bead shallowly crenulate, with long, slender setae; anterior angles obtuse, rounded, not prominent; posterior angles widely obtuse, not prominent. Scutellum 1.5× wider than long, with 48 minute punctures. Elytron 2.8× longer than wide, finely rugo-punctate, pruinose iridescent, with scattered setae only near the lateral borders; epipleural border extended along complete margin, narrowed toward apex and provided with fringe of long setae on all length; humeral calla rounded, prominent; apical calla rounded. Metathoracic wings completely developed. Propygidium slightly shiny, rugo-punctate with many short setae. Pygidium dull, pruinose iridescent, widely convex, with scattered, shallow punctures and minute setae; apical margin with 28 slender setae; basal margin briefly interrupted at middle by shallow fovea. Pterosternum with long, dense, yellowish vestiture. Visible abdominal sternites 2° to 4° convex at midline, with small setiferous punctures; sternite 5° convex, prominent, with slightly depressed patch of granulose punctures and erect, short setae at middle; anal plate widely concave, finely rugose-granulose, with scattered erect setae, posterior border elevated and briefly sinuate at middle. Protibiae slightly shorter than protarsi (0.8:1), with two big teeth and one small tooth on external border, preapical spur long, straight, acute, longer than 2° protarsomerus. Mesotibiae with one oblique, strong, setiferous, transverse carina and acute, setiferous tubercle toward proximal articulation on external side; upper apical spur straight, narrowed, 0.3× longer than lower spur. Metatibiae shorter than metatarsi (0.8:1), with one oblique, strong setiferous transverse carina and setiferous tubercle toward proximal articulation on external side; apical spurs articulated with border, upper spur lanceolate, shorter than 2° metatarsomerus, and 1.3× longer than the curved, lower spur. Tarsomeres semicylindrical, elongated, with enlarged apex, some setae around the apex and some setae ventrally; metatarsomeres 2°–4° ventrally with two lines of stout setae. Tarsal claws symmetrical, similar on all legs, with acute tooth at middle of ventral border (Figs. 40). Genital capsule with long and sinuose paramera, fused at their expanded, dorsal basis; apex narrowed, right angled turned, slightly compressed. Tectum convex. Aedeagus long and wide, with sclerotized tubular support with arrow-shaped, acute apex; membranous apex densely covered with microscopic spines and claw-like, curved sclerotized structure at each side (Figs. 41–45). Length of genital capsule from apex of parameres to the border of basal piece: 3.8 mm. Total body length: 18.3 mm. Humeral width: 7.8 mm.

Allotype.—Female. Similar to holotype except as follows: clypeus and frons with punctuation coarser than in male; length of antennal club as long as preceeding five segments; pygidial disk slightly upturned toward the apex, with preapical transverse rugosities; 5° sternite convex, densely punctate at middle; anal plate strongly convex, densely punctate. Ventral genital plates slightly asymmetrical, convex, rounded, without setae; dorsal genital plates fused, with distal border nearly straight, with rounded sides and some slender setae (Fig. 46). Total body length: 19.0 mm. Humeral width: 8.1 mm.

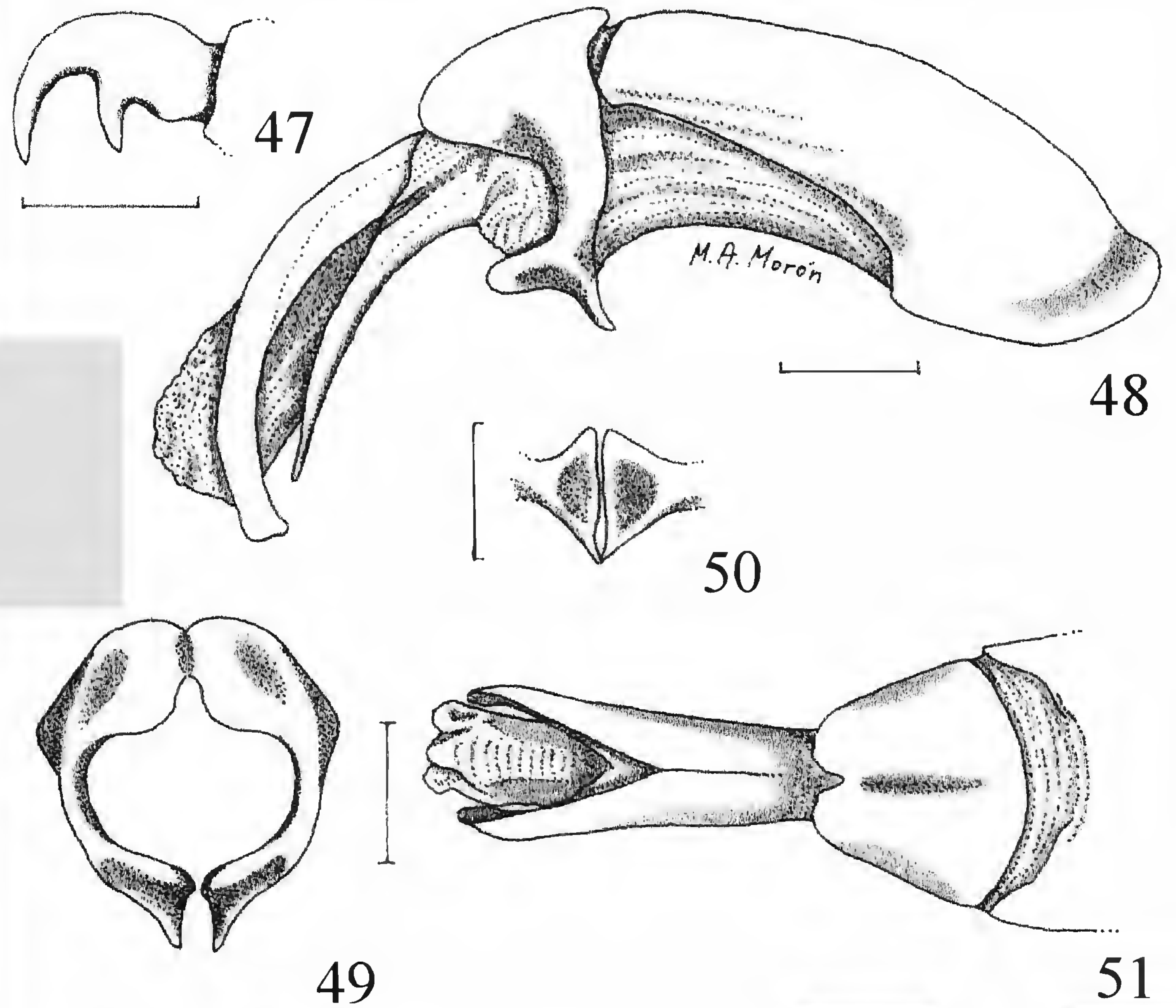
Type Locality.—Concepción Papalo municipality, state of Oaxaca, México (17°50′30″ N; 96°52′50′ W).

Variation.—Male paratypes are similar to holotype except as follows: density of punctures on the clypeus and frons is variable; reddish pruinose iridescent vestiture is more accentuated in some specimens than in others; crenulation on the lateral border of pronotum is less marked in some specimens; number of setae at the sides of each elytron is also different; total body length: 16.8–18.5 mm, humeral width: 7.0–8.1 mm. Female paratypes varies mainly in the intensity of elytral luster and growth of preapical transverse rugae of pygidium; total body length: 19.0–20.0 mm, humeral width 8.0–8.4 mm.

Biological Data.—Specimens of *P. tsajumiana* were collected at traps with Hg vapor lights in mixed pine-oak forests located at an altitude of 2275–2475 m, formed mainly by *Pinus leiophylla* Schl. et Cham., *P. oaxacana* (Martínez) Mirov. (Pinaceae), *Quercus conspersa* Benth., *Q. laurina* H. & B., *Q. castanea* Née (Fagaceae) and species of *Arbutus* (Ericaceae), *Symplocos* (Symplocaceae) and *Clethra* (Clethraceae). Phenology: June (1); July (18). The other species of *Phyllophaga* flying at the same time and place were *P. (s.str.) vetula* (Horn), *P. (s.str.) pubicauda* (Bates) and two undescribed species of *P. (Phytalus).*

Remarks.—*Phyllophaga tsajumiana* is closely related to *P. nisuens* Saylor, but pruinose body vestiture, coarse head punctuation, and arrow-like shape of apex of aedeagus, are clearly different. With more data in the future both species will be included in a new species group.

Etymology.—Derived from old Chinanteca language, "*tsa-ju-jmi*", meaning



Figures 47–51. *Phyllophaga* (*s.str.*) *papaloana* Morón.
Figure 47. Male protarsal claw.
Figure 48. Holotype genital capsule, lateral view.
Figure 49. Paramera, distal view.
Figure 50. Apex of paramera, ventral view.
Figure 51. Genital capsule, dorsal view of distal half. Scale lines: Fig. 47 = 0.5 mm; Figs. 48–51 = 1 mm.

"people with old word", and the name of the Indian people that actually live in the vicinity of the type locality of this species (Pardo, 1995).

PHYLLOPHAGA (*PHYLLOPHAGA*) *PAPALOANA* MORÓN, NEW SPECIES
(Figs. 47–51)

Types.—(Described from 2 males). Holotype, male; MEXICO: OAXACA, Concepción Papalo, 23 June 1998, 2400 m, G. Nogueira; deposited: M.A. Morón collection, Xalapa. Paratype: same data as holotype except, 11 July 1997, 2500 m (1 male) (IEXA).

Holotype.—Male. Head shiny, dark reddish brown, pronotum elytra, pygidium, sterna and legs shiny reddish brown. Clypeus rounded, slightly bilobed, wider than long (3.9:1), anterior border brief and widely sinuated with margins scarcely elevated, surface slightly convex, dense and irregularly rugo-punctate, without setae. Fronto-clypeal suture nearly straight, clearly impressed. Frons wider than long (2.3:1) convex, irregularly punctate, with some scattered, slender setae toward ocular borders. Antenna 10 segmented, with 3 segmented club; lamellae 1.2× longer than the length of five preceding segments combined, segment 4° or 5° longer than segment 3, segments 6° and 7° wider than long, each one with short, acute process directed forward. Frons 5× wider than each eye dorsal diameter. Canthus short, curved and rounded, with 8 setae. Labrum bilobed, deeply notched, with curved slender setae on borders. Mentum concave, polished with lateral slender setae, anterior border widely notched. Pronotum wider than long (1.8:1) and 2× wider than frons. Pronotal disk with small, round punctures irregularly distributed, separated by a distance of 1–2 diameters, without setae; lateral borders strongly angulated, marginal bead briefly crenulate, with long, slender setae; anterior angles obtuse, rounded, not prominent; posterior angles widely obtuse, not prominent. Scutellum 1.8× wider than long, with 34 small punctures. Elytron 3× longer than wide, moderately rugo-punctate, with scattered setae only near lateral borders; epipleural border extended along complete margin, narrowed toward apex and provided with many long setae scattered on all lenght; humeral calla rounded, prominent; apical calla rounded. Metathoracic wings completely developed. Propygidium slightly shiny, with scattered, fine punctures, without macroscopic setae. Pygidium shiny, widely convex, slightly rugose, with sparce, shallow punctures and some minute setae; apical margin with 26 slender setae; basal margin wide and vaguely interrupted at middle, represented by shallow, punctate sulcus. Pterosternum with long, dense, yellowish vestiture. Visible abdominal sternites 2° to 4° convex at midline, with small setiferous punctures; sternite 5° convex, prominent, with poorly defined patch of granulose punctures and some, short setae at middle; anal plate slightly concave, finely rugose-granulose, with some scattered, erect setae, posterior border slightly elevated and briefly sinuate at middle. Protibiae nearly as long as protarsi (0.95:1), with two big teeth and one small tooth on external border, preapical spur long, straight, acute, slightly longer than 2° protarsomerus. Mesotibiae with one oblique, strong, setiferous, transverse carina and one setiferous point toward proximal articulation on external side; upper apical spur straight, narrowed, 0.2× longer than lower spur. Metatibiae nearly as long as metatarsi (0.95:1), with one oblique, strong setiferous transverse carina on external side; apical spurs articulated with border, upper spur lanceolate, curved, slightly shorter than 2° metatarsomerus, and 1.5× longer than curved, apical rounded, lower spur. Tarsomeres semicylindrical, elongated, with enlarged apex, some setae around the apex and some setae ventrally; metatarsomeres 2°–4° ventrally with two lines of stout setae. Tarsal claws symmetrical, similar on all legs, with curved, acute tooth at middle of ventral border (Figs. 47). Genital capsule with long and deeply sinuose paramera, fused at their expanded, dorsal basis; with preapical, compressed and expanded process (Fig. 50). Tectum convex. Aedeagus long and wide, with sclerotized, curved bar support, with rounded apex; membranous apex covered with microscopic spines (Figs. 48–51). Length of genital capsule from apex of parameres to the border of basal piece: 5.4 mm. Total body length: 20.0 mm. Humeral width: 7.9 mm. *Female.* Unknown.

Type Locality.—Concepción Papalo municipality, state of Oaxaca, México (17°50′30″ N; 96°52′50′ W).

Variation.—Male paratype is similar to holotype except as follows: body color slightly light; pygidial disk with slight longitudinal rugosities; total body length: 19.5 mm, humeral width: 8.01 mm.

Biological Data.—Specimens of *P. papaloana* were collected at traps with Hg vapor lights in mixed pine-oak forests located at an altitude of 2400–2500 m, formed mainly by *Pinus leiophylla* Schl. et Cham., *P. oaxacana* (Martínez) Mirov. (Pinaceae), *Quercus laurina* H. & B. (Fagaceae) and species of *Arbutus* (Ericaceae) and *Clethra* (Clethraceae). Phenology: June (1); July (1). The other species of *Phyllophaga* flying at the same time and place were *P. (s.str.) punctulicollis* (Bates), *P. (s.str.) nisuens* Saylor and *P. (Phytalus) lineata* (Bates).

Remarks.—*Phyllophaga papaloana* is related to *P. nisuens* Saylor, and *P. tsajumiana* Morón but details of the head, pronotal and elytral punctuation, microstructure of last abdominal sternites, tarsal claw shape and general design of the paramera and aedeagus, are very different. Male genital structure suggest some relationship with species in the "*pubicauda*" complex, but details of aedeagus, form of tarsal claws and pronotal sculpture are different.

Etymology.—Derived from Nahuatl language name of type locality, *papalotl, Papalo,* meaning "butterfly" (Simeón 1978).

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LITERATURE CITED

Jaeger, E. C. 1978. A source book of biological names and terms (3rd ed.) C. C. Thomas Publisher. Springfield.

Luginbill, P. & H. R. Painter. 1953. May beetles of the United States and Canada. U.S. Dep. Agr. Tech. Bull. 1060. 102 pp.

Manrique, L. 1988. Atlas cultural de México. Linguistica. Secretaría de Educación Pública e Instituto Nacional de Antropología e Historia, Grupo Editorial Planeta, México. 183 pp.

Morón, M. A. 1986. El género *Phyllophaga* en México. Morfología, distribución y sistemática supraespecífica (Insecta: Coleoptera). Publ. 20, Instituto de Ecología, México.

Pardo, M. T., 1995. Chinantecos. *In*: Etnografía contemporánea de los pueblos indígenas de México. vol. V. Instituto Nacional Indigenista y Secretaria de Desarrollo Social, México. pp. 5–132.

Sanderson, M. W. 1958. Faunal affinities of Arizona *Phyllophaga*, with notes and descriptions of new species. J. Kansas Entomol. Soc., 31: 158–173.

Selander, R. B. & P. Vaurie. 1962. A gazetteer to accompany the "Insecta" volumes of the "Biologia Centrali Americana". American Mus. Nov. No. 2099: 1–70.

Simeón, R., 1988. Diccionario de la lengua Náhuatl o Mexicana. Siglo Veintiuno, México. 781 pp.

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ADULT CADDISFLY (TRICHOPTERA) PHENOLOGY IN TWO COLD-DESERT ENDORHEIC SPRING-STREAMS IN WASHINGTON STATE

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Abstract.—The species diversity and phenology of adult caddisflies was studied for two springs in the cold desert physiographic province of Eastern Washington State. During 1998 and 1999, adult caddisflies were collected using two light trapping methods: active collection using a mercury vapor light and passive collection using an ultraviolet light (UV). This study revealed a suprisingly diverse adult caddisfly fauna comprising eight families, 18 genera, and 26 species, with nine of the species collected being new distribution records of the State of Washington. Two species revealed significant range extensions with the closest records being from Utah.

Key Words.—Insecta, Trichoptera, Caddisflies, phenology, Washington, Springs.

Our goal was to describe the species diversity and phenology of adult caddisflies from two spring-streams in the cold desert physiographic province of Eastern Washington State. This area consists of semi-arid shrub-steppe habitat (Daubenmire 1970) and contains numerous springs. The most prominent water body is the nearby Columbia River. Shrub-steppe habitat is typically dominated by big sagebrush (*Artemisia tridentata* Nutt.), and Sandberg's bluegrass (*Poa sandbergii* Vasey). Range fires and exotic plant species have altered the native vegetation diversity (PNNL 1998).

In arid areas, spring-streams have been the focal point of human habitation. Permanent human habitation ceased on Hanford in 1943 when the site was acquired by the U.S. government. Some cattle and wild horses heavily utilized the spring-streams and riparian habitat near the study sites until 1961 (Rickard and Cushing 1982). Currently a large elk herd utilizes the spring-streams causing some damage to riparian and emergent vegetation.

The Trichoptera fauna of Washington State has not been summarized in recent times. The last comprehensive treatment of Washington Trichoptera distribution was by Davis (1948).

The two largest spring-streams on the Hanford Site (Fig. 1), Snively and Rattlesnake Springs, have been studied since 1972, beginning with productivity studies (Wolf and Cushing 1972), followed by insect food habits (Cushing and Rader 1982), primary production (Cushing and Wolf 1982, 1984), secondary production (Gaines 1987a, b; Gaines et al. 1992), trophic relations (Gaines et al. 1989), and organic carbon utilization (Mize 1993). Many of these studies included a description of the benthic aquatic insect fauna. Frest and Johannes (1993) surveyed the mollusks of Hanford and Newell (1998) surveyed the entire macroinvertebrate fauna of the two spring-streams. Cushing and Gaines (1989) theorized various recolonization routes for aquatic insects following routine spates that devastated

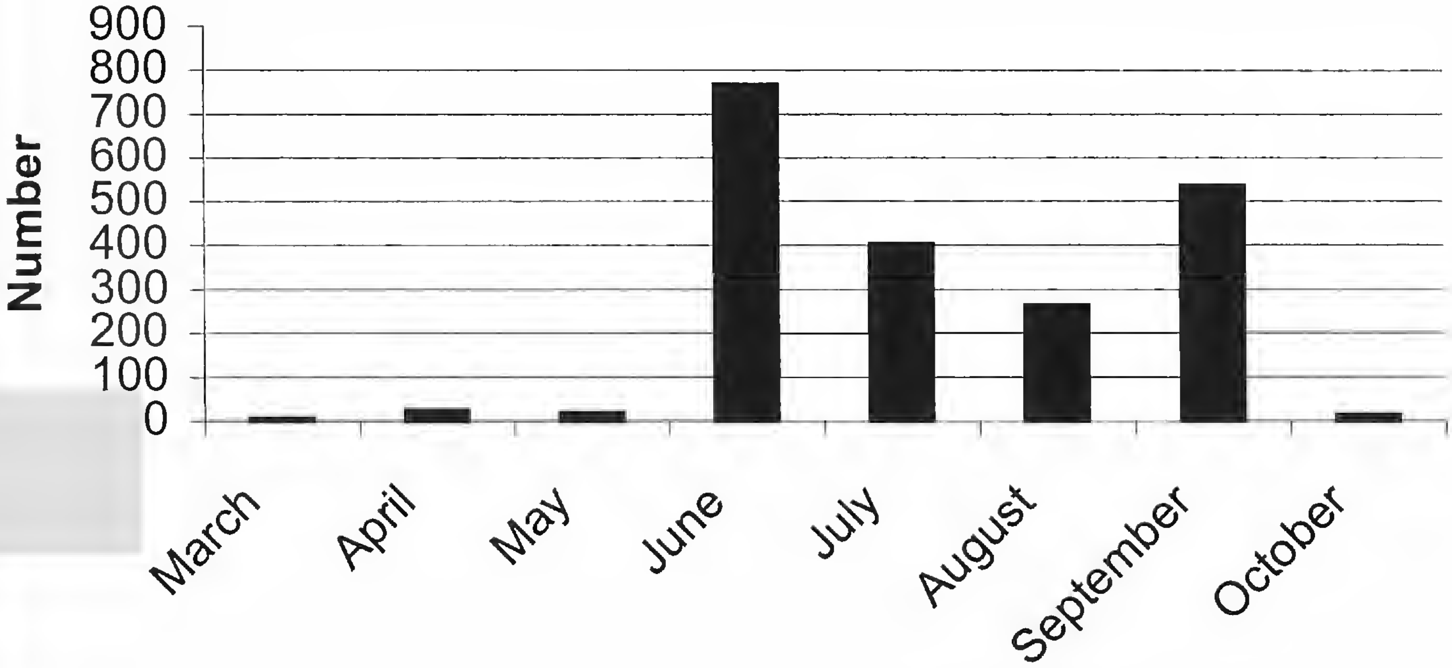

Figure 1. Total number of adult caddisflies captured each month at both spring streams.

the spring-streams. These two springs have been thoroughly studied for nearly 30 years with the major emphasis on the benthic insect fauna.

Study Area

The study site is located in northern Benton County, Washington, on the U.S. Department of Energy's Hanford site. The Hanford site occupies an area of about 1450 km^2 (PNNL 1998). The Hanford site is bisected north south by state highway 240. The land west of this highway (304 km^2) is called the Fitzner-Eberhardt Arid Lands Ecology Reserve (ALE) under management of the U.S. Fish and Wildlife Service. The ALE has less human use than other portions of Hanford. Public access has been denied since 1943 (PNNL 1998).

Rattlesnake (46°30.48′ N, 119°41.96′ W) and Snively (46°27.53′ N, 119°43.30′ W) Springs are permanent spring-fed streams located about 32 km north of Richland, Washington. Rattlesnake Spring arises from seeps and flows for about 2.5–3.5 km before disappearing into the ground. Annual baseflow is about 0.01 m^3/sec and water temperature ranges from 2° to 22° C (PNNL 1998). Winter spates occur periodically in the 350 km^2 catchment basin but have not been measured. During these spates, stream width can increase from one m to 15 m, devastating the riparian vegetation and the aquatic fauna (Cushing and Gaines 1989).

Snively Spring originates from seeps about five km south of Rattlesnake Spring and the stream flows for about 3.6 km before sinking into the ground approximately one km west of Rattlesnake Spring. Schwab et al. (1979) estimated discharge at 0.0022 to 0.0031 m^3/sec, and Gaines (1987a, b) estimated discharge at 0.02 m^3/sec to 0.05 m^3/sec. Water temperature ranged from 3° to 19° C.

Dense riparian vegetation lining both streams, is comprised of bulrush (*Schoenoplectus* = *Scirpus* sp.), spike rush (*Eleocharis* sp.), cattail (*Typha latifolia* L.), wild rose (*Rosa* sp.), wild clematis (*Clematis ligusticifolia* (Nutt.)), peachleaf willow (*Salix amygdaloides* Anders.), stinging nettles (*Urtica dioica* L.), and other species. Some cottonwood trees are found along Rattlesnake Spring (*Populus trichocarpa* (T & G)) (Saskschewsky et al. 1992). Both streams have a heavy

Table 1. Diversity and combined abundance of individual caddis adults captured during 1998 and 1999 at both spring-streams.

Family/genus	Species	Number	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Hydroptilidae										
Hydroptila	*argosa* Ross	50				●	●		●	
**Hydroptila*	*modica* Mosely	2							●	
Leucotrichia	*pictipes* (Banks)	1						●		
Glossosomatidae										
**Culoptila*	*cantha* (Ross)	61					●	●	●	
Glossosoma	*velonum* Ross	18				●			●	
**Protoptila*	*erotica* Ross	21				●		●	●	
Psychomyiidae										
**Psychomyia*	*flavida* Hagen	26				●	●		●	
Hydropsyche										
Cheumatopsyche	*campyla* Ross	908			●	●	●	●	●	
Hydropsyche	*californica* Banks	449			●	●	●	●	●	
Hydropsyche	*cockerelli* Banks	74		●	●	●	●	●	●	
Parapsyche	*almota* Ross	5							●	
Brachycentridae										
**Amiocentrus*	*aspilus* (Ross)	1			●					
Lepidostomatidae										
Lepidostoma	*cinereum* (Banks)	24		●			●		●	
Limnephilidae										
Hesperophylax	*designatus* (Walker)	11	●	●					●	
**Limnephilus*	*abbreviatus* Banks	1		●						
**Limnephilus*	*assimilis* (Banks)	3		●	●					
Limnephilus	*frijole* Ross	2							●	
Limnephilus	*sitchenssi* (Kalenati)	1		●						
Limnephilus	*spinatus* Banks	68							●	●
Leptoceridae										
Ceraclea	*latahensis* (Smith, SD)	2						●	●	
Nectopsyche	Species	6				●	●		●	
**Oecetis*	*avara* (Banks)	68				●		●	●	
**Oecetis*	*immobilis* (Hagen)	2			●				●	
**Oecetis*	*inconspicua* (Walker)	1						●		
Triaenodes	*tardus* Milne	17						●	●	
**Ylodes*	*frontalis* (Banks)	314		●	●	●	●	●	●	

growth of watercress (*Rorippa nasturtium-aquaticum* (L.) Schinz & Thell.), duckweed (*Lemna minor* L.), and species of filamentous algae in lentic areas.

METHODS AND MATERIALS

Adult caddisflies were collected using two light trapping methods: 1) active collection using a mercury vapor light; and, 2) passive collection using an ultraviolet light (UV). Both light systems were available from BioQuip Products, Gardena, California. Taxa were sampled during 1998 and 1999, from March through November. Sampling was performed on an approximate biweekly basis.

The mercury vapor light method involved a 150-watt lamp suspended at about

Table 2. Total number and percentage of caddis adults captured by Family from both springs with percent of total.

FAMILY	NUMBER				Total	% of Total
	Rattlesnake Spr.		Snively Spr.			
Hydropsychidae	1094	63%	242	89%	1336	66%
Leptoceridae	370	21	13	5	383	19
Glossosomatidae	98	6	4	2	102	5
Limnephilidae	88	5	2	<1	90	4
Hydroptilidae	47	3	6	2	53	3
Psychomyiidae	22	1	4	2	26	1
Lepidostomatidae	24	1	0		24	1
Brachycentridae	1	<1	0		1	<1
					2015	

three feet above two white fabric sheets spread on the ground. Caddisflies landing on the sheets were captured and placed in alcohol. When the number of specimens coming to the light was small (less than about 50) all specimens were taken. When the number was much greater, at the end of the collecting period (approximately two hours after sunset) the sheets were rolled up with the specimens inside and frozen. The material on the sheets was later sorted and all specimens were retrieved, but this complete retrieval method was not employed until 1999.

The ultraviolet light method employed a bucket trap with four vanes around an 18-inch 15-watt UV light held vertically above the bucket. A funnel on top of the bucket prevented the captured specimens from escaping. At the end of the collection time (about two hours after sunset), the caddisfly specimens in the bucket were removed and placed in alcohol. When large numbers of insects were in the traps, the contents were transferred to plastic bags, frozen, and then sorted to retrieve all caddisflies. The complete retrieval method for UV light trapping was not employed until 1999.

Voucher specimens of the taxa collected are in the Richard E. Fitzner Natural History Collection at Washington State University Tri-Cities branch at Richland, Washington.

Results

This study revealed a surprisingly diverse adult caddisfly fauna comprising eight families, 18 genera, and 26 species (Table 1). Only one genus, *Nectopsyche,* did not reveal a male adult, negating a species identification. Previous benthic studies (Gaines 1987a, b; Gaines et al. 1989, 1992; Newell 1998) revealed only two families and four genera.

The greatest numbers of adults were captured in June (766), and the smallest number in March (4) (Fig. 1). The Hydropsychidae comprised 66% of all adults (Table 2). The Family Brachycentridae was represented by a single specimen. *Cheumatopsyche campyla* adults comprised nearly half of all adults (45%) (Table 3). Approximately 54% of the adults were females and 46% were males.

Three of the top four most abundant species (*Cheumatopsyche campyla, Hydropsyche californica,* and *H. cockerelli*) (Table 3) are also abundant in the Columbia River, just 20 km away (Newell 1998). Other species present in the Co-

Table 3. The six most abundant species collected at the two spring streams, percent of total number collected, and peak emergence period.

SPECIES	Number	% of Total	Emergence Peak
Cheumatopsyche campyla	908	45%	Last half of June to early July
Hydropsyche californica	349	17	Last half of June
Ylodes frontalis	287	14	Last half of August through September
Hydropsyche cockerelli	74	4	First half of August
Limnephilus spinatus	68	3	Second half of September
Oecetis avara	68	3	Last half of June

lumbia River and at least one of the spring streams are: *Glossosoma velonum, Hydroptila argosa,* and *Psychomyia flavida.* Unidentified species of the following genera are also known from the Columbia River: *Nectopsyche* sp., and *Oecetis* sp. The terrain between the Columbia River and the springs is relatively flat and this area has frequent high winds. The records of only four larval genera in over 15 years of benthic sampling in the two springs compared to the large number of genera collected during this study suggests many species originated in the nearby river.

The fauna of the spring streams consists of species primarily eastern and southern United States in distribution. Nine of the 26 species collected appear to be new distribution records of the state. These new records are marked with an asterisk (*) in Table 1. While most of these new records are expected, the collections of *Limnephilus abbreviatus* and *L. assimilis* are significant range extensions as the closest records appear to be from Utah.

LITERATURE CITED

Cushing, C. E. & R. T. Rader. 1982. A note on the food of *Callibaetis* (Epehemeroptera:Baetidae). Great Basin Nat., 41(4): 431–432.

Cushing, C. E. & E. G. Wolf. 1982. Organic energy budget of Rattlesnake Springs, Washington. Amer. Midl. Nat., 107(2): 404–407.

Cushing, C. E. & E. G. Wolf. 1984. Primary production in Rattlesnake Springs, A cold desert spring-stream. Hydrobiolobia, 114: 229–236.

Cushing, C. E. & W. E. Gaines. 1989. Thoughts on recolonization of endorheic cold desert spring-streams. J. N. Am. Benthol. Soc., 8(3): 277–287.

Daubenmire, R. F. 1970. Steppe vegetation of Washington. Washington Agri. Exper. Sta. Tech. Bull. 62. Wash. Agri. Exper Sta., Pullman, Washington.

Davis, J. J. 1948. The caddis flies of the state of Washington. Unpubl. M.S. Thesis, Washington State University, Pullman, Washington.

Frest, T. J. & E. J. Johannes. 1993. Mollusc survey of the Hanford Site, Benton and Franklin Counties, Washington. PNL-8653, Pacific Northwest Laboratory, Richland, Washington.

Gaines, W. E. 1987a. Secondary production of benthic insects in three cold-desert streams. PNL-6286, Pacific Northwest Lab., Richland, Washington.

Gaines, W. E. 1987b. Secondary production of benthic insects in three cold-desert streams. Unpubl. Master's Thesis, Central Washington University, Ellensburg, Washington.

Gaines, W. E., C. E. Cushing & S. M. Smith. 1989. Trophic relations and functional group composition on benthic insects in three cold desert streams. Southwestern Naturalist, 34(4): 478–482.

Gaines, W. E., C. E. Cushing & S. M. Smith. 1992. Secondary production estimates of benthic insects in three cold desert streams. Great Basin Nat., 51(1): 11–24.

Mize, A. L. 1993. Differential utilization of allochthonous and autochthonous carbon by aquatic insects of two shrub-steppe desert spring-streams. Pacific Northwest Lab, PNL-88684, Battelle, Richland, Washington.

Newell, R. L. 1998. Diversity of aquatic invertebrates of the Hanford Reach of the Columbia River, some tributaries, and two adjacent springs, Washington State, USA. Final Report to The Nature Conservancy for THE BIODIVERSITY INVENTORY AND ANALYSIS OF THE HANFORD SITE, Annual Report 1998.

Pacific Northwest National Laboratory (PNNL). 1998. Hanford National Environmental Policy Act (NEPA) characterization, PNNL-6415 Rev.10, Battelle, Richland, Washington.

Rickard, W. H. & C. E. Cushing. 1982. Recovery of streamside woody vegetation after exclusion of livestock grazing. J. Range Management, 35(3): 360–361.

Saskschewsky, M. R., J. L. Downs, W. H. Rickard & G. I. Baird. 1992. Vascular plants of the Hanford Site. WHC-EP-0554. Westinghouse Hanford Company, Richland, Washington.

Schwab, G. E., R. M. Culpritts, Jr. & D. A. Schwab. 1979. Spring inventory of the Rattlesnake Hills. W. K. Summers and Associates, Inc., Socorro, New Mexico.

Wolf, E. G. & C. E. Cushing. 1972. Productivity of Rattlesnake Springs, IN Pacific Northwest Laboratory Annual Report for 1971, BNWL-1650 PT2, Ecological Sciences, Battelle, Richland, Washington.

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NESTED SUBSETS AND PARTITION PATTERNS IN ANT ASSEMBLAGES (HYMENOPTERA, FORMICIDAE) OF COLOMBIAN DRY FOREST FRAGMENTS

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Abstract.—We analyzed the conservation status of ant assemblages in seven dry forest fragments located in the Cauca River valley in southwestern Colombia, by means of nested subsets techniques which are applicable in situations where a fragmented landscape can be compared with an archipelago. Ant communities were intensively sampled between 1994 and 1995 in all forests as well as in their surrounding matrices (i.e., neighboring agricultural lands). From 123 ant species found, 63 species were captured only in the forest habitat and 60 ant species in both forests and matrices ("habitat generalist"). No significant species-area relation was found. Monte Carlo simulations and N index showed a significant nesting for "habitat generalist" ant species. The opposite was true for the ant species limited to forests: we found a pattern of extreme non-nestedness (i.e., the opposite of nestedness pattern), which cannot be explained in terms of random effects. This led us to amplify the nested subsets analysis by the concept of "partition pattern" which describes a scheme, where species found on one island of an archipelago are not likely to be found on any other one. The relevance of partition identification in conservation biology is obvious: in a partitioned archipelago, it is essential to protect all component islands. Each one possesses a fauna not repeated in the whole archipelago. Destroying this fauna means extinguishing it in the whole archipelago.

Key Words.—Insecta, Dry forest, Formicidae, fragmentation, nested subsets.

One of the main issues in conservation biology is the widespread transformation of natural land for human use, resulting in the fragmentation and insularization of many formerly continuous habitats (Cutler 1991). Although Colombia has been regarded as a megadiverse country (Brown 1989) with various biotic endemic centers (Terborgh & Winter 1983), it is being affected by an extensive destruction of its tropical forest. The Andean region, where most of the Colombian population is concentrated, is the zone most affected by human action (Saavedra & Freese 1986) with the consequent fragmentation of ecosystems. The dry tropical forest, as found in the interandean valleys, is the most endangered habitat of all the major lowland tropical forests (Janzen 1988). Slash and burn agriculture formerly applied to this fertile land, and the recent advance of extensive fire-managed sugar cane monocultures, have contributed to the progressive destruction of these tropical dry forests.

A fragmented landscape such as the one just described, can be compared with an oceanic archipelago, in which the patches of suitable habitat could be considered "islands", surrounded by an "ocean" of anthropogenic matrix. Although this assumption is fundamental for the application of island biogeography to conservation, it has to be handled carefully, because the mainland habitat islands are separated in reality by other habitats and are not completely isolated. Thus, depending on the matrix surrounding a particular remnant, some species may not be isolated at all, but others may be trapped as if they were embedded in actually "isolated islands" (Doak & Mills 1994).

In many natural and anthropogenic habitats, the fauna of the archipelago tends to form nested subsets (Cutler 1991). This pattern, termed "nested subset model" by Patterson and Atmar (1986), arises in an archipelago when species occurring on species-poor islands are mere subsets of the species living on islands richer in biota. Nested subset analysis tests for patterns between species identities and the numbers of species occurring on different islands (Doak & Mills 1994). A nested pattern has been variously attributed to both selective immigration and selective extinction (Cutler 1991).

If a nested subsets model fits in a situation with a strong species-area relation, it supports the argument that a large reserve, rather than many small ones, preserves more vulnerable biota. However, a nested subsets pattern does not necessarily imply that a predictable extinction sequence will result from shrinking remnant size and it is quite possible to have a nested subset and no significant species-area relationship or vise versa, as argued by Doak and Mills (1994). The power of nested subsets techniques is that they support statements concerning predictability of species lost or colonizations, in an ordered sequence from the species-rich to species-poor remnants (Doak & Mills 1994).

Due to their ubiquity, abundance and their importance in energy and matter transfer in tropical terrestrial ecosystems, arthropods, especially insects, have been proven a valuable tool in studies of conservation biology (Kremen et al. 1993). Ants (Hymenoptera: Formicidae) have been proposed as bioindicators of species diversity (Andersen & Majer 1991, Roth et al. 1994), disturbance (Brown 1989, Olson 1991, Burbidge et al. 1992, Majer 1992) and successional stages or ecosystem rehabilitation (Majer 1983, 1985; Mackay & Vinson 1989).

This paper analyzes the conservation status of ant assemblages in seven dry forest fragments located in the same river valley in southwestern side Colombia, by means of nested subsets techniques. We discuss new insights concerning the application and interpretation of Patterson and Atmar's nested subsets index.

MATERIALS AND METHODS

Study area.—The study was carried out in the Cauca Valley, an alluvial valley formed by the Cauca River. The valley is about 220 km long and 10–20 km wide (coordinates 30°5′, 5°05′ N and 76°04′, 76°30′ W) with an extension of about 421.000 ha. It is between 900–1000 m above sea level. Its soils are of extraordinary fertility, and its climatic conditions are very appropriate to agricultural use: the average temperature is about 24° C. There are two rainy seasons (March–May, September–November), each followed by a dry season. The mean annual rainfalls range between 1000 and 2000 mm. According to the Holdridge classification system, this region is designated as tropical dry forest (Espinal 1967).

It is known from anecdotal sources that this valley was once covered by continuous and extensive, closed canopy forests (Alvarez & Kattan 1995) which rapidly retreated after the Spaniards' colonization. Simultaneously, extensive crop and cattle fields and also numerous settlements appeared in this landscape. By 1957, the forest area reduction was severe, only 25,320 ha of the valley were covered by forest. Only 29 years later, this forest area was further reduced by 66% (Corporación Autónoma Regional del Valle del Cauca 1990).

Today, the valley is almost totally dominated by sugar cane and other crops and by pastures (Alvarez-López & Kattán 1995). The intensive fragmentation left only small isolated forests, with extensions between 1 and 15 ha. They are of

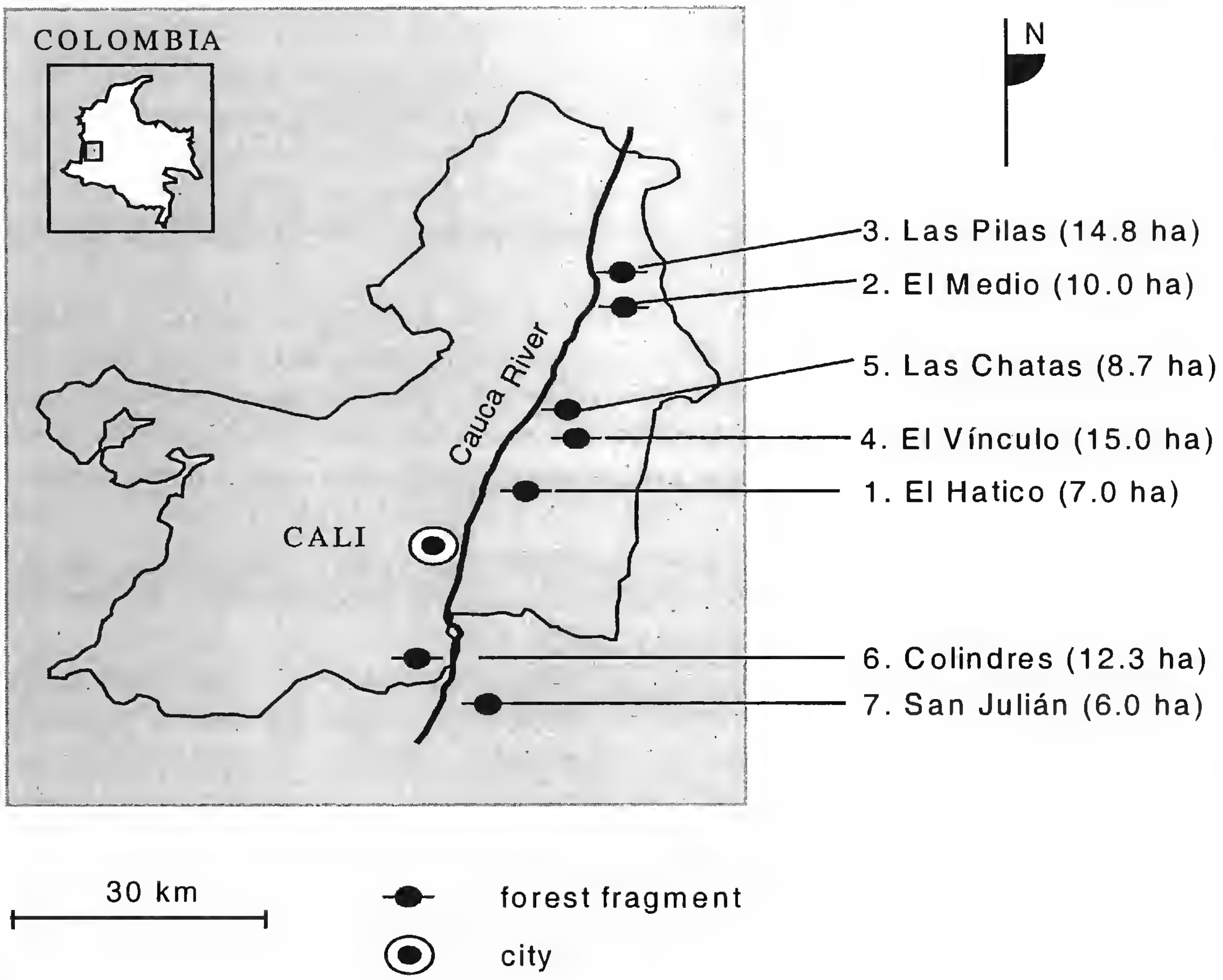

Figure 1. Localization of the study sites. The forest fragments are ordered according to species richness of ants: 1 denotes the richest fragment. Forest area is denoted in parenthesis.

secondary growth, with 20–40 m high canopies, in which species such as *Laetia americana* L., *Guadua angustifolia* Kunth, *Xylopia ligustrifolia* Humboldt & Bonpland ex Dunal and *Anacardium excelsum* (Bertero & Balb. Ex Kunth) dominate. The common biographic history allows us to consider the region as an archipelago of forest remnants embedded in a ocean-like anthropogenic "matrix", term defined by Samways (1994) as "the most extensive and continuous portion of a landscape, which often surrounds a fragment of different nature".

In this study we selected seven dry forest fragments along Cauca river valley (Fig. 1). It is important to state here that there was neither transition zone nor ecotone in any of the fragments studied.

Sampling.—Ant assemblages were sampled twice in each forest fragment and its corresponding matrix. The first sampling set was conducted at three-week intervals between August and September 1994 and the second was carried out between January and February 1995.

Sampling in the forest fragments and their surrounding matrix was done according to Armbrecht (1995). In brief, four 100 m long transects were designated, two inside the forest fragment beginning 20 m inside from the forest edge, and two in matrices beginning 20 m outside the border. The transects inside the forest were parallel to each other, but perpendicular to the forest border. The transects in the matrix were located in the same way, along the same lines.

Ten equidistant, 10 m separated stations were labeled along each transect. At each station, the following procedures were carried out: firstly, three tuna bait traps (i.e., 5 g tuna-in-oil on 7 × 10 cm piece of paper) were installed in different places (10 cm underground, on the soil surface and attached to a tree trunk at 1.70 m height). Also a pitfall trap (i.e., a plastic glass 6 cm diameter, containing a 1:1 alcohol-water mixture) was set up at each station to trap falling ants. Both tuna baits and pitfall traps were left out for four h. In addition, a total of 50 liters/transect (5 liters/station) of forest litter was collected and sifted with a Winkler sac. Ants caught in the sifted material were separated in the laboratory. Finally, eight h of visual scrutiny and manual capture were performed along all transects (10–15 min/station), searching for ants in the different microhabitats. The total sampling effort in a forest and its surrounding matrix included a total of 320 hours of pitfall trapping, 880 hours of tuna baits attraction, 80 samples of litter and 16 person-hours of manual collection.

Ants were determinated taxonomically to genus level according to Holldobler and Wilson (1990), Mackay and Vinson (1989), and Jaffé et al. (1993). Specific level was assessed by specialists from different U.S. and Colombian Institutions (see acknowledgment). Voucher specimens are deposited at the "Museo de Entomología de la Universidad del Valle", Cali, Colombia.

Data Analysis.—The geographic separation of the selected forest fragments allowed us to use the nested subsets principle in the analysis concerning biological conservation. The nested subsets concept is based on the richness of each island, i.e., number of species. The distribution of species in a group of islands follows a nested subsets pattern if the species of a poorer island can always be found on the richer ones (Patterson 1987).

Obviously, it is not probable to find a pure nested subsets pattern in an archipelago, so it is necessary to define an index which allows an evaluation of how close a given pattern of species is to a nested subsets pattern. There are various alternative indices (see for instance Patterson & Atmar 1986, Cutler 1991, Wright & Reeves 1992). We used the index of unexpected absences described in Patterson and Atmar (1986). The difficulty with all definitions is that these indices are not normalized; that is, the specific structure of the archipelago and the number of species found do affect the absolute size of the index. In order to judge the closeness of a pattern to nestedness, Patterson and Atmar (1986) proposed calculating the indices of a number of random patterns and comparing their probability distribution with the index of the observed pattern.

There are different possibilities for simulating the required random patterns. Patterson and Atmar (1986) proposed the following: the simulation algorithm called RANDOM0 generates the given number of species, supposing a uniform distribution of the number of species per island. In RANDOM1, the distribution of species per island follows the observed richness. Obviously, RANDOM1 is closer to the real situation, and can therefore be considered more reliable.

We implemented a modified version of the Monte Carlo algorithm proposed by Patterson and Atmar (1986) to reduce the computing time to 1000 simulations to a few seconds.

The procedure for determining the index of unexpected absences (N), which we used to evaluate the observed and simulated patterns of species, is the following: the islands are ranked in order of richness and the species, in order of their frequency of occurrences. Using this order, the presence–absence matrix is constructed. For each species, the poorest island containing it is found, and the number of absences in all richer islands is determined (the unexpected absences). This number is a measure of how strictly this species follows the conservation principle. In a pure conservation pattern, one would not expect any absences. The index N, the sum of the unexpected absences of all species, describes the deviation of the observed pattern from a completely nested one.

We found it convenient to standardize the index N of unexpected absences (as emphasized by Cutler 1991, Wright & Reeves 1992, Cook 1995). We standardized the probability distribution function of the simulated N indices, dividing them by the standard deviation and subtracting the mean value. By the same operation, applied to the calculated N index of the studied archipelago, we obtained the standardized index Ñ. Based on the Monte Carlo simulation process, the index Ñ is independent of the specific matrix structure and density. It is therefore possible to compare evaluations of different archipelagos, evaluations of one archipelago in different instances, or as in our case, subgroups of species found in the archipelago.

Using the standardized index Ñ it is easy to interpret the nestedness of a pattern. Values near 0 indicate a complete random pattern, the more negative the values, the more significant is the nested pattern. High positive values indicate a pattern which is significantly not random.

The following statistics for the simulated N indices were determined: total mean, variance, standard deviation and highest and lowest values. *t*-tests (Zar 1984) were used to assess the probability of the calculated N index being the result of a normal distribution of values.

RESULTS

We recorded 3006 capture events, 69.7% of them in the forest transects, 30.3% in the matrix. One capture event refers to an ant species captured by any of the methods described above regardless the number of workers collected. We found a total of 136 different ant species. After excluding the species present only in the matrix, which are of no relevance in our study, we counted a total of 123 ant species; 63 species were captured only in the forest and 60 were captured in both forest and matrix. The appendix shows the presence-absence matrix for species in each of the forest fragments. No significant correlation in the species-area relationship was found for the fragments ($r = 0.11$; $n = 7$; $P > 0.5$).

Figure 2 shows the species saturation curves for all species sampled, as well as forest and matrix habitats separately. As recommended by Longino and Colwell (1997), we included all sampling methods. The curves show stabilization after ⅔ of the total capture events, thus confirming sufficiency of our sampling effort (Armbrecht & Ulloa-Chacon 1999).

The nesting index N was calculated and Monte Carlo simulations type RANDOM0 and RANDOM1 were done. Here we will discuss only the results obtained by simulation using RANDOM1; the results using RANDOM0 are similar, but slightly weaker. The index of unexpected absences is quite near the mean value obtained by 1000 simulations, indicating that the pattern found can be explained by mere randomness (Table 1).

Given the separate surveys in forests and the surrounding fields, we were able

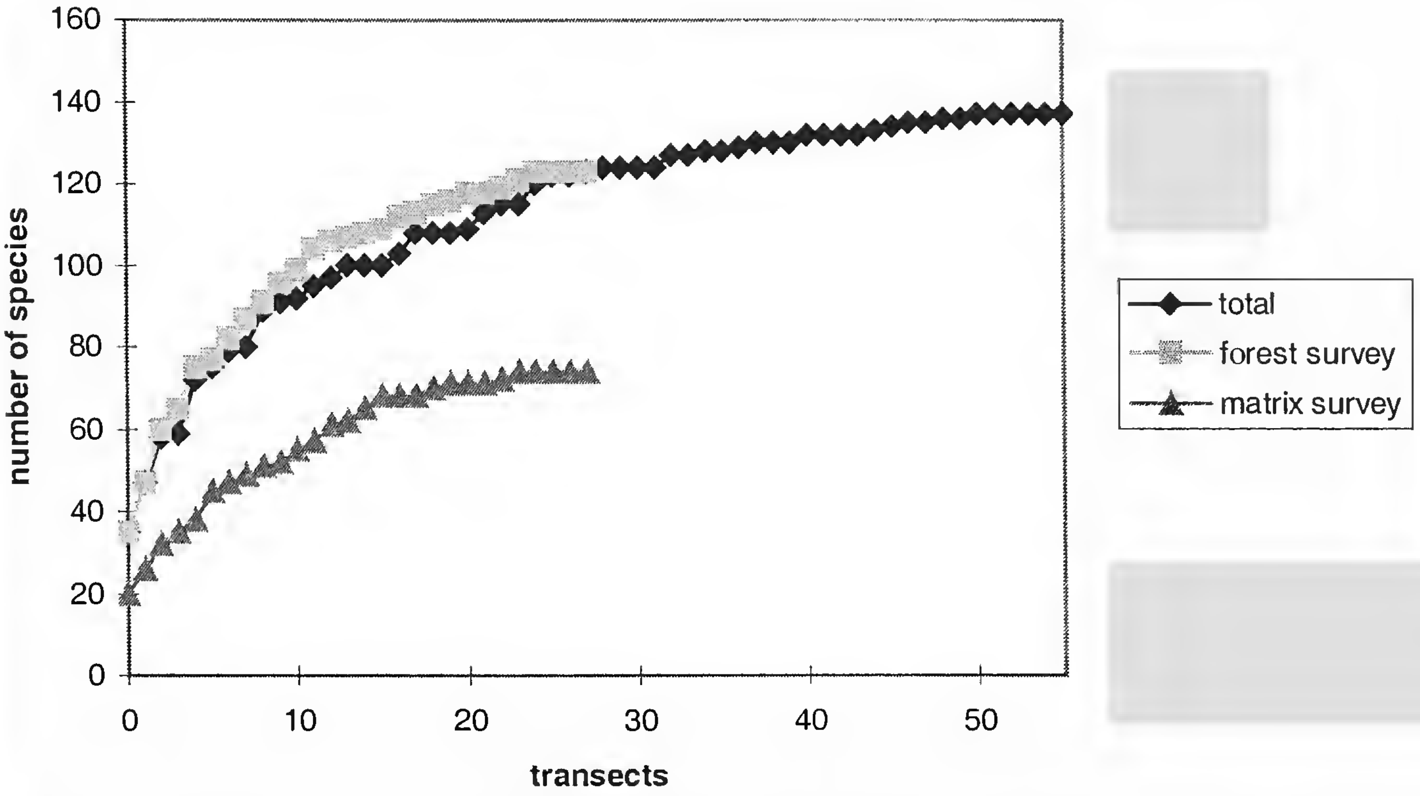

Figure 2. Saturation curves for species sampled in the forest and matrix transects (total), in the forest transects only (forest survey) and in the surrounding matrix only (matrix survey). Data from different transects were ordered randomizing individual fragment transects. Note that the "total" curve is less steep initially than "forest survey" because the accumulation of species slows down initially due to the effect of the less rich matrices included in this group.

to analyze separately the group of ant species found only in the forest (exclusive forest habitat species) and those present in both forest and matrix ("habitat generalist" species) (Table 1). The behaviors of these two groups are completely contrary: the group of species present in the forest and its surrounding matrix present a nested pattern. The group of exclusive forest habitat species does not follow a nested subsets scheme, but neither is the pattern completely random. We found a value of the unexpected absence index which is significantly above the mean value ($P = 0.01$). We term this pattern, characterized by a significant non-nestedness, a partition pattern. The species which contributed most to the high N

Table 1. Summary of the nestedness analysis of all ant species found in the study (first row), and the two subgroups in which we divided it: "habitat generalists" and "exclusive forest species". N is the observed index of unexpected absences. $\bar{N}$ is the standardized index proposed by us, in which values near 0 indicate a complete random pattern (see text). Additionally we report the mean value, standard deviation, maximum and minimum obtained in the Monte Carlo simulation of 1000 archipelagos, using RANDOM1. P refers to the probability that the observed values could be explained by randomness.

	Actual data			Monte Carlo simulation				
Group	Spp.	N	$\bar{N}$	Mean N	S.D.	Min	Max	P<
All species	123	247	0.43	241.0	13.89	192	283	0.67
"Habitat generalist" species*	60	80	−2.23	99.1	6.55	66	122	0.013
Exclusive forest habitat species**	63	105	4.30	78.0	6.28	54	107	0.99

* Refer to ant species found both in forests and matrices

** Refer to ant species found only inside forests.

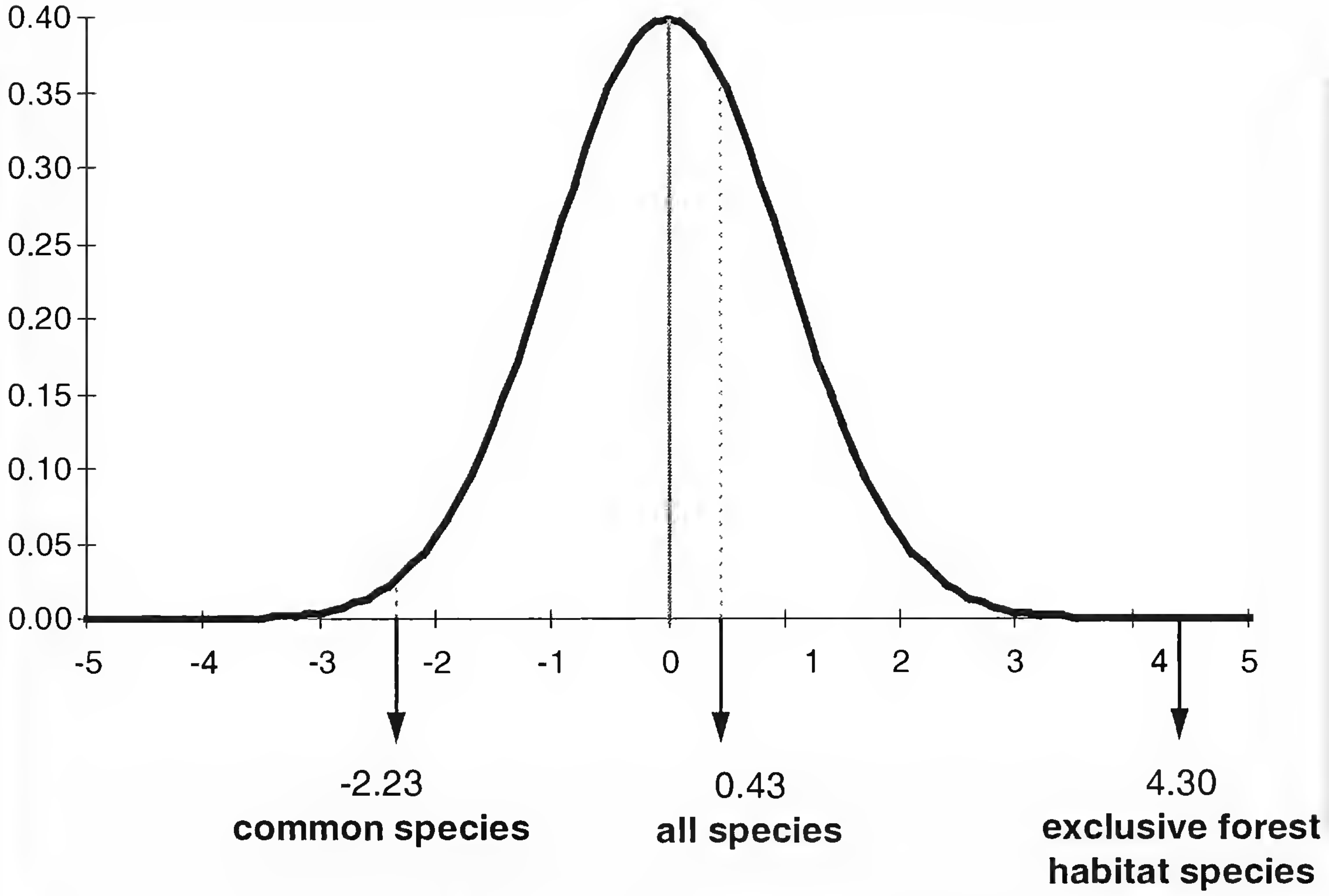

Figure 3. Standardized normal distribution of Ñ showing the values for the three group combinations of ant species analyzed in the study.

index are the ones which are present in only one forest. They explain 66.7% (70 of 105) of the unexpected absences.

In order to show the contrary behaviors of the two groups we standardized the normal distributions of the simulated indices and the observed index of the different combination groups (Fig. 3). The random pattern shown by the combinations of all species can thus be explained by the superposition of the two groups: the nested group of "habitat generalist" species and the group of exclusive forest habitat species, which is significantly not nested.

Discussion

The Concepts of Nestedness and Partition.—Species of an archipelago follow a nested subsets pattern if those species present on the poorer islands are also present on the richer ones. In this case, the index N of unexpected absences is significantly below the value expected in a completely random pattern. Nestedness could be explained by extinction (i.e., Brown & Gibson 1983, Patterson & Atmar 1986, Patterson 1987) or colonization (Darlington 1957, Simberloff & Wilson 1967) in a "nested way". When assumptions are met (Atmar & Patterson 1993), the species of an archipelago follow a predictable scheme of extinction if there is a sequence of species ordered according to their susceptibility to extinction. Species present a scheme of selected immigration, if they have followed a predictable "colonization program" possibly determined by selected dispersal. In both cases, the nested pattern of species in the archipelago can be attributed to the conditions of the islands: they must follow a scheme whereby the habitat "capacity" for supporting ant species diminishes in a sequential order from the species-rich to the species-poor island (that means, the habitats also follow a nested pattern).

Here we would like to develop a concept to apply in a situation where a partition pattern is found, that is, a pattern of significant non-nestedness. Nestedness means that the species occurring on the poorer islands are all present on the richer ones. The extreme opposite situation is a partition pattern, where each species occurs on only one island. A nested pattern presents a very low index of unexpected absences; the index for partition schemes is very high. This means that a partition pattern could not be explained as random variation. There must be an explanation, as for nested structures.

The reason why real archipelagos or habitat fragments show a partitioned fauna can, in analogy to the nested case, be attributed to their ecological and geographical conditions. In the case of partition, that means, that habitat conditions present in one island, will not occur on other ones: they are mutually exclusive. Alternatively, the priority of access to an establishment site can give a forest ant species a competitive advantage because of greater colony size. Therefore, the ants species left in forest fragments are apt to be most successful in replacing themselves, especially if establishment of outsiders is restricted by low rates of colonization by habitat specialists because of the low quality of the matrix. Consequently, each fragment conserves its special fauna. The implications for conservation are serious: if one of the habitat islands disappears, the remnant fauna will also disappear, because it is only present in this single island.

Implications for the Situation Studied.—We assume that before fragmentation each ant species in the forest had the same probability of being present in any part of the continuously wooded geographical Cauca River valley. If all the fragments had the same history, the largest fragment would have retained more species. The lack of a significant correlation in the species-area relationship may be due to the fact that the seven wooded fragments are about the same size (6–15 ha), but present a large variation in the number of ant species. Thus, the richest forest (El Hatico) with 67 species, has nearly double fauna of the poorest forest (San Julian) with only 34 species (Appendix).

For the analysis of the nesting for the species common to both forest and matrix (“habitat generalists”), we consider the forest plus its nearest matrix as the island, because the samples were taken no further than 150 m away from the forest borderline. The result is a highly significant nestedness. Following Doak and Mills (1994), it is important to consider that island fragments are separated from other terrestrial communities by habitats that might be occupiable by the species under study. Therefore, depending on the type of matrix surrounding the fragments, some species will not really be isolated, but others will be trapped, with the matrix acting as a barrier equivalent to oceanic islands. As a working hypothesis, we propose that the agricultural practices of the matrix, which includes the progressive utilization of land to single crop farming explain the extinctions (or the fail of successful colonizations). For instance, it has been shown for coffee crops that high quality agricultural matrices sustain more associated biodiversity than low quality ones (Perfecto & Snelling 1995, Perfecto et al. 1996). Forests which have been protected throughout generations and which are surrounded by the richest matrices (for example, El Hatico, El Medio) had also the richest ant faunas. We suggest that those species which accept a wide range of living conditions are able to immigrate from the surrounding fields and pastures to the forest-matrix fragments and that they are colonizing new areas in a predictable sequence. The pattern found for "habitat generalists" ants may therefore indicate that the fragments are true isolates, from the viewpoint of very low rates of colonization by ants across the intervening matrix. We suggest that a sustainable management of the agricultural landscape can be the key for biodiversity conservation.

Contrary to the group of species found in forest and matrix, in the group of species exclusively occurring in forest, a partition pattern was found, indicating that each forest preserves its own species. Thus, many species living in forests with few species are not found in forests with many species. How can this pattern be explained? One possibility is that demographic rarity has affected the geographic rarity. However, if this had been the case, one would expect a purely random pattern (Doak & Mills 1994), not the partition pattern we found. An alternative explanation for this pattern is that throughout the process of fragmentation microhabitats and communities of the different fragments have turned out to be mutually exclusive, so that each forest sustains a particular forest ant fauna that is almost isolated by "low quality" matrices. The important conclusion from the partition pattern found is that if any of these forest fragments disappears, an important portion of rare, exclusive forest ant species will disappear with it. Moreover, ants, as bioindicators, may reflect biodiversity in other taxa like invertebrates or plants (Majer 1983), so that the danger of local extinction may extend to an even broader range of organisms. In this heavily fragmented distribution, each forest remnant, be it large or small, constitutes a refuge for preserving biodiversity.

General Remarks.—The concept of nestedness should be supplemented by the concept of partition, a pattern where the N index is higher than it would be expected from a random process. A partitioned pattern means that many species are found in only one island, more than could be expected in a random scheme. This means, that all the islands in the archipelago deserve special attention. Only protection of the archipelago as a whole can lead to the conservation of fauna.

We found it helpful to standardize the index of unexpected absences, N, in order to allow comparison among different groups of species on an archipelago (or even among archipelagos) with respect to nestedness or partition. The standardization uses means and standard deviations of the simulated indices, thus compensating for the effects of size and density of the presence–absence matrix.

It is important to keep in mind that results of nested subsets analysis could be ambiguous if the subgroups involved present nested as well as partitioned patterns. The results for the whole group are thus only the superposition of the evaluations of the subgroups. In studies, that intend to apply nestedness analysis, it is very important to include intensive sampling of the matrix. The findings of the present paper depend highly on the possibility of distinguishing species of an exclusive forest habitat and species found in the surrounding fields as well.

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Literature Cited

Alvarez-López, H. & G. Kattan. 1995. Notes on the conservation status of resident diurnal raptors of the middle Cauca valley, Colombia. Bird Conserv. Internal., 5: 137–144.

Andersen, A. N. & J. D. Majer. 1991. The structure and biogeography of rain forest ant communities in the Kimberley region of northwestern Australia. pp. 333–346. *In* McKenzie N. L., R. B. Johnston & P. G. Kendrick, (eds.). Kimberley Rainforests. Surrey Beatty & Sons, Chipping Norton, Australia.

Armbrecht, I. 1995. Comparación de la mirmecofauna en fragmentos boscosos del valle geográfico del río Cauca, Colombia. Bol. Mus. Entomol. Universidad del Valle, 3: 1–10.

Armbrecht, I & P. Ulloa-Chacon. 1999. Rareza y diversidad de hormigas en fragmentos de bosque seco colombianos y sus matrices. Biotropica, 31: 546–653.

Atmar, W. & B. D. Patterson. The measure of order and disorder in the distribution of species in fragmented habitat. Oecologia, 96: 373–382.

Brown, J. H. & A. C. Gibson. 1983. Biogeography. C. V. Mosby Company, St. Louis, Missouri.

Brown, K. Jr. 1989. The conservation of neotropical environments. Insects as indicators. pp. 354–404. *In* Collins, N. M. & J. A. Thomas, (eds.). The conservation of insects and their habitats. 15th Symposium of Royal Entomological Society of London. Academic Press, Hartcourt Brace Jovanovich.

Burbidge, A. H., K. Leicester, S. McDavitt & J. D. Majer. 1992. Ants as indicators of disturbance at Yanchep National Park, Western Australia. J. Roy. Soc. West. Aust., 75: 89–95.

Cook, R. R. 1995. The relationship between nested subsets, habitat subdivision and species diversity. Oecologia, 101: 204–210.

Corporación Autónoma Regional del Valle del Cauca, CVC. 1990. Informe 90-7. Comparación de la cobertura de bosques y humedales entre 1957 y 1986, con delimitación de las comunidades naturales críticas en el valle geográfico del río Cauca. Cali, Valle, Colombia.

Cutler, A. 1991. Nested faunas and extinction in fragmented habitats. Cons. Biol., 5: 496–505.

Darlington, P. J. Jr. 1957. Zoogeography: the geographical distribution of animals. John Wiley & Sons, New York.

Doak, D. F. & L. S. Mills 1994. A useful role for theory in conservation. Ecology, 75: 615–626.

Espinal, L. S. 1967. Apuntes sobre ecología colombiana. Universidad del Valle, Cali, Colombia.

Holldobler, B. & E. O. Wilson. 1990. The ants. Harvard University Press, Cambridge, Massachusetts.

Jaffe, K., J. Lattke & E. Pérez. 1993. El mundo de las hormigas. Equinoccio Ediciones. Universidad Simon Bolivar, Venezuela.

Janzen, D. H. 1988. Tropical dry forest, the most endangered major tropical ecosystems. pp. 130–137. *In* Wilson, E. O. (ed.). Biodiversity. National Academy Press, Washington D.C.

Kremen, C. R., R. K. Colwell, T. L. Erwin, D. D. Murphy, R. F. Noss & M. A. Sanjayan. 1993. Terrestrial arthropod assemblages: their use in conservation planning. Cons. Biol., 7: 796–808.

Longino, J. T. & R. K. Colwell. 1997. Biodiversity assessment using structured inventory: capturing the ant fauna of a tropical rain forest. Ecol. Applic., 7: 1263–1278.

Mackay, W. P. & S. V. Vinson. 1989. A guide to the species identification of the new world ants. Sociobiology, 16: 3–47.

Majer, J. D. 1983. Ants: bio-indicators of minesite rehabilitation, land use and land conservation. Environ. Manag., 7: 375–383.

Majer, J. D. 1985. Recolonization by ants of rehabilitated Mineral sand mines on North Stradbroke Island, Queensland with particular reference to seed removal. Aust. J. Ecol., 10: 31–48.

Majer, J. D. 1992. Ant recolonization of rehabilitated bauxite mines of Pocos de Caldas, Brazil. J. Trop. Ecol., 8: 97–108.

Olson, D. 1991. A comparison of the efficacy of litter sifting and pitfall traps for sampling leaf litter ants (Hymenoptera: Formicidae) in a wet forest, Costa Rica. Biotropica, 32: 166–172.

Patterson, B. D. 1987. The principle of nested subsets and its implications for biological conservation. Cons. Biol., 1: 323–334.

Patterson, B. D. & W. Atmar. 1986. Nested subsets and the structure of insular mammalian faunas and archipelagos. Biol. J. Linnean Soc., 28: 65–82.

Perfecto, I. & R. Snelling. 1995. Biodiversity and the transformation of a tropical agroecosystem: ants in coffee plantations. Ecol. Appl., 5: 1084–1097.

Perfecto, I., R. A. Rice, R. Greenberg & M. E. Van der Vort. 1996. Shade coffee: a disappearing refuge for biodiversity. Bioscience, 46: 598–608.

Roth, D. S., I. Perfecto & B. Rathcke. 1994. The effects of management systems on ground foraging ant diversity in Costa Rica. Ecol. Appl., 4: 423–436.

Saavedra, C. J. & C. Freese. 1986. Prioridades biológicas de conservación en los Andes tropicales. Parques, 11: 8–11.

Samways, M. J. 1994. Insect conservation biology. Chapman & Hall, London.

Saunders, D. A., R. J. Hobbs & C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Cons. Biol., 5: 18–32.

Simberloff, D. & J. L. Martin 1991. Nestedness of insular avifaunas: simple summary statistics masking complex species patterns. Ornis Fennica, 68: 178–192.

Simberloff, S. D. & E. O. Wilson. 1969. Experimental zoogeography of islands: the colonization of empty islands. Ecology, 50: 278–296.

Terborgh, J. & B. Winter. 1983. A method for sitting parks and reserves with special reference to Colombia and Ecuador. Biol. Cons., 27: 45–58.

Wright, D. H. & J. H. Reeves. 1992. On the meaning and measurement of nestedness of species assemblages. Oecologia, 92: 416–428.

Zar, J. H. 1984. Biostatistical analysis. Prentice Hall, New Jersey.

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Appendix. Presence-absence matrix of the ant species in the seven sites (the forest fragment and its surroundings). The species labeled with "f" were found exclusively inside the forest (exclusive forest habitat) and not in its surrounding matrix. That is, they are exclusive forest habitat species as defined in the paper. Species without labeling were captured at least one time each in both the forest and matrix. Forests are ordered by richness, and ant species are ordered according to their presence from the richest to the poorest forests. 1: El Hatico, 2: El Medio, 3: Las Pilas, 4: El Vinculo, 5: Las Chatas, 6: Colindres, 7: San Julián.

Scientific name and code assigned during the study	Forest only	forest fragments						
		1	2	3	4	5	6	7
Wasmannia auropunctata		x	x	x	x	x	x	x
Myr-04 *Solenopsis ("Diplorhoptrum")*		x	x	x	x	x	x	x
Crematogaster sp.		x	x	x	x	x	x	x
Myr-08 *Solenopsis ("Diplorhoptrum")*		x	x	x	x	x	x	x
Camponotus novogranadensis		x	x	x	x	x	x	x
Camponotus crassus		x	x	x	x	x	x	x
Pseudomyrmex oculatus		x	x	x	x	x	x	x
Pseudomyrmex boopis		x	x	x	x	x	x	x
Pseudomyrmex elongatus		x	x	x	x	x	x	x
Paratrechina ca. pubens		x	x	x	x	x		x
For-13 *Camponotus* sp.		x	x	x	x	x		x
Brachymyrmex heeri		x	x	x		x	x	x
Pheidole sussanae		x	x	x		x	x	x
Cephalotes maculatus		x	x		x	x	x	x
Cyphomyrmex rimosus		x	x	x	x			x
Atta cephalotes		x	x	x	x			x
Myr-03 *Pheidole* sp.		x	x		x		x	x
Myr-32 *Pheidole* sp.			x	x	x		x	x
Pon-10 *Hypoponera* sp.	f		x	x	x		x	x
Dol-06 *Linepithema* sp.		x	x			x	x	x
Crematogaster curvispinosa	f	x				x	x	x
Pseudomyrmex gracilis		x	x			x		x
Pseudomyrmex pallens	f	x	x				x	x
Strumigenys eggersi	f		x	x	x			x
Pon-09 *Hypoponera* sp.	f			x		x		x
Dol-01 *Azteca* sp.	f	x			x			x
Dolichoderus lutosus	f	x				x		x
Cephalotes minutus						x		x
Crematogaster distans	f			x				x
For-11 *Camponotus* sp.	f	x						x

Apppendix. Continued.

Scientific name and code assigned during the study	Forest only	Forest fragments						
		1	2	3	4	5	6	7
Pseudomyrmex kuenckeli	f			x			x	
Myr-56 Crematogaster (Orthocrema) sp.	f					x		x
Myr-10 Cephalotes sp.	f							x
Myr-43 Cephalotes sp.	f							x
Myr-14 Pheidole sp.		x	x	x	x		x	
Pachycondyla constricta	f	x	x	x	x		x	
Procryptocerus hylaeus		x		x		x	x	
Dol-03 Azteca sp.		x			x	x	x	
Crematogaster acuta		x	x				x	
Pon-13 Pachycondyla n. sp.	f	x				x	x	
Linepithema dispertitum		x	x				x	
Pse-10 Pseudomyrmex sp.			x	x			x	
Myr-18 Trachymyrmex sp.	f			x			x	
Myr-23 Cephalotes(Paracryptocerus)	f	x					x	
Pseudomyrmex rochai	f	x					x	
Pachycondyla obscuricornis	f	x					x	
For-05 Camponotus	f					x	x	
Dol-07 Azteca	f			x			x	
Crematogaster ampla							x	
Cardiocondyla nuda	f						x	
Pachycondyla harpax	f						x	
Pon-15 Pachycondyla sp.	f						x	
Dol-13 Azteca sp.							x	
Labidus coecus			x	x	x	x		
Azteca velox				x	x	x		
Leptothorax echinatinopis			x	x		x		
Leptothorax pleuriticus	f	x		x		x		
Solenopsis geminata		x				x		
Leptothorax sp.				x		x		
Pachycondyla foetida	f	x				x		
Camponotus abdominalis	f	x				x		
Dol-12 Azteca sp.	f	x				x		
Pseudomyrmex ita						x		
Pse-15 Pseudomyrmex sp.	f					x		
Pseudomyrmex lisus	f					x		
Camponotus bidens	f					x		
Pachycondyla impressa		x	x	x	x			
Crematogaster evallans			x	x	x			
Myr-13 Solenopsis (“Diplorhoptum”) sp.			x	x	x			
Megalomyrmex drifti	f	x	x		x			
Myr-02 Pheidole (flavens group) sp.			x		x			
Myr-36 Pheidole (biconstricta group) sp.				x	x			
Myr-46 Pheidole sp.	f	x			x			
Myr-52 Pheidole (Trachypheidole) sp.		x			x			
Myr-59 Solenopsis sp.			x		x			
Myr-63 Strumigenys sp.	f			x	x			
Odontomachus chelifer		x			x			
Myr-15 Cephalotes sp.	f				x			

Apppendix. Continued.

Scientific name and code assigned during the study	Forest only	Forest fragments						
		1	2	3	4	5	6	7
Strumigenys smithii	f				x			
Octostruma balzani	f				x			
Gnamptogenys striatula	f				x			
Dol-16 Tapinoma sp.	f				x			
Myr-31 Pheidole (Hendecapheidole) sp.		x	x	x				
Myr-37 Pheidole (biconstricta group) sp.	f	x		x				
Myr-47 Pheidole sp.	f	x		x				
Sericomyrmex amabilis	f	x		x				
Myr-42 Pheidole sp.	f	x		x				
Dolichoderus bispinosus		x		x				
Myr-33 Solenopsis sp.				x				
Myr-39 Leptothorax (Nesomyrmex) sp.				x				
Acanthognathus brevicornis	f			x				
Pon-14 Pachycondyla sp.	f			x				
For-10 Brachymyrmex sp.	f			x				
For-16 Brachymyrmex sp.				x				
For-17 Camponotus sp.	f			x				
Dol-10 Azteca sp.	f			x				
For-06 Paratrechina sp.		x	x					
For-08 Camponotus (Tanaemyrmex) sp.	f	x	x					
For-19 Brachymyrmex sp.		x	x					
Dol-04 Azteca sp.		x	x					
Gnamptogenys annulata	f	x	x					
Myr-25 Crematogaster (Orthocrema) sp.			x					
Myr-27 Pheidole (Macropheidole) sp.	f		x					
Pseudomyrmex flavidulus			x					
Myr-29 Monomorium sp.	f		x					
Myr-35 Pheidole sp.			x					
Myr-60 Rogeria sp.	f		x					
Prionopelta antillana	f		x					
Gnamptogenys horni	f		x					
Pseudomyrmex termitarius	f		x					
For-09 Camponotus (Myrmobrachys?)			x					
Dol-15 Linepithema sp.	f		x					
Pseudomyrmex tenuissimus	f	x						
Pseudomyrmex levivertex		x						
Myr-48 Pheidole sp.		x						
Myr-50 Strumigenys sp.	f	x						
Mycocepurus smithii		x						
Myr-57 Strumigenys	f	x						
Myr-65 Solenopsis (Diplorhoptrum) sp.	f	x						
Myr-66 Pheidole	f	x						
For-18 Paratrechina	f	x						
Linepithema humile		x						
For-20 Camponotus sp.	f	x						
Total		67	53	50	41	38	37	34

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STATUS OF SOME HISTORICALLY UNFAMILIAR AMERICAN MAYFLIES (EPHEMEROPTERA)

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Abstract.—The status of each of 10 American species of Ephemeroptera that have not been reported for at least the past half century is evaluated. *Isonychia diversa* Traver and *Siphlonurus luridipennis* (Burmeister) are declared recently extinct, and *Ephemera compar* Hagen and *Pentagenia robusta* McDunnough are confirmed as such. The documented extirpation of the closely related European *Palingenia longicauda* (Olivier) may be indicative of the disappearance of *P. robusta* in North America. *Ephemera triplex* Traver, *Ephemerella ora* Burks, *Isonychia notata* Traver, *Leptophlebia grandis* (Traver), *Nixe otiosa* (McDunnough), and *N. rodocki* (Traver) are shown to be new junior synonyms of certain other, better known congeneric American species.

Key Words.—Insecta, Ephemeroptera, North American species, extinctions, new synonyms.

The recent turn of the century has marked the passing of approximately 200 years of describing the North American mayfly fauna (McCafferty 2001). Of the nearly 700 species presently known in North America, however, there are certain species known only from old historical records and usually based only on the original material from which they were described. Considering the ever increasing need to document biodiversity accurately and to gauge the possible vulnerability of species and their habitats, it has become important to re-examine the status of those historically unfamiliar species. If possible, it should be determined whether these unfamiliar species are valid, and if they are not valid, establish a concomitant synonymy. If they are valid, it should be further determined if they are truly restricted and rare, poorly sampled, or extinct. Otherwise, such historically unfamiliar species will continue to be presumed extant but rare and perhaps endangered species. This research is adjunct to the nationally sponsored North American Ephemeroptera database project at Purdue University.

The purpose of the study was to evaluate the status of 10 of the American species of mayflies described prior to 1950 that have never been reported since. Other species remain that currently fall into this category, but they are not treated here for various reasons, often because they are being treated elsewhere as part of continuing generic revisions.

The following narrative analyses are given in alphabetical order. Depositions of studied material, when applicable, are indicated within the text.

EPHEMERA COMPAR HAGEN

This species was based on a single male adult specimen from Foothills, Colorado (Hagen 1875), a locality that has remained dubious (see Edmunds & McCafferty 1984). George Edmunds studied the type of this species while visiting the Museum of Comparative Zoology at Harvard University in the 1950s. Edmunds (personal communication) came to the conclusion that this species was distinct from all other known species of *Ephemera*. Based on drawings of the type specimen rendered by Edmunds and recent comparisons with other North American species (including types), *E. compar* must be considered a valid species. Hagen (1875) was correct that *E. compar* was reminiscent of the European species

E. lineata Eaton (e.g., see Elliott & Humpesch 1983), although Traver (1935) intimated that it was near the widespread American species *E. simulans* Walker. Despite the call to search for this species in the appropriate areas of Colorado by Edmunds & McCafferty (1984) and extensive field work and ecological studies carried out on Colorado waters that have involved mayflies [see reports reviewed by McCafferty et al. (1993)], the species has not been found and should continue to be considered extinct, as first indicated by McCafferty (1996).

EPHEMERA TRIPLEX TRAVER

This species was described from adults taken from four localities in West Virginia in 1930 and 1931 (Traver 1935). It has not been reported subsequently, although considerable collections have been made in the area (e.g., Faulkner & Tarter 1977, Berner 1977, Kondratieff & Voshell 1983). Examination of types held at Cornell University and the study of additional material of *E. blanda* Traver from various states and localities (McCafferty 1975, 1994) revealed no substantial morphological or color difference between *E. triplex* and *E. blanda* (Traver 1932). In type material of both, background body coloration is light, markings are identical and often not very dark, and wings are essentially without pattern, although one or two very small light clouds are present in the forewings of some paratypes of *E. triplex.* Size and male genitalia of both are similar and also similar to that of *E. varia* Eaton. Given variation in wing staining in *E. varia* and *E. simulans* Walker, slight staining associated with *E. triplex* cannot be used in exclusion of other characteristics to uphold the name, and it is therefore placed as a subjective junior synonym of *E. blanda,* NEW SYNONYM.

EPHEMERELLA ORA BURKS

This species was described from a single male and a single female adult taken at Mt. Carmel, Illinois in 1946 (Burks 1947). The date attributed to the species description was incorrectly given as 1949 by Allen & Edmunds (1965) and has been inaccurately repeated as such in subsequent listings. The species has not been reported subsequently (e.g., Randolph & McCafferty 1998).

Burks (1947) stated that if it had not been for the pinkish tan eyes of the his live male specimen assigned to *E. ora,* he would have identified his specimens as *E. excrucians* Walsh. This was because Walsh (1862) had indicated that the eyes of his *E. excrucians* were egg-yellow. Subsequent to Burks' description, Leonard & Leonard (1962) had indicated the eyes of *E. excrucians* were orange-yellow, and Allen & Edmunds (1965) described them as pale orange. The male genitalia and the essential color pattern of the adults are the same in *E. ora* and examined materials of *E. excrucians.* [Allen & Edmunds (1965) designated a lectotype for *E. excrucians* and provided a figure of its genitalia.] Eye color may vary intraspecifically—it can vary depending on how long the adults have lived, and even appear different depending on the angle of light on the eye. This has been witnessed routinely in adults of the common species *Stenacron interpunctatum* (Say). George Edmunds (personal communication) has witnessed eye color change in live adults with the time of day, for example, in the genus *Ameletus* Eaton. In the absence of structural and color pattern differences, eye color alone cannot be safely used as a species-defining characteristic, and *E. ora* is here placed as a subjective junior synonym of *E. excrucians,* NEW SYNONYM.

ISONYCHIA DIVERSA TRAVER

This species was described by Traver (1934) from a single male adult taken in 1916 at Knoxville, Tennessee. A male subimago was also taken from the site three weeks later in 1916 (Kondratieff & Voshell 1984). As part of their revision of the *Isonychia* Eaton species in North America, Kondratieff & Voshell (1984) examined the type of the species held at Cornell University, redescribed the species, and having determined that it was highly distinctive within the genus, considered it as the exclusive member of a unique species grouping they referred to as the "*diversa* group". On the basis of a cladistic analysis, the diversa group was recognized as the subgenus *Borisonychia* McCafferty (McCafferty 1989). The subgenus and species are remarkable because of unique mushroom shaped penes.

Mayflies of East Tennessee are relatively well known (e.g., Long & Kondratieff 1996), as are nearby regions of North Carolina (see discussion of *Siphlonurus luridipennis,* below), but *I. diversa* has not been reported. Also, *Isonychia* spp. are well known to be attracted to lights. Considering that the extraordinary species is clearly valid, and given that considerable collecting efforts have not produced the species in nearly 85 years, *I. diversa* is here considered a recently extinct American species.

ISONYCHIA NOTATA TRAVER

This species has been known only from the holotype female adult reared from a larva and one other, immature larva indirectly associated with the female. The specimens were collected in 1930 from Bald Creek, North Carolina (Traver 1932). Subsequent collecting at the type locality by B. C. Kondratieff did not produce females that exactly matched Traver's description (Kondratieff & Voshell 1984), nor males that could possibly represent *I. notata.* Other sampling in the vicinity over the past 70 years has also not produced adults that might be identified as such, and the report of *I. notata* from North Carolina by Berner (1977) was shown by Kondratieff & Voshell (1984) to be a misidentification of *I. georgiae* McDunnough.

The only possibly distinguishing characteristic assigned specifically to *I. notata* is some distal coloration of the midtibiae in the female adult; the associated larvae are not distinguishable specifically from other larvae of the subgenus *Prionoides* Kondratieff & Voshell (Kondratieff & Voshell 1984). Overall, *I. notata* is similar to *I. georgiae.* The slight color variation in the tibiae of the female adult, at the exclusion of other distinguishing characteristics, however, is not reliable, and *I. notata* is here placed as a subjective junior synonym of *I. georgiae,* NEW SYNONYM.

LEPTOPHLEBIA GRANDIS (TRAVER)

This species (as *Blasturus* Eaton) was described from reared male and female adults and associated larvae taken from two lakes and a stream in the vicinity of Greensboro, North Carolina (Traver 1932). Traver (1932) described another species, *L. intermedia* (Traver), from a tributary of Cape Fear River near Buies Creek, North Carolina. Unlike *L. grandis, L. intermedia* has subsequently been collected throughout the Southeast (see Berner 1950, 1958, 1977).

Berner & Pescador (1988) discussed similarities of *L. intermedia* and *L. grandis.* Minor body size and slight difference in the length of the median caudal filament relative to the cerci remain the only traits that might possibly differentiate the two. Male genitalia, wing staining, and larval morphology reportedly will not differentiate them. Berner & Pescador (1988) stated "Circumstantial evidence points to synonymy of the two species; however, we are not yet taking the action of equating them." Size (little more than 10% difference) cannot be used to uphold *L. grandis,* particularly in light of findings of the effect of local developmental temperature regime on body size, etc. within the same species (e.g., McCafferty & Pereira 1984). *L. grandis* is therefore placed as a subjective junior synonym of *L. intermedius,* NEW SYNONYM. Because there is no chronological priority of either name over the other, prerogative of the first reviser is invoked in considering *L. intermedius* the senior name, even though *L. grandis* has page priority.

Nixe otiosa (McDunnough)

This species (as *Heptagenia* Walsh) was based on a single male adult taken at Maupin, Oregon in 1934 (McDunnough 1935). Traver (1935) realized that it was very similar to the relatively common western species *Nixe criddlei* (McDunnough), for example, with respect to the presence of short foretarsi associated with males. The genitalia are fundamentally similar, and the supposed differences in tint or degree of brown coloration in the two is of little consequence because of variability witnessed in populations of *N. criddlei* from throughout the West held in the Purdue Entomological Research Collection (PERC hereafter). The only possible differences that might support the validity of *N. otiosa* are differences that may seem to be present in genitalia based on figures assigned to each. However, if one compares the figures of the ventral genitalia labeled as "*n. sp. McD.*" (= McDunnough's single specimen of *N. otiosa*) and "*criddlei*" in Traver's (1935) figure 98, it is apparent that the genitalia of *N. otiosa* are simply a distortion of those drawn for *N. criddlei.* This was likely due in part to the genitalia of *N. otiosa* being drawn from a dry specimen rather than from fluid preserved genitalia that were then slide mounted, as was probably the case in all of the other species represented in figure 98 and elsewhere in Traver (1935). Medial spines appear high on the penes in *N. otiosa* (compared with all other drawings of related species, where the medial spines are shown in their natural basomedial position); and the spine that appears mediodistally on the ventral face of the penes in *N. criddlei* was incorrectly interpreted by Traver to be an additional and unique apical spine, as seen on the distorted penes drawn for *N. otiosa.* Another classic case of penes distortion in North American heptageniid mayflies was discussed and illustrated in detail with respect to *Anepeorus* McDunnough species by McCafferty & Provonsha (1985).

Although Traver (1935) indicated that there was some genitalic difference between *N. otiosa* and *N. criddlei,* Edmunds (in Bednarik and Edmunds 1980) stated that Traver had told him on several occasions that she believed *N. otiosa* was a synonym of *N. criddlei. Nixe otiosa* is here placed as a subjective junior synonym of *N. criddlei,* NEW SYNONYM.

Nixe rodocki (Traver)

This species was described (as *Heptagenia*) from four male adults and one female adult taken at Lewiston, Idaho in 1931 (Traver 1935). It was not found by Jensen (1966) in his survey of Idaho mayflies, and it has not been found by more recent workers in Idaho (G. Lester, personal communication). As pointed out by Bednarik & Edmunds (1980), it could possibly represent a variant of *Nixe simplicioides* (McDunnough), which is a widespread western species common in the Lewiston area. Traver's slide mounts of male genitalia associated with her species were obviously distorted to various degrees [see the two drawings of "*rodocki*" given in figure 98 in Traver (1935)]; also note that Traver's comment, that the species was unique because of "the peculiar long and twisted median spines on the penes," is curiously based on the obviously squashed and distorted genitalia drawn rather than the better mounted genitalia that was also drawn. Bednarik & Edmunds (1980) concluded that the only possible difference between *N. rodocki* and *N. simplicioides* was the presence of markings on the male abdomen of the former. Close reading of Traver's (1935) comments about *N. rodocki,* however, indicates that she did not find the dark patches on all five of her specimens and that such patches were difficult to see even when present.

A large series of *N. simplicioides* in PERC from the Payette River, 10 miles east of Payette, Idaho, demonstrated no abdominal maculation in adults. McDunnough (1926) indicated that adult specimens of Heptageniidae left too long in killing jars or subjected to moisture after death tend to darken. Edmunds (personal communication) surmised that this phenomenon might explain why Traver had specimens with darker abdomens. It was normal in 1931, when R. E. Rodock collected the original material of *N. rodocki,* for entomologists to use killing jars for fixing adult mayflies, rather than today's more common method of fluid fixation and preservation. Edmunds (personal communication) and his colleagues regularly collected *N. simplicioides* from the type locality of *N. rodocki,* but never saw darkened specimens as described for *N. rodocki* by Traver (1935). *Nixe rodocki* is here formally placed as a subjective junior synonym of *N. simplicioides,* NEW SYNONYM.

PENTAGENIA ROBUSTA MCDUNNOUGH

This species was described from Ohio by McDunnough (1926), based on a single male adult taken at Cincinnati. Examination of the specimen in the Canadian National Collection in the 1970s confirmed that the characteristics assigned to it by McDunnough were accurately represented. The well-known North American species *P. vittigera* (Walsh) is the only other recognized species of *Pentagenia.* Based on ample material of *P. vittigera* adults from a number of localities throughout its range (e.g., Lugo-Ortiz & McCafferty 1995, Randolph & McCafferty 1998), there is no variability that suggests that *P. robusta* is a variant of *P. vittigera.* McCafferty (1996) first regarded the species as being recently extinct.

A close relative of the Nearctic genus *Pentagenia* Walsh is the Palearctic genus *Palingenia* Burmeister (McCafferty & Edmunds 1976, McCafferty 1991). *Palingenia longicauda* (Olivier) was once very common throughout much of Europe. The longer recorded history of the insect fauna in Europe clearly indicates a relatively recent extirpation of *P. longicauda* that apparently may be associated with human population growth, industrialization, and the increases in river usage. This documentation not only demonstrates the vulnerability of some of the large clay-burrowing mayflies such as *Pentagenia* and *Palingenia,* but certainly may be instructive in terms of similar situations in North America related to the disappearance of *P. robusta* from the Ohio River, or the potential for the extinction of other large-river mayflies. Russev (1987) showed that between the years 1634 and 1900, *P. longicauda* occurred widely throughout Europe (from the Netherlands, Belgium and France to the Ukraine, Romania and Bulgaria) in the lower and middle courses of large and medium sized rivers. Between 1901 and 1927, the species became extirpated in western Europe and had become rare in central Europe. Between 1928 and 1978, *P. longicauda* populations existed only in far southeastern Europe in the lower Danube River and certain tributaries of the Tissa River, itself a tributary of the Danube.

SIPHLONURUS LURIDIPENNIS (BURMEISTER)

This species was based on a single female adult taken in North Carolina and originally considered in *Baetis* Leach by Burmeister (1839). Beginning with Hagen (1861), however, there was considerable confusion about this species, and the name was misapplied to the somewhat common eastern North American heptageniid species *Stenonema pulchellum* (Walsh). This incorrect concept was continued by Eaton (1871) and led to further misuse of the name and misidentifications of *S. pulchellum* in Canada, for example, by Clemens (1913) and Walley (1927) (see Traver 1935, McCafferty & Randolph 1998). Although not collected, the species has remained on recent national and local faunal lists (e.g., McCafferty 1997, Pescador et al. 1999).

Ulmer (1926) studied the type specimen of *S. luridipennis,* located in the Zoological Institute of the University of Halle, gave a detailed accounting of the species, and placed it in the genus *Siphlonurus* Eaton. Traver (1935) provided an English translation of Ulmer's German account. The species is highly distinctive among the 20 species of North American *Siphlonurus.* The most diagnostic feature is the size of the wings of the species. The body length is 16 mm, which is only slightly longer than most other species in the genus (although there may have been some shrinkage of the pinned specimen); however, the wings are much longer than those found in other North American species (20 mm in length vs. 9–14 mm in other species). Although there are Chinese species this large, North American workers might wonder if the female actually belongs to some other genus with such body and wing size but also with wing venation similar to that of *Siphlonurus,* such as *Siphlonisca* Needham (known only from the Northeast), *Isonychia,* perhaps the little known genus *Acanthametropus* Tshernova (the latter two known from the Southeast, and the lattermost rare), or even the genus *Siphluriscus* Ulmer. However, absolute forewing length and relative forewing length associated with the various species in these other genera do not correspond with that of *S. luridipennis.* Also, *Acanthametropus* is three tailed as an adult [Bajkova (1970) as *Isonychia polita* Bajkova]; *Siphlonisca* has some highly distinguishing characteristics associated with it such as lateral abdominal flanges (e.g., McCafferty & Edmunds 1997); Ulmer would have been familiar with *Isonychia;* and Ulmer would also certainly have been familiar with *Siphluriscus* because he had described that genus earlier from China (Ulmer 1920).

Despite the species' distinctiveness and the fact that North Carolina is perhaps one of the most collected areas in the world as far as mayflies are concerned (e.g., Traver 1932, 1933; Lenat & Penrose 1987), *S. luridipennis* has not been found in some 160 years and should now be considered a recently extinct American species.

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LITERATURE CITED

Allen, R. K. & G. F. Edmunds, Jr. 1965. A revision of the genus *Ephemerella* (Ephemeroptera, Ephemerellidae). VIII. The subgenus *Ephemerella* in North America. Misc. Publ. Entomol. Soc. Am., 4: 243–282.

Bajkova, O. Y. 1970. New and little known mayfly species (Ephemeroptera) from the Amur Basin. Entomol. Rev., 49: 82–87.

Bednarik, A. F. & G. F. Edmunds, Jr. 1980. Descriptions of larval *Heptagenia* from the Rocky Mountain region (Ephemeroptera: Heptageniidae). Pan-Pac. Entomol., 56: 51–62.

Berner, L. 1950. The mayflies of Florida. Univ. Fla. Press, Gainesville.

Berner, L. 1958. A list of mayflies from the lower Apalachicola River drainage. Quart. J. Fla. Acad. Sci., 21: 25–31.

Berner, L. 1977. Distributional patterns of southeastern mayflies (Ephemeroptera). Bull. Fla. St. Mus. Biol. Sci., 22(1): 55 pp.

Berner, L. & M. L. Pescador. 1988. The mayflies of Florida. Revised Edition. Univ. Presses of Florida, Gainesville.

Burks, B. D. 1947. New species of *Ephemerella* from Illinois (Ephemeroptera). Can. Entomol., 79: 232–236.

Burmeister, H. C. C. 1839. Handbuch der Entomologie. Neuroptera, 2: 757–1050, Berlin.

Clemens, W. A. 1913. New species and new life histories of Ephemeridae or mayflies. Can. Entomol., 45: 246–262, 329–341.

Eaton, A. E. 1871. A monograph on the Ephemeridae. Trans. Entomol. Soc. Lond. 164 pp.

Edmunds, G. F. Jr. & W. P. McCafferty. 1984. *Ephemera compar*: an obscure Colorado burrowing mayfly (Ephemeroptera: Ephemeridae). Entomol. News, 95: 186–188.

Elliott, J. M. & U. H. Humpesch. 1983. A key to the adults of the British Ephemeroptera. Freshwater Biol. Assoc. Sci Publ., 47: 101 pp.

Faulkner, G. M. & D. C. Tarter. 1977. Mayflies, or Ephemeroptera, of West Virginia with emphasis on the nymphal stage. Entomol. News, 88: 202–207.

Hagen, H. 1861. Synopsis of the Neuroptera of North America, with a list of South American species. Smithsonian Inst. Misc. Coll. xx + 347 pp.

Hagen, H. 1875. Report on the Pseudo-neuroptera collected by Lt. W. L. Carpenter in 1873 in Colorado. pp. 571–606. *In* Haden, V. F. (ed.). Annual report of the United States geographic and geological survey of the territory embracing Colorado. 1873.

Jensen, S. L. 1966. The mayflies of Idaho (Ephemeroptera). Unpubl. Masters Thesis. University of Utah, Salt Lake City.

Kondratieff, B. C. & J. R. Voshell, Jr. 1983. A checklist of the mayflies (Ephemeroptera) of Virginia, with a review of pertinent taxonomic literature. J. Georgia Entomol. Soc., 18: 273–279.

Kondratieff, B. C. & J. R. Voshell, Jr. 1984. The North and Central American species of *Isonychia* (Ephemeroptera: Oligoneuriidae). Trans. Am. Entomol. Soc., 110: 129–244.

Lenat, D. R. & D. L. Penrose. 1987. New distributional records for North Carolina macroinvertebrates. Entomol. News, 98: 67–73.

Leonard, J. W. & F. A. Leonard. 1962. Mayflies of Michigan trout streams. Cranbrook Inst. Sci., Bloomfield Hills, Mich.

Long, L. S. & B. C. Kondratieff. 1996. The mayflies (Ephemeroptera) of Tennessee, with a review of the possibly threatened species occurring within the state. Gr. Lakes Entomol., 29: 171–182.

Lugo-Ortiz, C. R. & W. P. McCafferty. 1995. The mayflies (Ephemeroptera) of Texas and their biogeographic affinities. pp. 151–169. *In* Corkum, L. D. & J. J. H. Ciborowski (eds.). Current directions in research on Ephemeroptera. Canadian Scholars' Press, Toronto.

McCafferty, W. P. 1975. The burrowing mayflies (Ephemeroptera: Ephemeroidea) of the United States. Trans. Am. Entomol. Soc., 101: 447–504.

McCafferty, W. P. 1989. Characterization and relationships of the subgenera of *Isonychia* (Ephemeroptera: Oligoneuriidae). Entomol. News, 100: 72–78.

McCafferty, W. P. 1991. Toward a phylogenetic classification of the Ephemeroptera (Insecta): a commentary on systematics. Ann. Entomol. Soc. Am., 84: 343–360.

McCafferty, W. P. 1994. Distributional and classificatory supplement to the burrowing mayflies (Ephemeroptera: Ephemeroidea) of the United States. Entomol. News, 105: 1–13.

McCafferty, W. P. 1996. The Ephemeroptera species of North America and index to their complete nomenclature. Trans. Am. Entomol. Soc., 122: 1–54.

McCafferty, W. P. 1997. Ephemeroptera. pp. 89–117. *In* Poole, R. W. & P. Gentili (eds.). Nomina Insecta Nearctica, a checklist of the insects of North America. Volume 4: Non-holometabolous orders. Entomol. Inform. Serv., Rockville, Maryland.

McCafferty, W. P. 2001. The gentle quest: 200 years in search of North American mayflies. *In* E. Domínguez (ed.). Trends in research in Ephemeroptera and Plecoptera. Kluwer Academics/ Plenum Press, New York. in press.

McCafferty, W. P. & G. F. Edmunds, Jr. 1976. Redefinition of the family Palingeniidae and its implications for the higher classification of Ephemeroptera. Ann. Entomol. Soc. Am., 69: 486–490.

McCafferty, W. P. & G. F. Edmunds, Jr. 1997. Critical commentary on the genus *Siphlonisca* (Ephemeroptera: Siphlonuridae). Entomol. News, 108: 141–147.

McCafferty, W. P. & C. Pereira. 1984. Effects of developmental thermal regimes on two mayfly species and their taxonomic interpretation. Ann. Entomol. Soc. Am., 77: 69–87.

McCafferty, W. P. & A. V. Provonsha. 1985. Systematics of *Anepeorus* (Ephemeroptera: Heptageniidae). Gr. Lakes Entomol., 18: 1–6.

McCafferty, W. P. & R. P. Randolph. 1998. Canada mayflies: a faunistic compendium. Proc. Entomol. Soc. Ontario, 129: 47–97.

McCafferty, W. P., R. S. Durfee & B. C. Kondratieff. 1993. Colorado mayflies (Ephemeroptera): an annotated inventory. Southwest. Natural., 38: 252–274.

McDunnough, J. H. 1926. Notes on North American Ephemeroptera with descriptions of new species. Can. Entomol., 58: 184–196.

McDunnough, J. H. 1935. Notes on western species of Ephemeroptera. Can. Entomol., 67: 95–104.

Pescador, M. L., D. R. Lenat & M. D. Hubbard. 1999. Mayflies (Ephemeroptera) of North Carolina and South Carolina: an update. Fla. Entomol., 82: 316–332.

Randolph, R. P. & W. P. McCafferty. 1998. Diversity and distribution of the mayflies (Ephemeroptera) of Illinois, Indiana, Kentucky, Ohio, and Wisconsin. Ohio Biol. Surv. Bull., New Ser. 13: vii + 188 pp.

Russev, B. K. 1987. Ecology, life history and distribution of *Palingenia longicauda* (Olivier) (Ephemeroptera). Tijdschrift Entomol., 130: 109–127.

Traver, J. R. 1932. Mayflies of North Carolina. J. Elisha Mitchell Sci. Soc., 47: 85–161, 163–236.

Traver, J. R. 1933. Mayflies of North Carolina. Part III. The Heptageniidae. J. Elisha Mitchell Sci. Soc., 48: 141–206.

Traver, J. R. 1934. New North American species of mayflies (Ephemerida). J. Elisha Mitchell Sci. Soc., 50: 189–254.

Traver, J. R. 1935. Part II. Systematics. pp. 237–739. *In* Needham, J. G., J. R. Traver & Y.-C. Hsu (eds.). The biology of mayflies with a systematic account of North American species. Comstock, Ithaca, New York.

Ulmer, G. 1920. Neue Ephemeropteren. Arch. Naturgeschichte, 85: 1–80.

Ulmer, G. 1926. *Baetis luridipennis* Burm. aus Nord-Amerika ist ein *Siphlonurus* (Ephemeropt.). Entomol. Mitteilungen, 15: 223–225.

Walley, G. S. 1927. Ephemeroptera. pp. 59–61. *In* Criddle, N. (ed.). The entomological record, 1926. Ann. Rep. Entomol. Soc. Ontario, 57: 47–62.

Walsh, B. D. 1862. List of the Pseudoneuroptera of Illinois in the cabinet of the writer, with descriptions of over forty new species, and notes on their structural affinites. Proc. Acad. Nat. Sci. Phila., 13: 361–402.

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RESPONSE OF THE KNAPWEED BIOCONTROL AGENT *AGAPETA ZOEGANA* L. (LEPIDOPTERA: COCHYLIDAE) TO PORTABLE LIGHTS

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Abstract.—*Agapeta zoegana* L. is a Eurasian root-mining moth introduced into North America for biological control of spotted knapweed, *Centaurea maculosa* Lamarck. The moth is established but is difficult to collect for redistribution. A study was conducted during July and August 1997 and 1998 to assess the noctural response of the moth to portable fluorescent and ultraviolet lights, and to determine if portable lights would aid in the collection of *A. zoegana* adults. The moth's attraction to portable lights was assessed during four 20-minute illumination periods beginning at 50, 95, 140, and 185 minutes after sunset (MAS). The mean number of male *A. zoegana* attracted to the portable lights was significantly higher than females during the 95 MAS (sex ratio 95:5) and 140 MAS (80:20), but was not different from females at the 50 MAS and 185 MAS periods. Male numbers were especially high at the 95 MAS period when an average of 113 males were sampled. Female numbers were very low at all four illumination periods, averaging around four individuals per period. Male and female numbers during daytime hours were not significantly different which indicated the disproportionately high number of males attracted to the portable lights was related to moth behavior rather than population sex ratio. Fluorescent and ultraviolet light were equally attractive to the moth. The use of portable lights in the field is an effective method for determining establishment of *A. zoegana,* but is not recommended for collection of moths for redistribution to new sites because of the low proportion of females collected during the illumination periods studied.

Key Words.—Insecta, *Agapeta zoegana,* portable light, spotted knapweed, collection.

Agapeta zoegana L. (Lepidoptera: Cochylidae), is a Eurasian root-mining moth introduced into North America for biological control of spotted knapweed, *Centaurea maculosa* Lamarck (Asteraceae). The first U.S. release of the moth was made in Montana in 1984. The biology, host specificity, and potential impact of the moth were described by Müller et al. (1988), Müller (1989) and Story et al. (2000). The moth overwinters as a larva in the knapweed root and emerges as an adult between mid-June and mid-September, with peak emergence occurring in early August (Story et al. 1991). Females begin mating on the day of emergence and usually begin ovipositing on the second night. The sex ratio of adults is 1:1 throughout most of the season (Story et al. 1991). The moth apparently has only one generation per year in Montana.

The moth is now well established at a number of sites in Montana. Collection of *A. zoegana* larvae is very difficult so methods to collect the adults at these sites for distribution to other locations are being assessed. Because *A. zoegana* adults have shown some attraction to lights (Fitzpatrick 1989), and the attraction of moths, in general, to lights is well documented, the possible use of portable lights to aid in field collection of the moth was of interest (Southwood 1978, Tucker 1983, Sorensen & Thompson 1984, Simmons & Elliott 1985, Taylor 1986, Gregg et al. 1993). The objectives of the study were to determine if time of night and type of light source influence the attraction of adult *A. zoegana* to portable lights, and whether these lights will aid in moth collections.

MATERIALS AND METHODS

Study location.—The study was conducted on the Teller Wildlife Refuge near Corvallis, Montana, USA (46°19′ N latitude, 114°09′ W longitude, elevation 1057 m). The study area was an abandoned pasture dominated by spotted knapweed (59% relative abundance), grass species (35%), and miscellaneous forbs (6%). Spotted knapweed was distributed throughout the field. The study area was approximately 0.8 km from the nearest buildings and associated lights.

Study procedure.—The study was conducted from approximately 2100 to 2400 h (MDT) on seven nights in 1997 and six nights in 1998 during late July through August (i.e., the primary period of adult *A. zoegana* emergence). A portable, 18-watt, battery-powered fluorescent light was illuminated for four 20-minute periods per night beginning at 50, 95, 140, and 185 minutes after sunset (MAS), with a 25-minute interval between illumination periods. These illumination periods are hereafter referred to as the 50 MAS, 95 MAS, 140 MAS, and 185 MAS illumination periods. Official sunset times for the area were obtained from The World Almanac (1997, 1998). Each illumination period was conducted at one of four sites located at approximately 110 m intervals along a private road. The four sites had comparable *A. zoegana* populations, as determined by visual counts of the moth made during the pevious afternoon. The order in which sites were sampled was changed each night to eliminate any time-of-night bias between sites. The 25-min interval between illumination periods allowed for the relocation of equipment to the next predetermined site. In 1997, all of the sampling per night was done by a single collector; in 1998, the same procedure was followed except that two collectors worked simultaneously in separate widely-spaced (> 250 m) sets of four collection sites, with one collector using the fluorescent light and the other using a 15-watt ultraviolet light (black light). The light-source types were alternated between the four-site on ensuing sampling nights. Sampling was done on warm, calm nights due to daytime observations which indicated the moths are reluctant to fly under windy conditions. Mean air temperature at 2200 h (MDT) on sampling nights was 19° C.

Equipment consisted of a white linen sheet, the portable light, and a tripod comprised of wooden poles (6 cm diam. and 2.5 m long) secured with a rope. The tripod was erected at a collection site, the sheet was draped over the tripod, and the light was suspended from the tripod approximately 0.8 m above the ground. All *A. zoegana* adults alighting on the illuminated sheet during the illumination period were vacuumed into one-liter paper cans with a modified hand vacuum (Story et al. 1999). Upon completion of the sampling for the night, the containers were held in a refrigerator at 4° C. During the morning following the night collection, the moths were sexed in the laboratory and then released at the collection sites.

The number of sampling nights was limited due to the avoidance of nights that were moonlit during 2100 to 2400 h, and the attempt to minimize impacts on the *A. zoegana* population. Preliminary observations indicated that portable lights were not as effective on moonlit nights.

Daytime collections of the moth were made on an afternoon within 24 hours (before or after) of the night collection. The daytime collections were made on calm days as explained earlier. The moths, which spend the daylight hours cling-

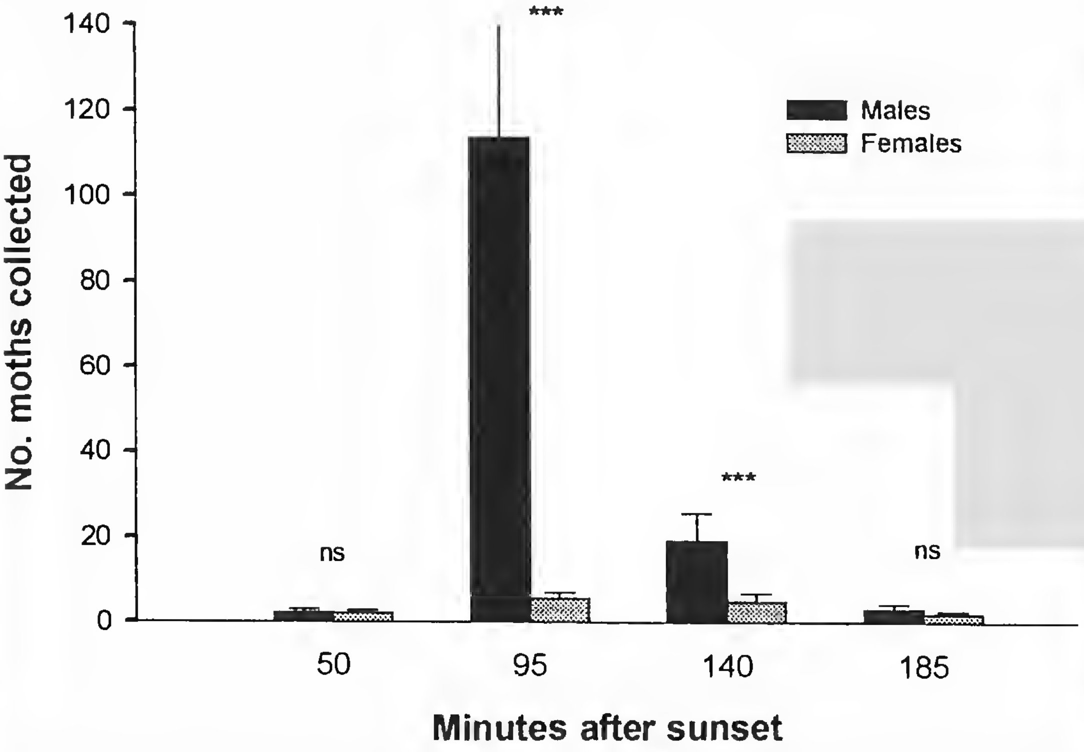

Figure 1. Mean number of *A. zoegana* adults collected at portable lights per illumination period in 1997 and 1998 (mean ± SEM); Student's t-test; ns = nonsignificant; *** = $P < 0.001$.

ing to knapweed plants, were collected near (but not at) each of the night collection sites with the use of the modified hand vacuum. Two or three people experienced with the use of hand vacuums collected moths for a total of 20 person-minutes per site. Each person collected every moth seen along individual, circuitous routes through each site. The collected moths were sexed in the laboratory and then released in the collection areas.

Most of the data were analyzed using analysis of variance (ANOVA) using Statistix For Windows (Analytical Software 1996). The Student's t-test was used to compare male and female moth numbers at each illumination period, and to compare male and female numbers in portable light versus daytime hand-vacuum collections. Mean comparisons were made with the least significant difference test.

RESULTS

Results of the portable light collections averaged across both 1997 and 1998 are shown in Fig. 1. Adult *A. zoegana* were attracted to portable lights at each of the four illumination periods. There was no significant difference in the mean number of *A. zoegana* adults of either sex attracted to the fluorescent versus the ultraviolet light (i.e., 36.9 ± 15.9 [SEM] versus 46.0 ± 23.4, [$F_{(1,37)} = 0.06$; $P = 0.81$] for males, respectively, and 2.3 ± 0.8 versus 4.2 ± 1.9 [$F_{(1,37)} = 0.86$; $P = 0.36$] for females, respectively).

The mean number of male *A. zoegana* attracted to the two types of lights per night was significantly higher than females (i.e., 37.3 ± 9.7 [SEM] males versus 3.6 ± 0.7 females; $F_{(1,130)} = 16.5$, $P = 0.0001$). The highest number of males was collected during the 95 MAS illumination period, when an average of 113.9 ± 123.3 (SD) males was attracted compared to 5.5 ± 6.6 females ($t = 3.8$, df = 18, $P < 0.0001$). On July 23, 1998, there were more moths on the sheet than could be collected during the 95 MAS period at both types of lights; thus, overall male numbers at the 95 MAS period would have been even higher if the excess

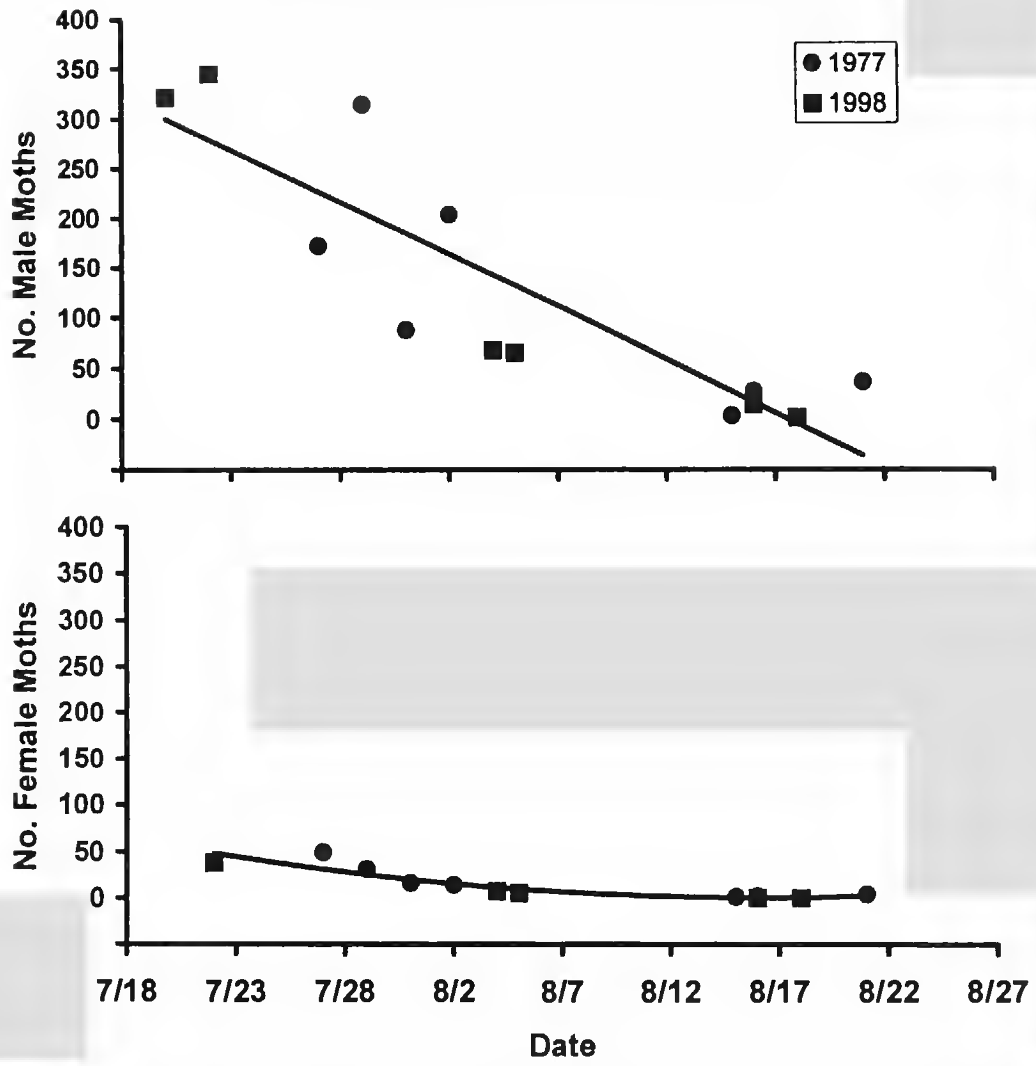

Figure 2. Mean number of *A. zoegana* adults collected at portable lights per date in 1997 and 1998.

moths had been collected. The number of males was also significantly higher than females during the 140 MAS illumination period (19.1 ± 26.7 [SD] versus 4.8 ± 8.8 [t = 2.1, df = 16; P = 0.0000), but there was no difference between male and female numbers during the 50 MAS (2.2 ± 3.0 versus 2.1 ± 2.9) and 185 MAS (3.1 ± 4.2 versus 1.9 ± 2.8) illumination periods ($P > 0.05$; Fig. 1). The male to female *A. zoegana* ratio at the four illumination periods was 51:49 at 50 MAS, 95:5 at 95 MAS, 80:20 at 140 MAS, and 62:38 at 185 MAS. Male numbers did not differ among illumination periods except for the 95 MAS which yielded significantly higher male numbers ($F_{(3,65)} = 11.9$; $P = 0.0000$). There was no significant difference in numbers of females collected among the four illumination periods ($F_{(3,65)} = 1.7$; $P = 0.17$). Total (male and female) moth numbers were not significantly different across years ($F_{(1,122)} = 0.2$; $P = 0.68$). Both male and female numbers were highest on sample dates in late July and early August, after which they gradually declined (Fig. 2).

The mean number of males and females captured in daytime hand vacuum collections was not significantly different (19.8 ± 12.2 [SD] males, 16.5 ± 7.9 females; t = 1.4, df = 12; P = 0.20). Female *A. zoegana* were collected at the rate of one per 5.5 minutes during portable light collections compared to one per 1.5 minutes during daytime collections with a hand vacuum.

DISCUSSION

The study demonstrated that portable lights are much more attractive to *A. zoegana* males than females, especially at the 95 MAS illumination period. The greater attraction of *A. zoegana* males to the lights was similar to behavior reported for other moth species (Sorensen & Thompson 1984, Levine 1989).

It is possible that alterations to the described technique could increase the numbers of females attracted to the light. For example, preliminary observations suggest that attraction of female moths to the portable light may increase if the females are incited to fly; this might be accomplished by a second collector walking circuitously through the knapweed within 50 m of the light while the light is illuminated. Also, it is possible that the proportion of females would have been higher if the illumination periods had been longer than 20 min. Such alterations were not examined but should be considered in future studies.

The fact that male and female numbers collected during the day were not significantly different indicates that the disproportionate number of males attracted to the portable lights was related to moth behavior rather than population sex ratio. The male-female behavioral differences were not identified, but may be related to female flight patterns. In their search for oviposition sites, females may fly at low elevations (i.e., below the top of the plant canopy), thereby minimizing their view of the portable light. Conversely, males may fly at higher elevations while searching for females, which could provide them a better view of the portable light (Tóth et al.). The daytime collection results were consistent with those of Story et al. (1991) who reported that the sex ratio of adult *A. zoegana* is 1:1 throughout most of the season. Daytime collections were not affected by the moth's flight behavior as the moth is relatively inactive during daylight hours.

As expected, numbers of both males and females attracted to the lights were highest on the late July and early August collection dates in both years, when the adult population typically peaks (Story et al. 1991). The total number of days when high numbers of *A. zoegana* adults were attracted to the light was not determined because the sampling did not necessarily start at the onset of peak emergence each summer. During this study, most moths were collected between 21 July and 3 August. It is possible that high moth numbers could also have been detected up to 7 days earlier (14 July).

Agapeta zoegana numbers collected at ultraviolet lights were generally greater than at fluorescent, but the differences were not significant due to high variability. Ultraviolet lights have been used extensively for light trapping of Lepidoptera, and studies have shown that some Lepidoptera are preferentially attracted to ultraviolet lights (Sorensen & Thompson 1984). The effectiveness of the fluorescent lights is advantageous because they are more readily available than UV lights.

High mountains, approximately 9 km west of the study site, caused sunset to occur earlier (approximately 20 minutes) for that area than reported in the World Almanac. In view of this, post-sunset moth activity in areas with flatter landscape may occur at later times following the World Almanac sunset time for that area than observed in this study.

Strong moonlight probably reduces *A. zoegana*'s attraction to lights, but insufficient data were collected to verify this hypothesis. Studies have shown that moon illuminance decreases light-trap catches of some Lepidoptera, probably because the moonlight reduces the contrast between the background and the light emitted by the portable light (Nowinszky et al. 1979, Dent & Pawar 1988, Yela & Holyoak 1997).

Because of the male *A. zoegana*'s strong attraction to light at the 95 MAS illumination period, the use of portable lights during the 95 MAS period is an effective method for determining establishment of the moth. However, due to the low number of females attracted at all illumination periods, the use of portable lights is not a recommended technique for collecting the moth for redistribution, when conducted during the illumination periods used in this study. Preliminary studies suggest that attraction of females to light does not increase later in the night. The use of a hand vacuum during daylight hours remains a better collection method for *A. zoegana* adults (Story et al. 1999).

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LITERATURE CITED

Analytical Software. 1996. Statistix for Windows. Tallahassee, Florida.

Dent, D. R. & C. S. Pawar. 1988. The influence of moonlight and weather on catches of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in light and pheromone traps. Bull. Entomol. Res., 78: 365–377.

Fitzpatrick, S. M. 1989. A potential collection method for *Agapeta zoegana* (Lepidoptera: Cochylidae), a knapweed-root-feeding moth. J. Entomol. Soc. Brit. Columbia, 86: 55–62.

Gregg, P. C., G. P. Fitt, M. Coombs & G. S. Henderson. 1993. Migrating moths (Lepidoptera) collected in tower-mounted light traps in northern New South Wales, Australia: species composition and seasonal abundance. Bull. Entomol Res., 83: 563–578.

Levine, E. 1989. Forecasting *Hydraecia immanis* (Lepidoptera: Noctuidae) moth phenology based on light trap catches and degree-day accumulations. J. Econ. Entomol., 82: 433–438.

Müller, H. 1989. Structural analysis of the phytophagous insect guilds associated with the roots of *Centaurea maculosa* Lam., *C. diffusa* Lam., and *C. vallesiaca* Jordan in Europe: field observations. Oecologia, 78: 41–52.

Müller, H., D. Schroeder & A. Gassmann. 1988. *Agapeta zoegana* (L.) (Lepidoptera: Cochylidae), a suitable prospect for biological control of spotted and diffuse knapweed, *Centaurea maculosa* Monnet de la Marck and *Centaurea diffusa* Monnet de la Marck (Compositae) in North America. Can. Entomol., 120: 109–124.

Nowinszky, L., S. Szabo, G. Toth, I. Ekk & M. Kiss. 1979. The effect of the moon phases and of the intensity of polarized moonlight on the light-trap catches. Z. ang. Entomol., 88: 337–353.

Simmons, G. A. & N. C. Elliott. 1985. Use of moths caught in light traps for predicting outbreaks of the spruce budworm (Lepidoptera: Tortricidae) in Maine. J. Econ. Entomol., 78: 362–365.

Sorensen, K. A. & H. E. Thompson. 1984. Light trap response of the buffalograss webworm, *Surattha indentella* Kearfott (Lepidoptera: Pyralidae), in Kansas. J. Kansas Entomol. Soc., 57: 719–722.

Southwood, T. R. E. 1978. Ecological methods. Chapman and Hall, New York.

Story, J. M., K. W. Boggs & W. R. Good. 1991. First report of the establishment of *Agapeta zoegana* L. (Lepidoptera: Cochylidae) on spotted knapweed, *Centaurea maculosa* Lamarck, in the United States. Can. Entomol., 123: 411–412.

Story, J., W. Good & L. White. 1999. Biocontrol of spotted knapweed: monitoring and collecting *Agapeta zoegana* and *Cyphocleonus achates*. Montana State University Extension Service MontGuide No. MT 9915.

Story, J. M., W. R. Good, L. J. White, & L. Smith. 2000. Effects of the interaction of the biocontrol agent, *Agapeta zoegana* L. (Lepidoptera: Cochylidae), and grass competition on spotted knapweed. Biol. Control., 17: 182–190.

Taylor, R. A. J. 1986. Time series analysis of numbers of Lepidoptera caught at light traps in East Africa, and the effect of moonlight on trap efficiency. Bull. Entomol. Res., 76: 593–606.

Tóth, M., P. M. Guerin, H. R. Buser, H. Müller, G. Szöcs, G. Sziráki & H. Arn. 1985. Z-11-tetradecenyl acetate: sex attractant of *Agapeta zoegana* (Lepidoptera: Tortricidae), a potential species for the biological control of knapweed. Can. Ent., 117: 1163–1165.

Tucker, M. R. 1983. Light-trap catches of African armyworm moths, *Spodoptera exempta* (Walker) (Lepidoptera: Noctuidae), in relation to rain and wind. Bull. Entomol. Res., 73: 315–319.

World Almanac. 1997. K-III Reference Corp. Mahwah, New Jersey.

World Almanac. 1998. K-III Reference Corp. Mahwah, New Jersey.

Yela, J. L. & M. Holyoak. 1997. Effects of moonlight and meteorological factors on light and bait trap catches of noctuid moths (Lepidoptera: Noctuidae). Environ. Entomol., 26: 1283–1290.

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Scientific Note

SYNANTHEDON CANADENSIS: A NEW CLEARWING MOTH RECORD FOR BRITISH COLUMBIA WITH NOTES ON ITS RESPONSE TO PHEROMONES (LEPIDOPTERA: SESIIDAE)

Synanthedon canadensis Duckworth and Eichlin, an attractive clearwing moth (relatively slender, wingspan of about 20–25 mm, and mostly blue-black with a prominent orange anal tuft), was originally described on the basis of two males collected in extreme southwestern Alberta (Duckworth, W. D. & T. D. Eichlin. 1973. Proceedings of the Entomological Society of Washington, 75: 157). Subsequently, a female was collected in north central Utah (Eichlin, T. D. & W. D. Duckworth. 1988. The moths of America north of Mexico, fascicle 5.1). Until now, in spite of its considerable range, no further specimens of this species had turned up, and nothing is known of its biology.

Two of us (RGB and BSL) are currently (1997–2000) operating a sex pheromone-based management program for control of the economically important Douglas-fir pitch moth, *Synanthedon novaroensis* (Henry Edwards), in *Pinus contorta* Douglas ex Loudon var. *latifolia* Engelmann (lodgepole pine) seed orchards. These orchards (and associated conifer clone banks, provenance tests, and silvicultural trials) are located at the Prince George Tree Improvement Station (PGTIS, 53.46N/122.43W) on the west bank of the Fraser River, 10 km south of Prince George, British Columbia. During the first two years of this program, we captured considerable numbers of male *S. canadensis* in traps baited to attract males of *S. novaroensis*. These are the first specimens collected in British Columbia and the only specimens to provide some information on the biology of the species.

(Z,Z)-3,13-octadecadienyl acetate is a known sex attractant for males of *S. novaroensis* as well as at least two dozen other North American sesiid species in several genera in the subfamilies Tinthiinae, Paranthreninae and Sesiinae. To trap male *S. novaroensis*, we baited green Unitraps (Phero Tech Inc., Delta, British Columbia) with 1000 μg each of a commercially available formulation of this pheromone (Phero Tech Inc., lot # 93047, 97% chemical purity) loaded on red rubber septa. Traps were hung from late April to early September each year and checked at biweekly intervals. Captured sesiids were identified to species by TDE (primarily), RGB, and BSL.

In addition to specimens of the target species, during the course of this work we trapped numerous males of the common Betulaceae-feeding Holarctic species *Synanthedon culiciformis* (Linnaeus) and 43 males (1997—4, 1998—37, 1999—0, 2000—2) of *S. canadensis*. In related work at the PGTIS site, but using traps baited with the corresponding alcohol, (Z,Z)-3,13-octadecadien-1-ol, specimens of another rarely captured moth, *Sesia spartani* Eichlin and Taft, were collected for the first time in Canada (Bennett, R. G., L. A. Rocchini, T. D. Eichlin & B. S. Lindgren. 2000. Pan-Pacific Entomologist, 76(2): 129–131).

Trap catches suggest that the flight of male *S. canadensis* lasts for about one month in the summer in the Prince George area. In 1997 all *S. canadensis* were captured in early to mid-June. The following year, specimens were trapped from mid- to late May through late June with the majority of specimens being trapped during the period 28 May to 11 June.

It is interesting to note that no, and very few, specimens of *S. canadensis* were collected in, respectively, the 1999 and 2000 trapping programs. In subjective terms, summer weather in the Prince George area was reasonably "normal" in 1997, hotter than usual in 1998, and uncharacteristically cool and wet in 1999 and 2000. The North American species of *Synanthedon* for which such information is known, utilize a variety of tree, shrub, and herbaceous perennial hosts (Eichlin & Duckworth 1988). The host species of *S. canadensis* remains unknown. We presume that a viable population of *S. canadensis* likely does not exist within the boundaries of the PGTIS but that specimens have flown into our traps from reservoir populations in the surrounding natural stands. These stands range from about 100 m to less than 20 m from individual PGTIS pine orchards. Possibly the unseasonably cool, wet weather during the 1999 flight period prevented adults from flying to the traps within the PGTIS. Additionally, given the tree species present in the orchards and trials at PGTIS, we feel that it is unlikely that any species of Pinaceae is the host for larvae of *S. canadensis.* The surrounding natural stands are dominated by trembling aspen (*Populus tremuloides* Michaux) and other Salicaceae as well as various Betulaceae, lodgepole pine, and interior spruce (*Picea glauca* (Moench) Voss × *engelmannii* Parry ex Engelmann).

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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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PLATYEDRA SUBCINEREA, A POTENTIAL COTTON AND HOLLYHOCK PEST, DOCUMENTED IN CALIFORNIA BY PINK BOLLWORM PHEROMONE AND URBAN BLACKLIGHT SURVEYS (LEPIDOPTERA: GELECHIIDAE)

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Abstract.—*Platyedra subcinerea* (Haworth) [= *vilella* (Zeller)], often called the 'Cotton Stem Moth,' is native to the Palaearctic Region but has been adventive in coastal New England since 1949. Adults began appearing in traps baited with synthetic pink bollworm pheromone in cotton fields in five counties in the San Joaquin Valley, California in 1992, at the San Francisco airport in 1994, and at lights in Berkeley in 1997. In 1999 and 2000 specimens were collected at three localities in the Sacramento Valley. Other recorded larval host plants include several Old World species of Malvaceae: *Althaea, Lavatera,* and *Malva.*

Key Words.—Insecta, introduced insect, mallows, *Gossypium,* Malvaceae, Palaearctic moth.

Platyedra subcinerea (Haworth) was described originally from England in 1828 and placed in the genus *Recurvaria.* Later this moth was described from Italy as *Gelechia vilella* by Zeller, the species name by which it was known for more than a century until the two were recognized as synonymous by Bradley (1966). It was recorded as widespread in Europe, in Asia to northern Persia [Iran], and North Africa by Meyrick (1895), who proposed the generic name *Platyedra.*

P. subcinerea (cited as *vilella*) was first recognized in North America based on specimens reared from hollyhock (*Althaea rosea,* Malvaceae) at Mineola, Nassau Co., New York in 1951 and 1952 (Anonymous 1953a). However, the introduction had occurred earlier; the species was already widely distributed in coastal New England, evidenced by specimens collected at Barnstable and West Barnstable, Barnstable Co., Massachusetts by C. P. Kimball in 1949–1951, the earliest 24 April 1949 (USNM, Brown in litt.). Surveys by the USDA during the summer of 1953 recorded *P. subcinerea* in Massachusetts, Connecticut, and widespread on Long Island, New York (Anonymous 1953b). After a decade, Okumura (1961) mapped the occurrence of *subcinerea* in New England, adding New Jersey, based on USDA records. Later collections include Portsmouth, Rockingham Co., New Hampshire, in 1965 and Hamden, New Haven Co., Connecticut in 1968 (USNM, Brown in litt.).

Occurrence in California.—*Platyedra subcinerea* was first detected in California in 1992, but its identity was not recognized at the time. Male moths were captured in sticky traps baited with sex attractant for *Pectinophora gossypiella* (Saunders) (Pink Bollworm, PBW). The Cooperative Pink Bollworm Program, a unique integrated pest control project administered by the California State Department of Food and Agriculture and funded almost entirely by assessments on the cotton growers, has been in continual operation since 1967. Probably the most successful and longest running biological control program in the world, this pro-

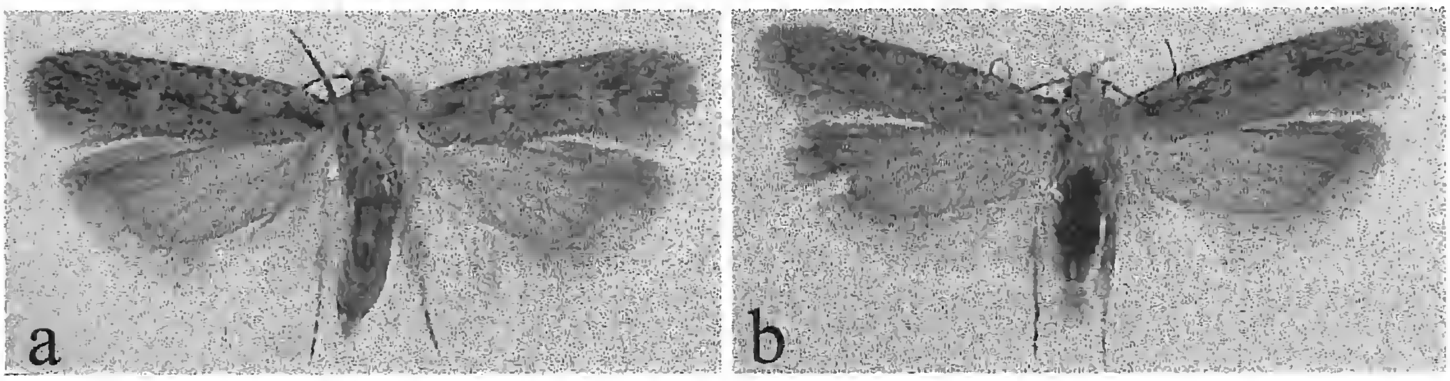

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Figure 1. Adult female (a) and male (b) of *Platyedra subcinerea* (Haworth), Berkeley, California.

ject effectively protects more than a million acres of cotton valued at nearly a billion dollars annually. In lieu of pesticides, sterile Pink Bollworm moths are released to overwhelm potential new populations of *P. gossypiella.*

To determine when to release sterile moths and monitor the releases, approximately 20,000 pheromone bait traps are deployed around an average of ca. 1,200,000 acres of cotton fields. They are inspected weekly from April through October. According to Marjorie Moody, Associate Insect Biosystematist and Supervisor of the PBW Identification Laboratory, CDFA, the first specimens of *P. subcinerea* were collected by Mark Spenhoff in Merced County in 1992. Moody stated, "We watched these moths spread [within one season] from Merced Co. south until they became general all over [the San Joaquin Valley]. We are still finding them [as of July 2000]. We know of no finds earlier than 1992."

In 1994 males were captured at the San Francisco Airport in traps baited with sex attractant lure for *Spodoptera litura* (F.) (Noctuidae) by the USDA Exotic Pest Survey at ports of entry.

Playedra subcinerea first appeared in urban settings at Berkeley in 1997. We conducted nightly inventory of moths attracted to lights on most dates when we were in residence, near the north edge of the city from 1978 to present (JAP) and at a site 3.25 km to the south from 1996 to 1999 (FAHS). This surveillance has revealed colonization by six species of exotic moths between 1983 and 1997 (Powell 1992, Powell & Passoa 1991, Powell et al. 2001). In 1997 we began observing *P. subcinerea,* the first in north Berkeley on April 18, and it was taken on five dates that year, including once at the Sperling site on July 1. We recorded *subcinerea* six times in 1998 and eight in 1999, between 27 February and 11 September, indicating established residency.

In 1999 *P. subcinerea* was collected in the Sacramento Valley at two localities: one specimen in March at house lights in Sacramento by W. D. Patterson and one in June at Davis, Yolo Co., where J. A. De Benedictis began continuous montoring of moths at blacklight in a suburban yard in early 1998. These places are about 105 km NE and 88 km NNE of Berkeley, respectively, and 115 km NW of the northernmost pink bollworm survey site in Merced County.

Identification.—We compared specimens to diagnoses given by Meyrick (1895) and Piskunov (1990) and to illustrations of the male genitalia shown by Pierce & Metcalfe (1935) and Piskunov. We compared moths and dissections of both sexes with specimens from Massachusetts that had been identified by R. W. Hodges. *Platyedra subcinerea* (Figs. 1a, 1b) is a small (FW length 7.5–9.0 mm), nondescript moth that superficially resembles some species of *Filatima* and *Anacampsis,* as well as the closely related *Pectinophora gossypiella.* It is paler than *P. gossypiella,* having tan forewings faintly mottled with dark brownish that in fresh examples tends to define a median longitudinal streak and two discal stigmata at the end of the cell. There is a small darker brown smudge at the base of the costa. California specimens are consistently tan in appearance, while Piskunov states the FW color is variable in Russian specimens, chocolate brown to gray. The genitalia (Figs. 2–4) are distinctive among California Gelechiidae. For preliminary diagnosis, *Platyedra* can be distinguished from most other superficially similar gelechiids by its antennal pecten, a row of large, erect scales along the venter of the antennal scape. *Pectinophora* and most *Bryotropha* species are the only other North American Gelechiidae that possess this feature.

Key characteristics of the larvae have been illustrated by Capps (1958) and Okumura (1961).

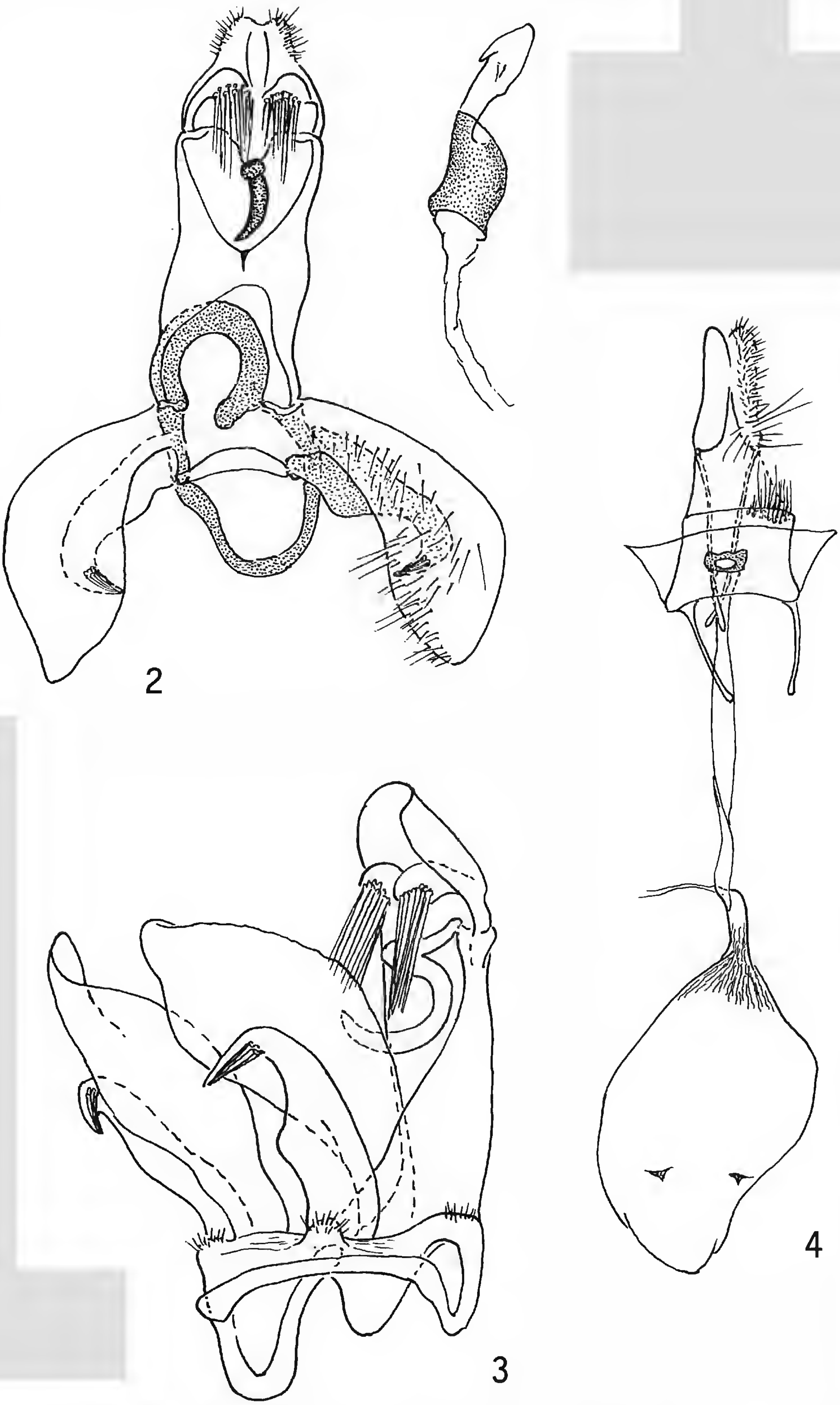
Biology.—In larval feeding *Platyedra subcinerea* is a specialist on Malvaceae. Meyrick (1895) described the life cycle in England: larvae feed in the flowers and seeds of *Malva sylvestris* in June and July, and the adults emerge in August and overwinter until May. Damage to cultivated cotton (*Gossypium herbaceum*) and other genera of Malvaceae was attributed to this species in North Africa and the Middle East in the 1920s and 1930s, where populations are multivoltine (Mimeur 1930, Yakhontov 1931, Goloviznin 1937). The common name, Cotton Stem Moth, evidently was coined after translation from Yakhontov's account in Russian.

The larvae of *P. subcinerea* fed in flowers and seed capsules of cotton plants in Morroco where they were grown adjacent to wild *Lavatera arborea* (Mimeur 1931). In western Uzbekistan [Uzbek SSR], first generation larvae mined the growing tips, then the stems of *Althaea officinalis* (Yakhontov 1931). Second generation larvae fed in cotton in the same manner, causing plants to become dwarfed and to spread horizontally. Goloviznin (1937) also reported first generation larvae confined to wild Malvaceae and later generations on cotton in northern Persia [Iran]. He observed five generations annually, and larvae fed chiefly in the fruit but sometimes in young stems.

In addition to cotton and hollyhock, the array of Malvaceae serving as larval host plants was summarized as: *Althaea nudiflora,* marsh mallow (*A. officinale*), velvet tree mallow (*Lavatera arborea*), herb tree mallow (*L. trimestris*), and high mallow (*Malva sylvestris*) (Anonymous 1953a, Okumura 1961). All of these are Eurasian and Mediterranean natives.

Likely larval hosts in Berkeley include three ornamental plants: *Lavatera assurgentiflora,* a native to the California Channel Islands, the Old World tree mallow, *L. thuringiacea,* and hollyhock. Cheeseweed (*Malva parviflora*) also may serve as a host. The long flight period in California, late March to late July in 1999, suggests two or more generations. We have not confirmed overwintering adults, although single specimens taken in February and September may have been reproductively dormant individuals.

Specimens examined.—CALIF: *Alameda Co.,* Berkeley, IV.18.97, V.18.97, VII.1.97, VII.26-28.97 [JAP slide 7939 female], IV.21.98 [JAP slide 7775 male], V.18.98, VI.19.98, VII.19.98, IX.11.98, II.27.99, III.28.99, IV.13-21.99 (5 dates), VII.28.99; *Fresno Co.* 1.6 km E Camden, VI.14.93, 1.6 km W Firebaugh, VII.7.93, 3.2 km NW Firebaugh, VII.8.93, 8 km SW Firebaugh, VI.22.93, 3.2



Figures 2–4. Genitalia structures of *P. subcinerea*: 2, male, ventral aspect, valvae bent anteriorly and vinculum distorted, aedeagus removed and shown to right (slide JAP 7775); 3, male, lateral aspect, aedeagus removed (JAP 8012); 4, female, ventral aspect (JAP 7939).

km SE Five Points, VII.1.92, 3.2 km S Huron, VI.21.93, 4.8 km N Huron, VII.8.93, 1.6 km W Malaga, VII.13.92, E jct. I-5 & Panoche Rd., VII.14.93, 1.6 km S jct. I-5 & Shields Rd., VI.21.93, 1.6 km W Tranquility, VI.23.93, 1.6 km S Tranquility, VI.23.93, 4.8 km SW Tranquility, VI.15.93; *Kern Co.*, 4.3 km W Delano, VII.14.93, nr. Mettler, VII.7.92; *Kings Co.*, 1.6 km N Corcoran, VII.9.93, 3.2 km NE Stratford, VII.8.93; *Madera Co.*, 9.7 km SW Chowchilla, VII.15.92; *Merced Co.*, 8 km S Atwater, VI.17.93, 13 km SW Atwater, VI.17.93, Dos Palos, VII.9-14.93, 4.8 km SE El Nido, VII.8.92, 8 km W Gustine, VII.8.93, 9.7 km SW Gustine, VI.25.92, VI.17.93, 11.3 km S Gustine, VI.22.93, Los Banos, VII.13.93, 3.2 km NW Los Banos, VII.1.92, 6.4 km SW Los Banos, VII.7.93, 9.7 km S Los Banos, VII.7.93, 9.7 km SE Los Banos, VII.13.93, 13 km W Los Banos, VI.23.93, 16 km SW Merced, VI.23.93, Santa Rita Park, VII.15.93, 1.6 km SW Santa Rita Park, VI.17.93, VII.13.93; *Sacramento Co.*, Sacramento, III.20.99 (W.D. Patterson); *San Mateo Co.*, San Francisco Airport, VI.17.94; *Tulare Co.*, 14.5 km SE Earlimart, VI.18.92; *Yolo Co.*, Davis, VI.17.99 [JAP slide 8012 male], III.15.2000 (J. A. De Benedictis). MASS: *Barnstable Co.*, Barnstable, V.30.59 [JAP slide 7936 male], West Barnstable, IV.30.49 [JAP slide 7937 female] (C. P. Kimball).

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Literature Cited

Anonymous. 1953a. United States (Bur. Entomol., USDA): first record of Cotton Stem Moth. FAO Plant Protect. Bull. 1: 90–91.

Anonymous. 1953b. United States (Bur. Entomol., USDA): survey of Cotton Stem Moth. FAO Plant Protect. Bull. 2: 29, 45.

Bradley, J. D. 1966. Some changes in the nomenclature of British Lepidoptera. Part 4. Entomol. Gazette 17: 213–235.

Capps, H. W. 1958. An illustrated key for identification of larvae of the cotton-pest species of *Pectinophora* Busck and *Platyedra* Meyrick (Lepidoptera: Gelechiidae). Bull. Entomol. Research 49: 631–632.

Goloviznin, D. D. 1937. Bollworms of the family Gelechiidae. Sotz. Nauka Tekh. 5: 87–98. [In Russian, summary in English. Abstract in Rev. Appl. Entomol. 26, 1938.]

Meyrick, E. 1895. A handbook of British Lepidoptera. MacMillan and Co., London, New York, 843 pp.

Mimeur, J. 1930. Un neuveau parasite du cotonnier au Maroc (*Platyedra vilella,* Zeller). Rev. Pathol. Veg. 17, fasc. 1: 4–6. [Abstract in Rev. Appl. Entomol. 18, 1930.]

Okumura, G. T. 1961. Identification of lepidopterous larvae attacking cotton, with illustrated key (Primarily California species). State Dept. Agric., Bur. Entomol. Special Publ. 282; 80 pp.

Pierce, F. N. & J. W. Metcalfe. 1935. The genitalia of the Tineina of the British Isles. F. N. Pierce; Oundle, Northhants, U.K.; 116 pp., 67 pl.

Piskunov, V. I. 1990. Family Gelechiidae. pp. 889–1024. *In* Medvedev, G. S. (ed.). Keys to the insects of the European part of the USSR. Volume IV, Lepidoptera, Part 2. 1989 Translation; E. J. Brill; Oxonian Press, New Delhi.

Powell, J. A. 1992. Recent colonization of the San Francisco Bay area, California, by exotic moths (Lepidoptera: Tineoidea, Gelechioidea, Tortricoidea, Pyraloidea). Pan-Pacific Entomol. 68: 105–121.

Powell, J. A. & S. Passoa. 1991. Rapid colonization of the western United States by the Palaearctic moth, *Agonopterix alstroemeriana* (Oecophoridae). J. Lepid. Soc. 45: 234–236.

Powell, J. A., P. & S. Russell & F. A. H. Sperling. 2001. Northward geographic expansion of two garden mint-feeding species of *Pyrausta* in California (Lepidoptera: Pyraloidea). Holarctic Lepid. [19 pp. ms, in press].

Yakhontov, V. V. 1931. The Cotton Stem Moth (*Platyedra vilella* Zell.) Za Khlopkov. Nezavisim., 5: 42–47. [In Russian. Abstract in Rev. Appl. Entomol. 21: 53–54, 1933.]

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INCIDENCE OF PRECOCIOUS EGG DEVELOPMENT IN FLIES OF FORENSIC IMPORTANCE (CALLIPHORIDAE)

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Abstract.—A common task of a forensic entomologist is to estimate the postmortem interval (PMI) based on the age of a blow fly larva collected from the corpse. Typically larval age is calculated by comparison to growth curves produced in the laboratory. Previous authors have noted that it is possible for a single blow fly egg to move from one of the ovaries into the vagina and be fertilized before the female has found an oviposition site. Such a developing egg and the resulting larva, which we call "precocious", would appear older compared to its siblings. To our knowledge this phenomenon has not been included in laboratory models of larval growth, raising the possibility that such a larva, if unrecognized, could lead an investigator to overestimate PMI. The relevance of precocious larvae to the practice of forensic entomology depends on how common they are in the field. We dissected and observed the internal reproductive organs of female blow flies caught at decayed meat baits in the San Francisco Bay area. Four species, *Calliphora terraenovae* Macquart, *C. vomitoria* (L.), *C. vicina* Robineau-Desvoidy, and *Lucilia sericata* (Meigen) included individuals found to have a single egg held in the vagina. In the case of *C. terraenovae,* 62% of gravid females contained an egg that had developed to the point where larval spines could be seen through the chorion. Based on these results and previous reports, it appears that precocious eggs are more likely to occur in members of the tribe Calliphorini (the bluebottles) compared to other blow fly lineages. Until this phenomenon is better understood, forensic entomologists may wish to subtract the time required for embryonic development when calculating the minimum possible age of a bluebottle larva.

Key Words.—Insecta forensic entomology, postmortem interval estimation, *Calliphora, Lucilia, Compsomyiops, Phormia.*

Blow fly larvae are the insects most commonly used as evidence in investigations of suspicious death (Smith 1986, Greenberg 1991). The carrion-feeding species very rarely deposit eggs on a live host, therefore the estimated age of a larva is also an estimated minimum postmortem interval (PMI) (Wells and LaMotte 2001). Laboratory growth curves have been developed for a wide variety of species and conditions (e.g., Introna et al. 1989, Goff et al. 1989, Byrd & Butler 1996, Greenberg & Wells 1998), and these usually serve as models of growth in the field.

A female blow fly of those species that have been studied simultaneously matures approximately 200 eggs, and unless the female is disturbed these are all deposited within a period of a few minutes (Hall 1948, Holt et al. 1979, Ives 1988, Wall 1993).

One factor that may complicate the estimation of maggot age when using such data was mentioned by Smith (1986) and discussed in detail by Erzinclioglu (1990). It is possible for a single egg to be held in the vagina (also called the common oviduct), having been fertilized as it passed the spermathecal ducts, in advance of the act of oviposition. That egg can then remain inside the mother, provided that a suitable oviposition site is not immediately found, at least until

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the egg has completed embryonic development. The amount of time that must elapse following egg maturation for this to happen is unknown. The senior author has observed eggs that hatch almost immediately following oviposition in laboratory colonies of Japanese *Aldrichina grahami* (Aldrich) and *Calliphora nigribarbis* Vollenhoven. This occurred when females had been provided a protein meal for egg development during a 24 hour period, and were then given meat for oviposition after three weeks had passed at 20° C. Such extremely "precocious" eggs were not observed among thousands that were obtained approximately 10 days following a protein meal. We suspect that the larva is expelled if it ecloses within the mother, but this also remains to be studied.

It is possible, therefore, for a blow fly to deposit a clutch of eggs in which a single individual immediately hatches while its siblings have just begun embryonic development. As far as we can determine, such precocious eggs have not been included in laboratory studies of maggot growth, and a forensic entomologist using laboratory reference data would overestimate the age of an unrecognized precocious larva by a time period that could be as much as that required for complete embryonic development. Depending on the species and temperature, blow fly embryonic development can require from approximately 14 hours to more than 13 days (Greenberg 1991, Wall et al. 1992, Davies & Ratcliffe 1994).

Erzinclioglu's (1990) report concerned *Calliphora vicina* Robineau-Desvoidy in Britain. Precocious eggs have also been observed in a *C. vicina* laboratory colony from Australia (J. Wallman, personal communication). This species, along with *A. grahami* and *C. nigribarbis,* mentioned above, are all members of the tribe Calliphorini, the bluebottle flies. This raises the possibility that bluebottles are more likely than other blow flies to exhibit this behavior.

Erzinclioglu (1990) seemed to believe that a high proportion of British *C. vicina* carried precocious eggs, although he provided no data. The relevance of precocious blow fly eggs or larvae to the practice of forensic entomology obviously depends upon the probability of encountering one in the field. In this study we recorded the incidence of precocious eggs in blow flies caught at decayed meat baits near the San Francisco Bay.

MATERIALS AND METHODS

Adult flies were collected at carrion bait using a hand net during the two periods of 14 Sep–4 Nov 1997 and 19 Dec 1997–1 Jan 1998. Collection sites were a number of California locations easily accessible from the city of Berkeley (Alameda CO) including the U.C. Berkeley campus, near China Camp State Park (Marin CO), and near the towns of Bolinas (Marin CO), Fairfax (Marin CO), and Fairfield (Solano CO).

In an effort to prevent the possible expulsion from an adult female of a precocious egg prior to preservation, flies were denied direct access to the bait, which was in a container sealed by tissue paper. Captured flies were also immediately immobilized in 95% ethanol that was kept chilled on dry ice.

Samples were then sorted according to sex and to species using the keys of Hall (1948). Females were dissected and classified as being apparently gravid (eggs appeared to be full size) or not. The presence of an egg in the common oviduct was recorded, and it was also noted if such an egg had completed development to the point where spinous rings were visible (Fig. 1), indicating that embryonic development was nearly complete.

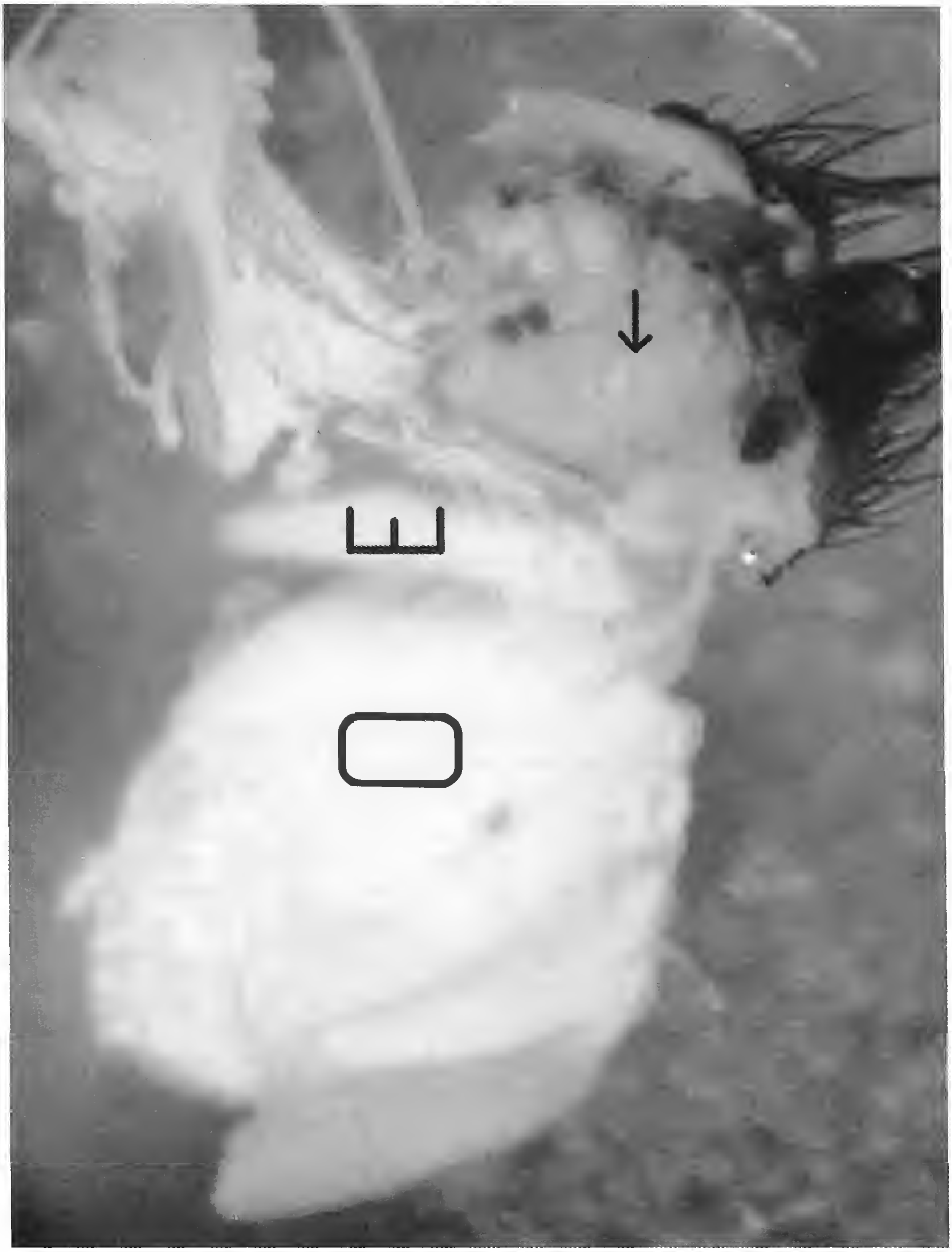

Figure 1. Internal female reproductive system of *Calliphora terraenovae.* The remaining exoskeleton with bristles is from the posterior end of the abdomen. One ovary has been removed. The arrow indicates one spinous ring of developing embryo located in the vagina. O = ovary, E = egg within an individual ovariole.

Results and Discussion

A total of 970 female blow flies were dissected (Table 1). The species observed were *Calliphora vomitoria* (L.), *C. vicina, C. terraenovae* Macquart, *Lucilia* (= *Phaenicia*) *sericata* (Meigen), *Compsomyiops callipes* (Bigot), and *Phormia re-*

Table 1. Egg development in calliphorid flies captured at decayed meat baits near San Francisco Bay. Each column represents a subset of the column to the left.

	Total females	Gravid	Precocious egg[b]	Embryonated[c]
FALL[a]				
C. vomitoria	22	1	0	—
C. vicina	33	27	3	0
L. sericata	197	95	1	0
C. callipes	146	40	0	—
P. regina	319	39	0	—
SUBTOTAL	717			
WINTER[a]				
C. terraenovae	118	55	49	34
C. vomitoria	57	45	3	1
C. vicina	2	2	1	0
L. sericata	3	3	0	—
C. callipes	30	16	0	—
P. regina	43	7	0	—
SUBTOTAL	253			
GRAND TOTAL	970			

[a] Collection periods were of 14 Sep–4 Nov 1997 and 19 Dec 1997–1 Jan 1998.

[b] Located in the vagina rather than in an ovary, and therefore probably fertilized.

[c] Spinous rings of developing larva visible through the chorion.

gina (Meigen). The numbers captured at each location are not shown because we felt that the total number of individuals was too small to draw conclusions about any real differences between study sites. The relatively larger proportion of *Calliphora* spp. in the winter samples is a typical seasonal pattern (Hall 1948).

Precocious eggs were observed in all three *Calliphora* spp. and *L. sericata* (Table 1). In *C. terraenovae* and *C. vomitoria* some eggs had developed to the point that the almost fully formed larva was visible within the chorion. In the case of *C. terraenovae* such obvious embryonic development was seen in 62% of gravid females, i.e., those that would be depositing eggs on a murder victim. Further observations are needed before we can confidently predict the proportion of wild flies carrying an egg that is about to hatch, but it can be quite high.

The single *L. sericata* carrying a precocious egg out of 98 gravid females may represent an anomaly, and we interpret our results as well as earlier observations (see above) to indicate that precocious eggs are much more likely to be found in bluebottles compared to other lineages of carrion-feeding blow flies. We believe that a forensic entomologist must consider these results when using bluebottle larvae to estimate time since death. Erzinclioglu (1990) suggested that when analyzing *C. vicina* present on a corpse the mode rather than the maximum size should be used for PMI estimation. However, Erzinclioglu supported his reasoning with a hypothetical example in which " . . . 500 flies [ovipositing on a corpse produce] 500 larvae that are larger and older than the remaining 150,000 larvae". We interpret this scenario to mean simultaneous oviposition by all females, which seems unlikely. Furthermore non-precocious larvae of equal age can be quite variable in length (Wells & LaMotte 2001) so we wonder how often the distinct size classes described by Erzinclioglu may be found. If fact, we are unaware of any data showing the distribution of larval sizes corresponding to a particular time since death in a human or other large corpse.

Practicing forensic entomologists may wish to conduct similar surveys of the carrion fly fauna at their location. Until we have a more complete understanding of the incidence of precocious eggs and how they may be recognized in the field, a conservative approach would be to treat any bluebottle larva as potentially precocious. This reasoning would apply no matter how many such larvae are used for the analysis. A minimum age could then be calculated by first using the relevant laboratory larval growth model and then subtracting the time needed for embryonic development.

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Literature Cited

Byrd, J. H. & J. F. Butler. 1996. Effects of temperature on *Cochliomyia macellaria* (Diptera: Calliphoridae) development. J. Med. Entomol., 33: 901–905.

Davies, L. & G. G. Ratcliffe. 1994. Development rates of some pre-adult stages in blowflies with reference to low temperatures. Med. Vet. Entomol., 8: 245–254.

Erzinclioglu, Y. Z. 1990. On the interpretation of maggot evidence in forensic cases. Med. Sci. Law, 30: 65–66.

Goff, M. L., A. I. Omori & J. R. Goodbrod. 1989. Effect of cocaine in tissues on the development rate of *Boettcherisca peregrina* (Diptera: Sarcophagidae). J. Med. Entomol., 26: 91–93.

Greenberg, B. 1991. Flies as forensic indicators. J. Med. Entomol., 28: 565–577.

Greenberg, B. & J. D. Wells. 1998. Forensic use of *Megaselia abdita* and *Megaselia scalaris* (Phoridae: Diptera): case studies, development rate and egg structure. J. Med. Entomol., 35: 205–209.

Holt, G. G., T. S. Adams & W. D. Sundet. 1979. Attraction and ovipositional response of screwworms, *Cochliomyia hominivorax* to simulated bovine wounds. J. Med. Entomol., 16: 248–253.

Introna, F., B. M. Altamura, A. Dell'Erba & V. Dattoli. 1989. Time since death definition by experimental reproduction of *Lucilia sericata* cycles in growth cabinet. J. Forens. Sci., 34: 478–480.

Ives, A. 1988. Aggregation and coexistence of competing insects: a theoretical model supported with evidence from the carrion-fly community. Ph.D. Dissertation. Princeton University.

Smith, K. G. V. 1986. A manual of forensic entomology. British Museum of Natural History, London.

Wall, R. 1993. The reproductive output of the blowfly *Lucilia sericata*. J. Insect. Physiol., 39: 743–750.

Wall, R., N. French & K. L. Morgan. 1992. Effects of temperature on the development and abundance of the sheep blowfly *Lucilia sericata* (Diptera: Calliphoridae). Bull. Entomol. Res., 82: 125–131.

Wells, J. D. & L. R. LaMotte. 2001. Estimating the postmortem interval. pp. 263–286. *In* J. H. Byrd & J. L. Castner (eds.). Forensic entomology: utility of arthropods in legal investigations. CRC Press, Boca Raton, Florida.

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FIRST COLLECTION OF *CHRYSOMYA MEGACEPHALA* (FABR.) IN EUROPE (DIPTERA: CALLIPHORIDAE)

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Abstract.—The first occurrence of *Chrysomya megacephala* (Fabricius) in continental Europe is reported here. This species was caught in a locality of southeastern Spain, using wind-oriented traps baited with liver and fish. The implications of this new distribution are discussed.

Key Words.—Insecta Calliphoridae, *Chrysomya megacephala,* new distribution, Spain, Europe.

Resumen.—Se notifica por vez primera la introducción del califórido *Chrysomya megacephala* (Fabricius) en Europa. Esta especie fue capturada en una localidad del sureste de España, atraída por trampas orientadas por el viento cebadas con hígado y pescado. Se discuten las implicaciones de su nueva distribución.

Blow flies of the genus *Chrysomya* Robineau-Desvoidy are abundant in warmer parts of the world and are important from medical and sanitary standpoints. Until recently, they were restricted to the Old World (Zumpt 1965) with seven species confined to the Palearctic region (Rognes 1998). *Chrysomya albiceps* (Wiedemann) is the only native species in Europe, where it breeds in organic wastes. Two *Chrysomya* species, *C. chloropyga* (Wiedemann) and *C. megacephala* (Fabr.), are expanding their ranges to the Canary Islands (Báez et al. 1981) and Madeira (Báez 1990) and were probably introduced from nearby Africa.

Chrysomya megacephala is known commonly as the Oriental latrine fly because of its association with latrines (Zumpt 1965). This species is regarded as among the most dangerous dipteran vectors of pathogens found in human and livestock feces (Wells 1991). It has dispersed from its original distribution in the Oriental and Australasian regions (Zumpt 1965) throughout the Palearctic region. It was introduced into South America more than two decades ago (Guimaraes et al. 1978) and into United States (Wells 1991, De Jong 1995).

There are several explanations for their spread, tied to human activities, including the movement of livestock (Santos Lima & Luz 1991). Several authors including Illingworth (1962) and Báez et al. (1981) have proposed that for *C. chloropyga* and *C. megacephala* the increasingly commercialized maritime route provides flies which colonize islands. At present, the distribution of *C. megacephala* covers in the Palaearctic: East Siberia, the Far East (former Soviet Union), Iran, Afghanistan, China, Japan, Egypt, Canary Islands, Madeira and Oriental, Australian, Afrotropical, Neotropical and Nearctic regions (Schumann 1986, Báez 1990).

Adult *C. megacephala* are found commonly near human dwellings (Zumpt 1965), attracted to carcasses, feces and other decomposing organic matter, for feeding and oviposition. The high natural population densities of this species and its high degree of synanthropy (Linhares 1981), allow *C. megacepaha* to be potential secondary agent of myiasis in humans and other animals (Zumpt 1965) and a major pest of fish products (Wall et al. 2000). Moreover, it can serve as a mechanical vector of enteropathogenic organisms to humans living in substandard

Table 1. Blow fly species caught in wind oriented traps baited with liver and fish in "Clot de Galvany" (Alicante, Spain).

calliphorids species	Liver		Fish		Totals
	Female	Male	Female	Male	
Chrysomya albiceps	178	14	129	7	328
Lucilia sericata	94	4	15	0	113
Calliphora vicina	13	9	17	1	40
Calliphora vomitoria	5	0	7	0	12
Chrysomya megacephala	2	0	6	0	8
Totals	319		182		501

conditions (Santos Lima & Luz 1991). This species is also of forensic importance (Wells & Kurahashi 1994).

This paper reports the first incidence of *C. megacephala* in continental Europe.

MATERIALS AND METHODS

Study Sites.—The area in southeastern Spain where the specimens were caught in a lowland area of 25,000 m^2 is periodically flooded with fresh water (38°15′ N, 0°40′ W, Elche, Alicante Province). The habitat is arid and about 2 km W of Mediterranean Sea. This site is related to several humid zones on the occidental European Mediterranean Coast and is of great intercontinental importance as a route for migratory birds from northern Europe to Africa. The vegetation is composed of the plant communities *Frankenio corymbosae–Arthrocnemetum macrostachyi* Rivas-Martínez et al., 1984, in the flooded zone and *Stipo tenacissimae–Sideritetum leucanthae* O. Bolòs, 1957, in the area close to the lagoon (Aranda & Sansano 1992).

Collections.—In Nov 1997, on the wetland area, two wind-oriented traps (WOT) (Vogt et al. 1985) baited with 300 g of fresh sardine each and two others baited with 300 g fresh pork liver each (both baits were previously frozen for three days). Traps were removed after three days.

Identification of Species.—The captured specimens were identified according González Mora & Peris (1988).

All collected calliphorids were deposited in the Entomology Collection of Alicante University (CEUA), department of Ciencias Ambientales y Recursos Naturales.

RESULTS AND DISCUSSION

In November 1997 with WOT traps, five species of calliphorids were caught (Table 1). *Chrysomya albiceps* was the most abundant necrophagous blow fly collected, followed by *Lucilia sericata* (Meigen). Moreover, six female specimens of *C. megacephala* were collected in traps baited with fish and two females in traps baited with pork liver.

In continental Europe and the Iberian Peninsula, the only species of *Chrysomya* is *C. albiceps* (Schumann 1986). This species is associated with myiasis in Africa (Zumpt 1965) but ecologically, it may be more important as a predator of other dipteran larvae. *Chrysomya albiceps* is most abundant in temperatures below 26° C (Holdaway 1933), whereas *C. megacephala* seems to tolerate a wider temperature range and may become abundant throughout tropical, subtropical, and temperate areas, with a northern limit similar to that of *C. albiceps* (Baumgartner & Greenberg 1984). Both species seem to be synanthropic, with a preference for human settlements.

Throughout the Iberian Peninsula, *L. sericata* and *C. albiceps* are the most abundant necrophagous flies (Martínez-Sánchez et al. 2000). The capture of eight adult females of *C. megacephala* within this limited geographic area almost certainly indicates a breeding populations. In areas where both *Chysomya* coexist, predation on larvae of *C. megacephala* by larvae of *C. albiceps* is evident, reducing the size of the surviving mature larvae and increasing the mortality rate of the former, though the survival rate of *C. albiceps* is also decreased (Aguiar-Coelho & Milward-de-Azevedo 1995). In the Canary Islands *C. megacephala* although not common, coexists with *L. sericata* and *C. albiceps* on most islands (Báez, personal communications).

Records of *C. megacephala* capture in Spain have been sent to Dr. Martin J. H. Hall at the Natural History Museum, Department of Entomology, Medical and Veterinary Division, London, which is a FAO Reference Laboratory for Screwworm & the Animal Myiases.

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LITERATURE CITED

Aguiar-Coelho, V. M. & E. M. V. Milward-de-Azevedo. 1995. Associaçao entre larvas de *Chrysomya megacephala* (Fabricius) e *Chrysomya albiceps* (Wiedemann), *Chrysomya megacephala* (Fabricius) e *Cochliomyia macellaria* (Fabricius) (Calliphoridae, Diptera) sob condiçoes de laboratório. Revta bras. Zool., 12: 991–1000.

Aranda, J. C. & V. Sansano. 1992. El medi i la vida al Clot de Galvany. *In* Ajuntament d'Elx (ed.) El Clot de Galvany d'Elx. Alicante, Spain.

Báez, M. 1990. Immigration of the oriental latrine fly, *Chrysomya megacephala* (Fabricius), into Madeira (Diptera, Calliphoridae). Bocagiana, 141: 1–2.

Báez, M., G. Ortega & H. Kurahashi. 1981. Immigration of the Oriental latrine fly, *Chrysomya megacephala* (Fabricius) and the Afrotropical filth fly, *C. chloropyga* (Wiedemann), into the Canary Islands (Diptera, Calliphoridae). Kontyu, 49: 712–714.

Baumgartner, D. L. & B. Greenberg. 1984. The genus *Chrysomya* (Diptera: Calliphoridae) in the New World. J. Med. Entomol., 21: 105–113.

De Jong, G. D. 1995. Report of *Chrysomya megacephala* (Diptera: Calliphoridae) in Northern New Mexico. Entomological News, 106: 192.

González Mora, M. D. & S. V. Peris. 1988. Los Calliphoridae de España 1: Rhiniinae y Chrysomyinae. Eos, 64: 91–139.

Guimaraes, J. H., A. P. Do Prado & A. X. Linhares. 1978. Three newly introduced blowfly species in Southern Brazil (Diptera, Calliphoridae). Rev. Brasil. Entomol., 22: 53–60.

Holdaway, F. G. 1933. The synonymy and distribution of *Chrysomya rufifacies* (Macq.), an Australian sheep blowfly. Bull. Entomol. Res., 24: 549–560.

Illingworth, J. F. 1962. Notes on *Chrysomya megacephala* (Fabr.) (Diptera). Proc. Hawaii. Entomol., Soc. 6: 266.

Linhares, A. X. 1981. Synanthropy of Calliphoridae and Sarcophagidae (Diptera) in the city of Campinas, Sao Paulo, Brazil. Rev. brasil. Entomol., 25: 189–215.

Martínez-Sánchez, A., S. Rojo & M. A. Marcos-García. 2000. Annual and spatial activity of carrion and dung flies in a Mediterranean holm-oak pasture ecosystem. Med. Vet. Entomol., 14: 56–63.

Rognes, K. 1998. Calliphoridae. pp 618–648. *In* Papp, L. & B. Darvas (eds.). Catalogue Palearctic of Diptera, vol. 3; Higher Brachycera. Science Herald, Budapest, Hungary.

Santos Lima, M. L. P. & E. Luz. 1991. Espécies exóticas de *Chrysomya* (Diptera, Calliphoridae) como veiculadoras de enterobactérias patogenicas em Curitiva, Paraná, Brasil. Acta Biol. Par., 20: 61–83.

Schumann, H. 1986. Calliphoridae. pp. 11–57. *In* Soós, A. & L. Papp (eds.). Catalogue of Palaearctic Diptera. Elsevier, Amsterdam, Netherlands.

Vogt, W. G., S. Runco & N. T. Starick. 1985. A wind-oriented fly trap for quantitative sampling of adult *Musca vetustissima* Walker. J. Austr. Entomol. S., 24: 223–227.

Wall, R., J. J. Howard & J. Bindu. 2000. The seasonal abundance of flies infesting drying fish in southwest India. J. Appl Ecol. (in press).

Wells, J. D. 1991. *Chrysomya megacephala* (Diptera: Calliphoridae) has reached the continental United States: review of its biology, pest status, and spread around the world. J. Med. Entomol., 28: 471–473.

Wells, J. D. & H. Kurahashi. 1994. *Chrysomya megacephala* (Fabricius) (Diptera: Calliphoridae) development: rate, variation and the implications for forensic entomology. Jpn. J. Sanit. Zool., 45: 303–309.

Zumpt, F. 1965. Myiasis in man and animals in the Old World. Butterworths & Co., London, England.

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ATTRACTION OF FEMALE DIGGER WASPS, *ASTATA OCCIDENTALIS* CRESSON (HYMENOPTERA: SPHECIDAE) TO THE SEX PHEROMONE OF THE STINK BUG *THYANTA PALLIDOVIRENS* (HEMIPTERA: PENTATOMIDAE)

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Abstract.—In field trials with male-produced sex pheromones of the stink bug *Thyanta pallidovirens*, the sphecid wasp *Astata occidentalis*, which preys on stink bugs, was also trapped. Only female wasps were trapped, suggesting that the bug pheromone is used by female *A. occidentalis* as a kairomone to locate prey for nest provisioning. The wasps were attracted by the main component of the stink bug pheromone, methyl (2*E*,4*Z*,6*Z*)-decatrienoate, and to blends of that compound with the minor components, the sesquiterpenes zingiberene, sesquiphellandrene, and α-curcumene.

Key words.—Insecta, *Astata occidentalis*, *Thyanta pallidovirens*, host attractant, methyl (2*E*,4*Z*,6*Z*)-decatrienoate, kairomone, pheromone.

Stink bugs (Hemiptera: Heteroptera: Pentatomidae), as their name suggests, produce copious quantities of odorous defensive secretions when disturbed. There is an increasing body of literature indicating that pentatomid species also produce volatile sex or aggregation pheromones (reviewed in McBrien and Millar 1999), albeit in lesser quantities than the defensive chemicals. These volatile signals are quite different chemically than the alcohols, aldehydes, esters, and hydrocarbons that typically constitute stink bug chemical defenses. The pheromones serve as a chemical beacon advertising the location of the emitting bug, and a variety of dipteran and hymenopteran predators and parasitoids are known to exploit these compounds as host-location kairomones (reviewed in Aldrich 1995, 1999).

Digger wasps (Hymenoptera: Sphecidae) in the subfamily Astatinae are ground-nesting, specialist predators of hemipteran nymphs and adults (Arnett 1993). Although their biology has received little study, the available host records suggest that female wasps specialize on a limited range of bug species (Evans 1957, 1996; Powell and Burdick 1960). The female wasps provision their underground nests with paralyzed bugs, usually providing each egg with several hosts for development. It has been suggested that sphecid wasps preying on stink bugs may use bug semiochemicals as host location cues (Aldrich 1995), but to date, there has been no hard evidence in support of this hypothesis. We have been investigating the sex pheromone chemistry of the stink bug *Thyanta pallidovirens* Stål for several years. Because of the considerable literature on the attraction of predators and parasitoids to heteropteran semiochemicals (review, Aldrich 1999), during field trials with reconstructed blends of the male-produced *T. pallidovirens* pheromones, we were careful to collect all insects caught in the pheromone-baited traps, not just the stink bugs that were the primary targets of the trapping experiments. We report here that traps baited with various blends of the *T. pallidovirens* pheromone components caught significant numbers of adult females of the wasp *Astata occidentalis* Cresson (Hymenoptera: Sphecidae: Astatinae).

MATERIALS AND METHODS

Field Trials.—In the first trial, traps consisted of plexiglass cylinders (20 cm long × 7.5 cm O.D.) with the ends enclosed by inward-pointing cones fashioned from window screen, with a 6 mm entrance hole at the tip of the cone. Traps were placed on the ground within alfalfa, vetch, or native weeds on field borders. Pheromone baits consisted of 11 m grey rubber septa (The West Co., Lititz, Pennsylvania) impregnated with methylene chloride solutions of the pheromone chemicals. Treatments were: 1) 1 mg of methyl (*E*2,*Z*4,*Z*6)-decatrienoate, 2) methyl (*E*2,*Z*4,*Z*6)-decatrienoate + α-curcumene (2.5 mg) + zingiberene (1.92 mg) + sesquiphellandrene (0.25 mg), and 3) a solvent-treated control. Traps were replicated twice and were checked twice weekly from June 29–July 13, 1998, collecting all insects in the traps for identification. In addition, for the period June 29–July 1, 2 tube traps baited with 3 virgin male *T. pallidovirens* each were included in the experiment.

In a second trial, using live male *T. pallidovirens* as baits, traps were fashioned from 3.8 liter clear plastic screw-cap soda bottles, with the bottoms cut off and rectangular slits cut in the sides to allow good ventilation and easy entry of bugs. The bottles were suspended with the conical end down, with ~200 ml of 20% ethylene glycol solution added to catch and preserve bugs. Traps were covered with a waxed cardboard wing-trap top (Pherocon 1C, Trécé, Salinas, California). The lure consisted of a 100 ml plastic vial containing three virgin male bugs and some green beans for food, suspended inside the trap body 5 cm above the ethylene glycol trapping solution. The vial had mesh-covered cut-outs around the sides to allow diffusion of semiochemicals produced by the male bugs. A pair of traps were hung from two pistachio trees separated by ~40 m in Madera County, California, pistachio orchards, and traps were retrieved 7–10 d later. The experiment was repeated three times.

Two further trials were conducted in tomato fields near Modesto, Stanislaus County, California, using commercial stink bug traps (Sierra Ag., Fresno, California) consisting of 4 liter clear plastic screw-cap jars with two inward-pointing screen cones on opposite sides of each jar. Traps were placed on the ground between beds. In the first of these trials, traps were baited with 1 ml snap-cap polyethylene centrifuge tubes loaded with neat *T. pallidovirens* pheromone. In the second of these trials, traps were baited with grey rubber septa impregnated with synthesized pheromones of either *T. pallidovirens* or the Consperse stink bug, *Euschistus conspersus* Uhler. In both trials, trap catches were tabulated weekly.

Voucher specimens of *A. occidentalis* were deposited at the University of California Riverside Entomology Museum.

Chemicals.—Methyl (2*E*,4*Z*,6*Z*)-decatrienoate and racemic α-curcumene were synthesized as previously described by Millar (1997) and Hall et al. (1975), respectively. Zingiberene was isolated from ginger oil (Spectrum Chemical Co., Gardena CA) (Millar 1998). Sesquiphellandrene was isolated from ginger oil by

Table 1. Total numbers of female *Astata occidentalis* caught in traps baited with synthetic sex pheromone of male *Thyanta pallidovirens*, or live male *T. pallidovirens*. Traps were replicated twice, and were in place from June 29–July 13, 1998, except for traps with live males, which were in place from June 29–July 1, 1998.

Lure*	Female wasps caught
Ester + sesquiterpenes	40
Ester alone	29
Blank	0
3 live male bugs	4

* Lure contents and doses are listed in Materials and Methods.

flash chromatography on silica gel (230–400 mesh, activated by drying at ~125° C overnight), eluting with hexanes. Consperse stink bug pheromone (methyl *E*2,*Z*4-decadienoate) was purchased from Bedoukian Research (Danbury, CT).

RESULTS

A total of 69 adult female *A. occidentalis* were captured in tube traps baited with experimental *T. pallidovirens* male sex pheromone blend (Table 1). No *T. pallidovirens* of either sex were caught in any of the traps containing wasps, clearly indicating that the wasps had been attracted by the synthesized pheromones. Furthermore, no wasps were captured in any control traps, nor were any male wasps captured. Both methyl (*E*2,*Z*4,*Z*6)-decatrienoate as a single component, or this ester as part of the 4-component mixture produced by sexually mature male *T. pallidovirens* (J. G. Millar, unpublished data) attracted female wasps, suggesting that the ester alone is primarily responsible for the attraction (Table 1). During a 3-day period of this trial, 2 traps baited with live male *T. pallidovirens* also trapped two female wasps each.

In a second trial, using traps in pistachio orchards baited with live male bugs, 2 traps baited with live male *T. pallidovirens* caught totals of 2 and 12 female *A. occidentalis* wasps respectively. However, blank controls were not included in this trial, whose principal purpose was the testing of a new stink bug trap design.

In a third field test conducted in tomato fields using synthetic *T. pallidovirens* pheromone dispensed from polyethylene vials, of the 86 female *A. occidentalis* caught in traps baited with the ester alone or the ester in combination with the sesquiterpenes, all but two of the wasps were caught in traps that had caught no bugs. These results confirmed that the wasps were attracted to the synthetically reconstructed pheromone of their stink bug prey.

Female wasps were attracted only to traps baited with *T. pallidovirens* pheromone. In a trial in which pheromone baits for *T. pallidovirens* and Consperse stink bug, *Euschistus conspersus*, were tested simultaneously, a total of 28 *A. occidentalis* females were caught in traps baited with *T. pallidovirens* pheromone blends, whereas only a single wasp was caught in traps baited with *E. conspersus* pheromone.

DISCUSSION

There is an increasing body of literature indicating that predators and parasitoids can eavesdrop on their hosts' pheromones, using these volatile chemicals as kairomones to locate their prey (reviewed in Haynes and Yeargan 1999). For example, numerous predatory beetles and flies locate their bark beetle prey using the beetles' aggregation pheromones (reviewed in Aldrich 1999), and the predatory bug *Elatophilus hebraicus* is attracted to the female sex pheromone of its prey, the scale *Matsucoccus josephi* (Mendel et al. 1995). Similarly, foraging yellowjacket wasps, *Vespula germanica*, locate leks of male Mediterranean fruit flies using the male-produced pheromone, and there was some evidence to suggest that the wasps learned to associate the odor of the pheromone with their prey (Hendrichs et al. 1994, 1998).

T. pallidovirens pheromone consists of an ester component with at least one of the three male-produced sesquiterpene hydrocarbons; the ester alone or the sesquiterpenes alone are not attractive to female bugs (J. G. Millar, unpublished data). *A. occidentalis* females were attracted to the *T. pallidovirens* ester as a single component, as well as to blends of the ester with other components. While suggesting that the ester component alone provides a unique and unambiguous signal enabling the wasp to find its specialized prey, it does not explain why *T. pallidovirens* requires a blend of at least two components for attraction. One possible explanation might be that the ester compound is used as a pheromone component by several *Thyanta* species, all of which may be suitable prey for the wasp, and that the species specificity of the pheromone signal is provided by the other components. Conversely, if the wasp preys upon several *Thyanta* species that share the same major pheromone component, it would be advantageous to respond to the single component alone, regardless of what other components were present.

The major component of the *E. conspersus* pheromone, methyl *E*2,*Z*4-decadienoate (Aldrich et al. 1991), differs from the *T. pallidovirens* ester by only a single double bond. Nevertheless, the wasps appeared to be able to distinguish it from the *T. pallidovirens* pheromone because in a field trial in which the pheromones of both species were tested simultaneously, 28 of the 29 wasps caught were captured in traps containing *T. pallidovirens* pheromone. Trap catches in all trials were also completely sex specific, with only female wasps being caught, as would be expected if female wasps were using their hosts' pheromone as a kairomone for finding nest provisions. Male wasps do not have this requirement, and would not be expected to be attracted.

During the experiments described, few *T. pallidovirens* of either sex were caught in pheromone-baited tube traps, for several possible reasons. First, the trap design appears to be unsuitable for stink bugs. Significant numbers of female *T. pallidovirens* were caught in subsequent experiments in tomato fields with the same lures but a different trap design (McBrien, Millar, and Cullen, manuscript in prep.). Second, the pheromone appears to be a relatively weak attractant for female bugs, as has been reported with the pheromones of several other phytophagous stink bug species (reviewed in Millar and McBrien 1999). Third, there is mounting evidence that over shorter distances, male and female stink bugs locate each other through substrate-borne vibrational signals (e.g., Ota and Cokl 1991, Cokl et al. 2001). These signals obviously are not provided by a pheromone-baited trap. Thus, female bugs may indeed be attracted to the vicinity of a pheromone source, but may have difficulty locating the pheromone source because it does not produce the vibrational signals required for short-range guidance.

LITERATURE CITED

Aldrich, J. R. 1995. Chemical communication in the true bugs and parasitoid exploitation. pp. 318–363. *In* Cardé, R. T. & W. J. Bell (eds.). Chemical ecology of insects 2. Chapman and Hall, NY.

Aldrich, J. R. 1999. Predators: Pheromones, kairomones, and synomones. pp. 357–381. *In* Minks, A. K. & J. Hardie (eds.). Pheromones of non-lepidopteran insect pests of agriculture. CAB International, Wallingford, England.

Aldrich, J. R., M. P. Hoffmann, J. P. Kochansky, W. R. Lusby, J. E. Eger & J. A. Payne. 1991. Identification and attractiveness of a major pheromone component for Nearctic *Euschistus* spp. stink bugs (Heteroptera: Pentatomidae). Env. Entomol., 20: 477–483.

Arnett, R. H. 1993. American insects. A handbook of the insects of America north of Mexico. Sandhill Crane Press, Gainesville, FL.

Cokl, A., H. L. McBrien & J. G. Millar. 2001. Comparison of substrate-borne vibrational signals of two stink bug species, *Acrosternum hilare* (Say) and *Nezara viridula* (L.) (Heteroptera: Pentatomidae). Ann. Ent. Soc. Am., 94: 471–479.

Evans, H. E. 1957. Ethological studies on digger wasps of the genus *Astata* (Hymenoptera: Sphecidae). J. New York Entomol., Soc. 65: 159–185.

Evans, H. E. 1996. Prey records and nest structure of six species of Astatinae and Philanthinae from Colorado (Hymenoptera: Sphecidae). pp. 68–71. *In* Norden, B. B. & A. S. Menke (eds.). Contributions on Hymenoptera and associated insects dedicated to Karl V. Krombein. Memoirs Entomol. Soc. Washington.

Hall, S. S., F. J. McEnroe & H.-J. Shue. 1975. A convenient synthesis of (±)-α-curcumene. VI. Application of alkylation-reduction to the total synthesis of terpenes. J. Org. Chem., 40: 3306–3307.

Haynes, K. F. & K. V. Yeargan. 1999. Exploitation of intraspecific communication systems: Illicit signalers and receivers. Ann. Entomol. Soc. Am., 92: 960–970.

Hendrichs, J., B. I. Katsoyannos, V. Wornoayporn & M. A. Hendrichs. 1994. Odour-mediated foraging by yellowjacket wasps (Hymenoptera: Vespidae): Predation on leks of pheromone-calling Mediterranean fruit fly males (Diptera: Tephritidae). Oecologia, 99: 88–94.

Hendrichs, M. A. & J. Hendrichs. 1998. Perfumed to be killed: interception of Mediterranean fruit fly (Diptera: Tephritidae) sexual signaling by predatory foraging wasps (Hymenoptera: Vespidae). Ann. Ent. Soc. Am., 91: 228–234.

McBrien, H. L. & J. G. Millar. 1999. Phytophagous bugs. pp. 277–304. *In* Minks, A. K. & J. Hardie (eds.). Pheromones of non-lepidopteran Insect pests of agriculture. CAB International, Wallingford, England.

Mendel, Z., L. Zegelman, A. Hassner, A. Fabienne, M. Harel, S. Tam & E. Dunkelblum. 1995. Outdoor attractancy of males of *Matsucoccus josephi* (Homoptera: Matsucoccidae) and *Elatophilus hebraicus* (Hemiptera: Anthocoridae) to synthetic female sex pheromone of *Matsucoccus josephi.* J. Chem. Ecol., 21: 331–241.

Millar, J. G. 1998. Rapid and simple isolation of zingiberene from ginger essential oil. J. Nat. Prod., 61: 1025–1026.

Millar, J. G. 1997. Methyl (2*E*,4*Z*,6*Z*)-deca-2,4,6-trienoate, a thermally unstable, sex-specific compound from the stink bug *Thyanta pallidovirens.* Tet. Lett., 38: 7971–7972.

Ota, D. & A. Cokl. 1991. Mate location in the southern green stink bug, *Nezara viridula* (Heteroptera: Pentatomidae), mediated through substrate-borne signals on ivy. J. Insect Behav., 4: 441–447.

Powell, J. A. & D. J. Burdick. 1960. Observations on the nesting behavior of *Astata occidentalis* Cresson in central California. Pan-Pac. Entomol., 36: 25–30.

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RESISTANCE OF *EUCALYPTUS* SPECIES TO *GLYCASPIS BRIMBLECOMBEI* (HOMOPTERA: PSYLLIDAE) IN THE SAN FRANCISCO BAY AREA

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Abstract.—The resistance of 21 cultivated *Eucalyptus* species to *Glycaspis brimblecombei* Moore was assessed from 1998 to 2000 in the San Francisco Bay area of Northern California. Based on the presence of eggs and nymphs, and the occurrence and severity of tree defoliation, the majority of the species were rated as resistant or tolerant including *E. cinerea* F. Muell., *E. cladocalyx* F. Muell., *E. ficifolia* F. Muell., *E. globulus* Labill., *E. grandis* Hill ex Maiden, *E. paniculata* Smith, *E. platypus* Hook, *E. polyanthemos* Schauer, *E. pulverulenta* Sims, *E. robusta* Smith, *E. saligna* Smith, *E. sideroxylon* A. Cunn ex Woollis, and *E. viminalis* Labill. Four species (*E. diversicolor* F. Muell., *E. leucoxylon* F. Meull., *E. macrandra* F. Muell, ex Benth and *E. nicholii* Maiden & Blakely) were rated as tolerant to moderately susceptible. Only three species (*E. camaldulensis* Dehnh., *E. rudis* Endl. and *E. tereticornis* Smith) exhibited heavy defoliation and were rated as moderately to highly susceptible. Leaf epicuticular wax appears to be involved with resistance because all glaucous species or glaucous leaf types within a species were resistant.

Key Words.—Insecta, red gum lerp psyllid, resistance, *Eucalyptus*, *Glycaspis brimblecombei*, glaucousness.

The red gum lerp psyllid, *Glycaspis brimblecombei* Moore (Moore 1964), was first reported in California in 1998 and became the sixth *Eucalyptus* psyllid species found in the state (Brennan et al. 1999). Prior to the arrival of *G. brimblecombei*, the blue gum psyllid (*Ctenarytaina eucalypti* Maskell) was the only economically important *Eucalyptus* psyllid in California. Whereas *C. eucalypti* affected primarily plantations of the cut foliage species *E. pulverulenta* Sims (Dahlsten et al. 1998), *G. brimblecombei* has attacked several *Eucalyptus* species in a variety of settings (street and freeway plantings, parks, commercial landscapes, schools, private gardens, and commercial fiber plantings).

Little is known about the resistance of *Eucalyptus* species to *G. brimblecombei*. In its native range (Australia), *G. brimblecombei* occurs on eight *Eucalyptus* species (*E. blakelyi* Maiden, *E. brassina* Blake, *E. bridgesiana* Baker, *E. camaldulensis* Dehnh., *E. camphora* Baker, *E. dealbata* Cunn. ex Schauer, *E. mannifera* ssp *maculosa* Baker, *E. nitens* Deane & Maiden, and *E. tereticornis* Smith (Moore 1970, 1983, 1988; Morgan 1984; Carver 1987); however, with exception of recent studies (Brennan & Weinbaum in press-a, in press-b, in press-c) on resistance mechanisms of *E. globulus*, we are unaware of any work on the resistance of other *Eucalyptus* to this psyllid species. This paper reports on the resistance of 21 *Eucalyptus* species to *G. brimblecombei* in the San Francisco bay region of Northern California.

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MATERIALS AND METHODS

To assess the resistance of *Eucalyptus* species to *G. brimblecombei*, we conducted a survey during Jul and Aug, 1999, and Oct and Nov, 2000. The survey was based on our preliminary observations during Jul and Aug, 1998 (when the psyllid was first found in northern California). The survey took place in the cities of Albany, East Palo Alto, El Cerrito, Fremont, Oakland, Palo Alto, and San Francisco. We assessed the resistance to *G. brimblecombei* by recording the presence of eggs, and early and late stage nymphs of *G. brimblecombei* on expanding and expanded leaves of shoots in the lower 3m of the canopy, and noted defoliation in the entire canopy. Defoliation was assessed qualitatively by noting the sky visible through the canopy and retention of recently expanded leaves. To minimize potential individual tree variation, in most cases we rated defoliation on a group of individuals within each species. Each year approximately three terminal shoots each from at least three to five branches distributed around the tree canopy were inspected from each individual. Each year, three or more individuals of each species were observed once except for *E. diversicolor, E. robusta* and *E. saligna* where only one individual was observed. In most cases the same trees were observed during both years of the survey. The trees included in the survey were estimated to be at least 10 to 15 years old. Where juvenile and adult form leaves were present, we assessed resistance on both leaf types.

Specimens of each species were collected, pressed and determined in the laboratory. Consulted herbaria included: CDA (California Department of Food and Agriculture), University of California & Jepson Herbaria, California Academy of Sciences, University of California, Davis. Plant vouchers were retained at CDA where they are available for review.

The following rating system was used to assess psyllid resistance.

1. No eggs or nymphs present.
2. Only eggs present.
3. Eggs and early instar nymphs present.
4. Eggs, early and late instar nymphs present but no defoliation of host plant.
5. Eggs, early and late instar nymphs present, and light defoliation of host plant.
6. Eggs, early and late instar nymphs present, and heavy defoliation of host plant.

Based on this rating system, we classified the species as resistant (rating 1–3), tolerant (4), moderately susceptible (5), and highly susceptible (6).

RESULTS

The results of the survey were consistent across both years of the survey and thus only the overall resistance rating is reported (Table 1). There was considerable variation in the resistance to *G. brimblecombei* among the *Eucalyptus* species, but little variation between individual trees within a species at each site. Although eggs and nymphs were found on the leaves of most species, only three (*E. camaldulensis, E. rudis* and *E. tereticornis*) exhibited heavy defoliation. By November 2000, the highly susceptible species were nearly completely defoliated and many appeared close to death. All of the glaucous-leaved species (*E. cinerea, E. polyanthemos, E. pulverulenta*) were resistant. Similarly the glaucous juvenile leaves of *E. globulus* were resistant relative to the glossy adult leaves. *G. brimblecombei* eggs and early stage nymphs were generally only found on tolerant

Table 1. Relative resistance of 21 *Eucalyptus* species to *Glycaspis brimblecombei.*

Species[A]	Location[B]	Resistance	
		1–6 Rating[C]	Descriptive Rating[D]
E. camaldulensis Dehnh.	AW, SU	6	Highly Susceptible
E. cinerea F. Muell. ex Benth.	AW, SU	1	Resistant
E. cladocalyx F. Muell	AW	1–3	Resistant
E. diversicolor F. Muell.	SU	3–5	Tolerant–Mod. Susceptible
E. ficifolia F. Muell.	OK, SF	1	Resistant
E. globulus Labill. (juvenile leaves)	AW, SU, EC	1	Resistant
E. globulus Labill. (adult leaves)	AW, SU, EC	1–4	Resistant–Tolerant
E. grandis Hill ex Maiden	AW	4	Tolerant
E. leucoxylon F. Muell.	SU	5	Tolerant–Mod. Susceptible
E. macrandra F. Muell. ex Benth	AW, SU	4–5	Tolerant–Mod. Susceptible
E. nicholii Maiden & Blakely	OK, AB	4–5	Tolerant–Mod. Susceptible
E. paniculata Smith	AW	1–2	Resistant
E. platypus Hook. (including forms approaching *E. nutans* F. Muell.)	SU	1–3	Resistant–Tolerant
E. polyanthemos Schauer	AW, SU	1	Resistant
E. pulverulenta Sims	SU	1	Resistant
E. robusta Smith	OK	1–3	Resistant
E. rudis Endl.	EC, OK, PA	5–6	Mod.–Highly Susceptible
E. saligna Smith	SU	1	Resistant
E. sideroxylon A. Cunn. ex Woollis	SU	1–4	Resistant–Tolerant
E. spathulata Hook ssp. *spathulata*	OK	1	Resistant
E. tereticornis Smith	AW	6	Highly Susceptible
E. viminalis Labill. ssp. *viminalis*	AW, SU, EP	1–4	Resistant–Tolerant

[A] *Eucalyptus* nomenclature follows that in Flora of Australia (1988). Unless otherwise noted, resistance ratings apply to shoots with the adult form leaves. Resistance was rated for all species in 1999 and 2000, with exception of and *E. paniculata, E. saligna* and *E. viminalis* where resistance was only rated in 1999. Three or more individuals were observed for all species except *E. diversicolor, E. robusta* and *E. saligna* where only one individual of each was observed.

[B] AB = Albany, AW = Ardenwood Historic Park (Fremont), EC = El Cerrito, EP = East Palo Alto, OK = Oakland, PA = Palo Alto, SF = San Francisco, SU = Stanford University (Palo Alto).

[C] Resistance Scale 1–6: 1 = No eggs or nymphs. 2 = Eggs only. 3 = Eggs and early instar nymphs. 4 = Eggs, early and late instar nymphs, but no defoliation. 5 = Eggs, early and late instar nymphs, and light defoliation. 6 = Eggs, early and late instar nymphs and heavy defoliation.

[D] Mod. = Moderately.

species such as *E. globulus* or *E. sideroxylon* when these species were growing in proximity to highly susceptible species.

Discussion

The results indicate clear differences in the resistance of *Eucalyptus* species to *G. brimblecombei.* Although eggs were found on most of the species, early and late stage nymphs occurred on less than half of the species, and only three (*E. camaldulensis, E. rudis* and *E. tereticornis*) were heavily defoliated.

Resistance of *Eucalyptus* species to *G. brimblecombei* may be influenced by abiotic factors (i.e., ambient temperature, soil conditions, exposure) because we observed more defoliation of moderately to highly susceptible species such as *E. rudis* in warmer areas such as Palo Alto than in cooler areas such as El Cerrito or San Francisco. Resistance may also be affected by tree vigor whereby younger more vigorous trees of susceptible species may appear resistant or tolerant in the first few years of growth. In addition, as is the case with *E. globulus*, resistance of other species may differ on the juvenile versus adult form leaves. Despite these possible influences on resistance, we suggest caution in future plantings of the moderately and highly susceptible species prior to the identification of resistant varieties or the establishment of successful biological controls. Studies with species of *Leucaena* and *Pyrus* have found considerable within and between species variation to other economically important psyllids (i.e., *Heteropsylla cubana* Crawford, *Psylla pyricola* Foerster, *Cacopsylla pyri* L.) (Sorensson & Brewbaker 1987, Bell & Stuart 1990, Berrada et al. 1995). Future studies should access within species resistance to *G. brimblecombei* of commonly planted and economically important species such as *E. camaldulensis*.

It is unclear if defoliation on the highly susceptible species was caused by direct feeding damage of the psyllid or by sooty mold that thrived on the psyllid honeydrew. In other non-myrtaceous genera, sooty mold growth on homopteran honeydew can increase leaf temperatures by several degrees (Wood et al. 1988), reduce light penetration to the leaf surface by up to 98% and thus reduce net photosynthesis by as much as 70% (Wood et al. 1988, Kaakeh et al. 1992), and cause premature leaf abscission (Sparks & Yates 1991). *Eucalyptus* species that experienced the most defoliation typically exhibited the greatest amount of sooty mold on their leaves. Sooty mold susceptibility is related to leaf surface morphology (Sparks & Yates 1991), which may help to explain differences in defoliation between the moderately susceptible (*E. leucoxylon, E. macrandra*) and highly susceptible species (*E. camaldulensis, E. rudis* and *E. tereticornis*).

Apparently glaucousness in *Eucalyptus* is involved in resistance to *G. brimblecombei.* Glaucousness is common in *Eucalyptus* and is due to epicuticular wax that occurs as tubes ('structural waxes') and plates ('non-structural waxes') (Barber 1955, Hallam & Chambers 1970). Tube waxes give leaves a 'bloom' (i.e., *E. cinerea, E. pulverulenta* and juvenile form leaves of *E. globulus*) and can be easily removed by rubbing the leaf. In contrast plate waxes are difficult to remove by rubbing and give leaves a dull matt appearance (e.g., *E. polyanthemos*). The epicuticular wax on the glaucous juvenile leaves of *E. globulus* had a negative effect on the survival and stylet probing behavior of *G. brimblecombei* adults (Brennan & Weinbaum 2001, in press-a). The epicuticular wax increased the slipperiness of glaucous juvenile leaves and prevented the psyllid from adhering to the leaf surface (Brennan & Weinbaum in press-b). This resistance mechanism may explain the absence of *G. brimblecombei* eggs on the glaucous juvenile leaves of *E. globulus*, and both the glaucous juvenile and adult leaves of *E. pulverulenta* and *E. cinerea.* It is likely that some other mechanism confers resistance to species such as *E. polyanthemos* where the glaucousness is due to plate waxes, and other nonglaucous yet resistant species (i.e., *E. cladocalyx, E. ficifolia, E. nicholii, E. platypus, E. spathulata*).

Cultivated *Eucalyptus* provide some of the most challenging identification problems in plants. The taxa listed in this paper were carefully compared to annotated herbarium specimens and the determinations are felt to be as reliable as is possible considering that wild and cultivated material of the same species are often considerably dissimilar in appearance. Several resistant or tolerant specimens, that may represent hybrids or their derivatives, remain unnamed.

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LITERATURE CITED

Barber, H. N. 1955. Adaptive gene substitutions in Tasmania eucalypts: I. Genes controlling the development of glaucousness. Evolution, 9: 1–14.

Bell, R. L. & L. C. Stuart. 1990. Resistance in Eastern European *Pyrus* germplasm to pear psylla nymphal feeding. HortScience, 25: 789–791.

Berrada, S., T. X. Nguyen, J. Lemoine, J. Vanpoucke & D. Fournier. 1995. Thirteen pear species and cultivars evaluated for resistance to *Cacopsylla pyri* (Homoptera: Psyllidae). Environmental Entomology, 24: 1604–1607.

Brennan, E. B., R. J. Gill, G. F. Hrusa & S. A. Weinbaum. 1999. First record of *Glycaspis brimblecombei* (Moore) (Homoptera: Psyllidae) in North America: Initial observations and predator associations of a potentially serious new pest of *Eucalyptus* in California. Pan-Pacific Entomologist, 75: 55–57.

Brennan, E. B. & S. A. Weinbaum. (2001). Performance of adult psyllids in no-choice experiments on juvenile and adult leaves of *Eucalyptus globulus*. Entomologia Experimentalis et Applicata, 100: 179–185.

Brennan, E. B. & S. A. Weinbaum. (in press-a). Stylet penetration and survival of 3 psyllid species on adult leaves and 'waxy' and 'de-waxed' juvenile leaves of *Eucalyptus globulus*. Entomologia Experimentalis et Applicata.

Brennan, E. B. & S. A. Weinbaum. (in press-b). The effect of epicuticular wax on adhesion of psyllids to glaucous juvenile and glossy adult leaves of *Eucalyptus globulus* Labill. Australian Journal of Entomology.

Carver, M. 1987. Distinctive motory behavior in some adult psyllids (Homoptera: Psyllidae). Journal of the Australian Entomological Society, 26: 369–372.

Dahlsten, D. L., D. L. Rowney, W. A. Copper, R. L. Tassen, W. E. Chaney, K. L. Robb, S. Tjosvold, M. Bianchi & P. Lane. 1998. Parisitoid wasp controls blue gum psyllid. California Agriculture, 52: 31–34.

Hallam, N. D. & T. C. Chambers. 1970. The leaf waxes of the genus *Eucalyptus* L'Hérit. Australian Journal of Botany, 18: 335–389.

Kaakeh, W., D. G. Pfeiffer & R. P. Marini. 1992. Combined effect of spirea aphid (Homoptera: Aphididae) and nitrogen fertilization on net photosynthesis, total chlorophyll content, and greeness of apple leaves. Journal of Economic Entomology, 85: 939–946.

Moore, K. M. 1964. Observations on some Australian forest insects. 18. Four new species of *Glycaspis* (Homoptera: Psyllidae) from Queensland. Proceedings of the Linnean Society of New South Wales, 89: 163–166.

Moore, K. M. 1970. Observations on some Australian forest insects. 23. A revision of the genus *Glycaspis* (Homoptera: Psyllidae) with descriptions of seventy-three new species. Australian Zoologist, 15: 248–342.

Moore, K. M. 1983. New species and records of *Glycaspis* Taylor (Homoptera: Spondyllaspidae) with phyletic groupings. Journal of the Australian Entomological Society, 22: 177–184.

Moore, K. M. 1988. Associations of some *Glycaspis* species (Homoptera: Spondyliaspididae) with their *Eucalyptus* species hosts. Proceedings of the Linnean Society of New South Wales, 110: 19–26.

Morgan, F. D. 1984. Psylloidea of South Australia, D. J. Woolman, Government Printer, South Australia.

Sorensson, C. T. & J. L. Brewbaker. 1987. Psyllid resistance of Leucaena species and hybrids. Leucaena Research Reports, 7: 29–31.

Sparks, D. & I. E. Yates. 1991. Pecan cultivar susceptibility to sooty mold related to leaf surface morphology. Journal of the American Society of Horticultural Science, 116: 6–9.

Wood, B. W., W. L. Tedders & C. C. Reilly. 1988. Sooty mold fungus on pecan foliage suppresses light penetration and net photosynthesis. HortScience, 23: 851–853.

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THE *RUSTICA* SPECIES GROUP OF HAWAIIAN *DROSOPHILA* (DIPTERA: DROSOPHILIDAE)

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Abstract.—The *rustica* group, NEW SPECIES GROUP, of Hawaiian *Drosophila* is proposed based on unique characteristics of the male labellum and female ovipositor. The structure of the labellum is similar to the sclerotized labellum found in the closely related *haleakalae* species group, although additional modifications are also present. Three species are placed in this group, *D. curiosa* Hardy & Kaneshiro, NEW SPECIES, a new species endemic to Hawai'i, *D. praesutilis* Hardy, a species from O'ahu, and *D. rustica* Hardy, from the islands of Maui and Moloka'i.

Key Words.—Insecta, Diptera, Drosophilidae, Hawaiian *Drosophila, rustica* species group, *Drosophila curiosa.*

Although the *picture wing* species group has been extensively studied, the basal lineages within the Hawaiian *Drosophila*, such as the *haleakalae* species group and its relatives, are largely unknown. Throckmorton (1966), based upon examination of a variety of internal morphological characters, suggested that the *ciliated tarsus* species *D. imparisetae* Hardy was closely related to the *haleakalae* species group (Fig. 1A). Spieth (1966) confirmed this close affinity based on field observations of mating behavior. He found that males from both *D. imparisetae* from the *ciliated tarsus* group, and *D. fungiperda* (Hardy 1966), from the *haleakalae* group, "took station" on leaves of shrubs and small trees where they could be easily seen by observers. These hypotheses, however, were based on a small number of taxa and were not analyzed in a rigorous phylogenetic context.

Recently, molecular data has been used to determine the phylogenetic relationships among the Hawaiian Drosophilidae. Bonacum (2001), in contrast to other molecular work (Kambysellis et al. 1995, Baker & DeSalle 1997), has recently suggested that the *ciliated tarsus* species group is not basal within the Hawaiian *Drosophila* lineage or closely related to the *haleakalae* group at all (Fig. 1B). Instead, he placed the *ciliated tarsus* species within a clade of leaf breeding taxa, including the *modified tarsus* and *antopocerus* species groups (Fig. 1B). The *haleakalae* group is entirely mycophagous (Heed 1968). The *ciliated tarsus* species, however, have been reared from a variety of substrates, predominantly leaves (*Cheirodendron, Clermontia*) but also including fruits (*Clermontia, Myrsine* and *Sapindus*), stems (*Cheirodendron, Clermontia*), fungus, and ferns (Heed 1968).

This recent shift in notions concerning the relationships within the Hawaiian *Drosophila* highlights two points. First, systematic relationships within and among some of the major groups of Hawaiian *Drosophila* should be considered preliminary, as they are based on only a few taxa or rigorous phylogenetic studies. Second, the ecological habits of these groups, as suggested by Heed (1968), may

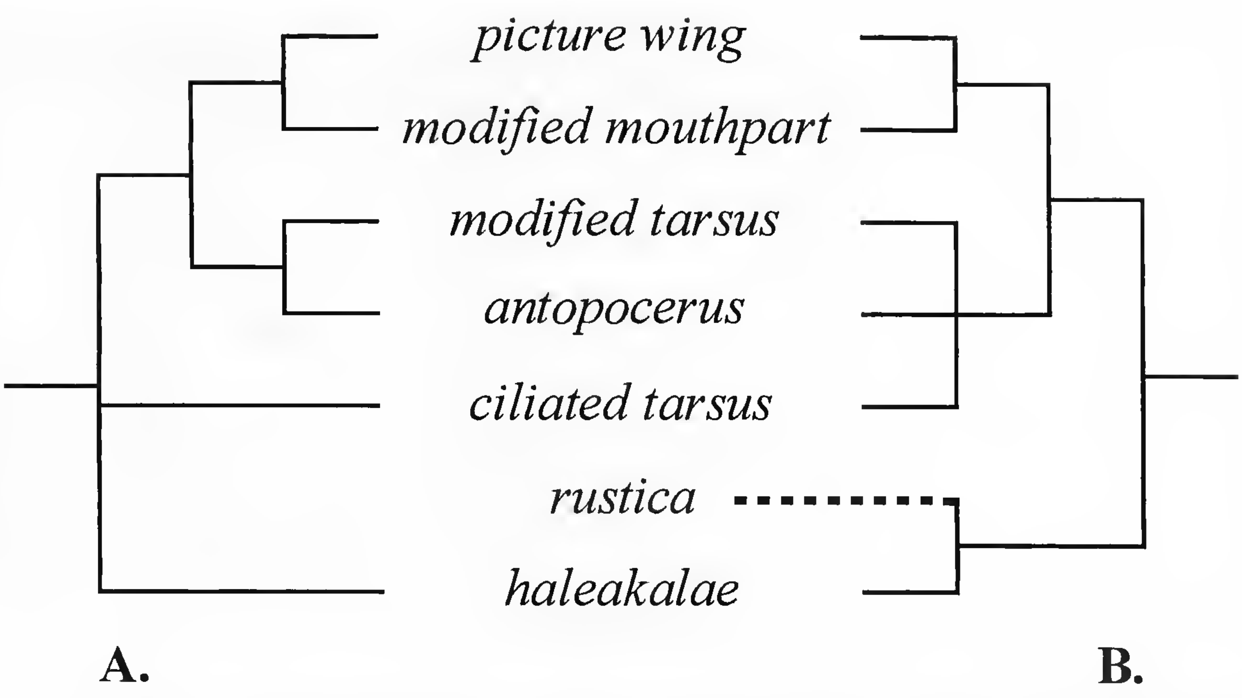


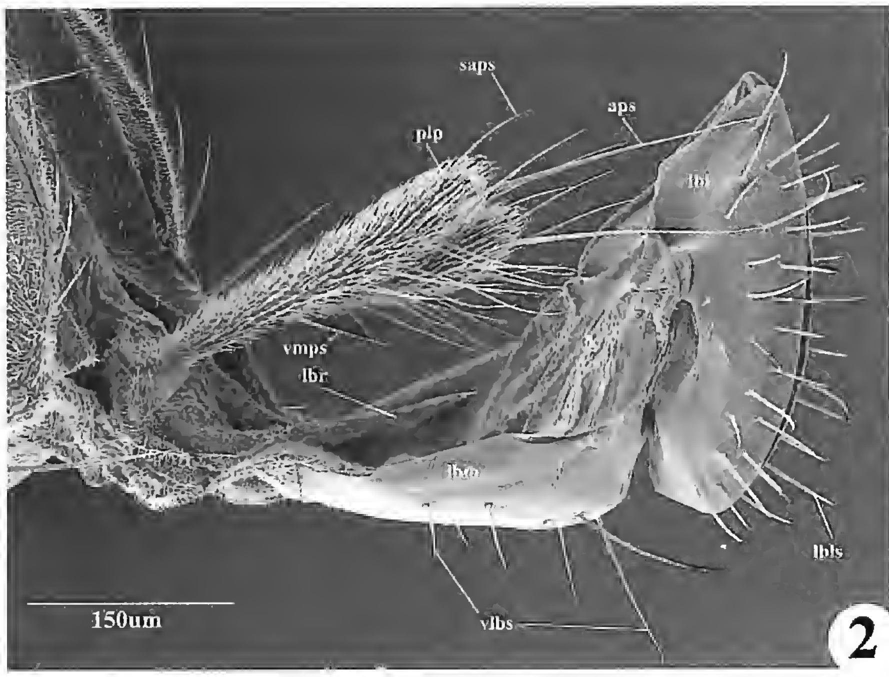
Figure 1. Proposed phylogenetic relationships in the Hawaiian *Drosophila*. (A) Morphological hypothesis proposed by Throckmorton (1966). (B) Molecular phylogeny of the Hawaiian *Drosophila* (Bonacum, 2001) with a tentative placement (dashed line) of the *rustica* species group.

be more reliable indicators of phylogeny than male secondary sexual characteristics.

The *rustica* group is difficult to place definitively because it possesses morphological characters which are found in other groups. Males of the three species placed in the *rustica* group possess a heavily sclerotized labellum, a character typically found only in the *haleakalae* species group (Figs. 2, 3). The labellar structure in *D. rustica* differs from that of the *haleakalae* group in that two additional peg-like seta are present on the dorsolateral margin of the labellum (Fig. 3). Females of *D. rustica* are also distinct, possessing heavily sclerotized spermathecae, a character not seen in any *haleakalae* group species. The cilia on the foretibia of *D. rustica* males closely resembles that of some *ciliated tarsus* species (Hardy 1965: 453; fig. 182b), suggesting a close relationship among these groups, even though males of *D. curiosa* and *D. praesutilis* lack ciliation on the foretarsi. However, it should be noted that ciliation on the forelegs of Hawaiian *Drosophila* males is quite common and may have arisen independently multiple times *via* sexual selection. As such, it may not be the best character on which to base the placement of the *rustica* species group. Because of the limited number of specimens of *D. curiosa* and *D. praesutilis*, the spermathecae and labellae of these species were not examined in detail. We are tentatively placing the *rustica* group close to the *haleakalae* group (Fig. 1B), but are unable at this time to determine the exact phylogenetic affinities of this group. Further study of morphological and molecular characters will be required to determine the relationships between the *rustica* group and its close relatives in the *haleakalae* and *ciliated tarsus* groups.

MATERIALS AND METHODS

When possible, a variety of measurements were made from representatives of each species in the *rustica* species group (Sturtevant 1942, Grimaldi 1987). Abbreviations and definitions used include: thorax length (TL), distance from anterior notal margin to the posterior apex of the scutellum; wing length (WL), maximum



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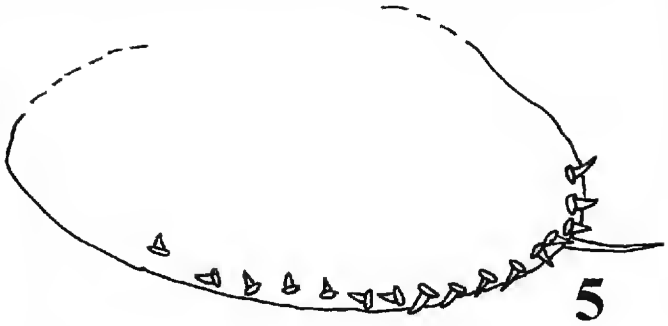

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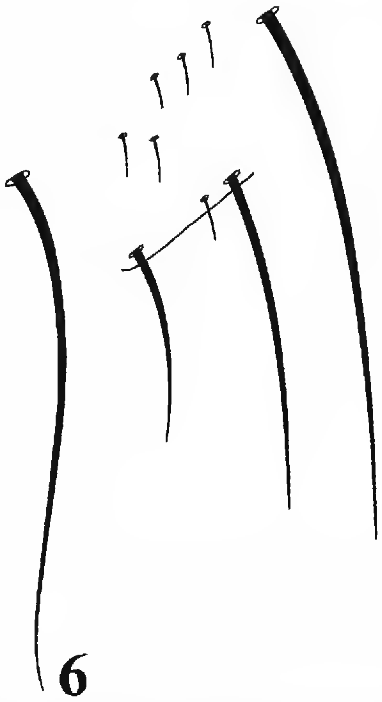

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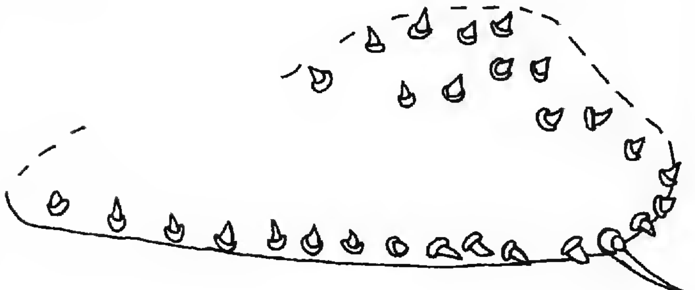

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Figure 2. *Drosophila multiciliata*, lateral view of mouthparts. aps—apical palpal setae, lbl—labellum, lbls—labellar setae, lbm—labium, lbr—labrum, plp—palp, saps—subapical palpal setae, vlbs—ventral labial setae, vmps—ventro-medial palpal setae.

Figure 3. *Drosophila rustica*, apical view of labellum with dorsolateral peg setae.

Figure 4. *Drosophila curiosa*, posterolateral region of mesonotum.

distance from the humeral crossvein to the apex of the wing; ratio of thorax length to wing length (TL/WL); head width (HW), greatest distance between apical margins of the eyes; ratio of head width to thorax length (HW/TL); costal index (CI), length of costa from subcostal break to R2+3/length of costa from R2+3 to R4+5; fourth vein index (4V), length of M1 from crossvein dm-cu to apex/length of M1 from crossvein r-m to crossvein dm-cu; length of CuA1 from crossvein dm-cu to apex/length of crossvein dm-cu (5X); length of costa from R2+3 to R4+5/length of M1 from crossvein r-m to crossvein dm-cu (4C); and length of CuA1 from crossvein dm-cu to apex/length of M1 from crossvein r-m to crossvein dm-cu (M).

DROSOPHILA CURIOSA HARDY & KANESHIRO, NEW SPECIES
(Figs. 4, 5, 8)

Diagnosis.—*D. curiosa* differs from closely related forms by lacking ciliation on the front tibia or tarsi; having wings hyaline with a comparatively long costal fringe and crossvein r-m located near the middle of cell 1st M2; and with pleurae and scutellum which are entirely pale yellow. The labellum of males possesses a heavily sclerotized black rim.

Types.—Holotype, male, deposited B. P. Bishop Museum (BPBM #16356) poor condition, wing broken off; data: USA, HAWAIIAN ISLANDS. *HAWAI'I:* Kapua Land Section, Hoopuloa Quadrant, slopes of Mauna Loa, South Kona, 2650 ft., Jul 1977, D. E. Hardy, TL = 1.1 mm; HW = 0.8 mm; HW/TL = 0.8. Allotype, female, deposited BPBM # 16356a; data: same data as holotype, TL = 1.0 mm; WL = 1.8 mm; TL/WL = 0.5; HW = 0.8 mm; HW/TL = 0.8; CI = 2.4; 4V = 2.5; 5X = 2.2; 4C = 1.3; M = 0.5.

Description.—*Male, Female. Head.* Mostly yellow; black rim of labellum present in male, absent in female; head appendages yellow; medial portion of occiput, vertex, frontal triangle and parafrontalia extending to proclinate setae brown; frontal triangle shining, extending almost to level of proclinate setae; arista of male with six dorsal and three ventral rays in addition to apical fork, female arista with four dorsal and three ventral rays in addition to apical fork, inner margin of arista with five to six short, inconspicuous, widely-spaced setulae.

Thorax. Mostly yellow to rufous, with faint tinge of brown on sides of mesonotum; mesonotum subshining, lightly yellow-gray pollinose; one slightly enlarged black seta, two times longer than other setae, present in each dorsocentral row opposite anterior supraalar setae; posterolateral area of mesonotum sparsely setose (Fig. 4). *Legs.* Entirely yellow, lacking ornamentation; front basitarsus half as long as tibia. *Wings.* Hyaline, costal fringe extending about 3/5 the distance between apices of veins R2+3 and R4+5; section of vein Ml +2 between r-m and dm-cu crossveins equal in length to last section of vein M3+4. *Abdomen.* Mostly rufous, tinged with brown; fourth and fifth tergites pale yellow except for narrow basal margin of former; male genitalia not studied; ovipositor oval in shape (Fig. 5), apex with about four peg ovisensilla, ventral margin with thirteen peg ovisensilla which extend to 3/4 ovipositor length, dorsolateral region lacking ovisensilla, inner subapical ovisensilla about 1/4 ovipositor width.

Distribution.—Known only from the Big Island of Hawai'i (Fig. 8).

Etymology.—This species is named *curiosa* because it possesses a mixture of characteristics which make it difficult to place.

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Figure 5. *Drosophila curiosa*, lateral view of ovipositor.

Figure 6. *Drosophila rustica*, lateral view of ovipositor.

Figure 7. *Drosophila rustica*, posterolateral region of mesonotum.

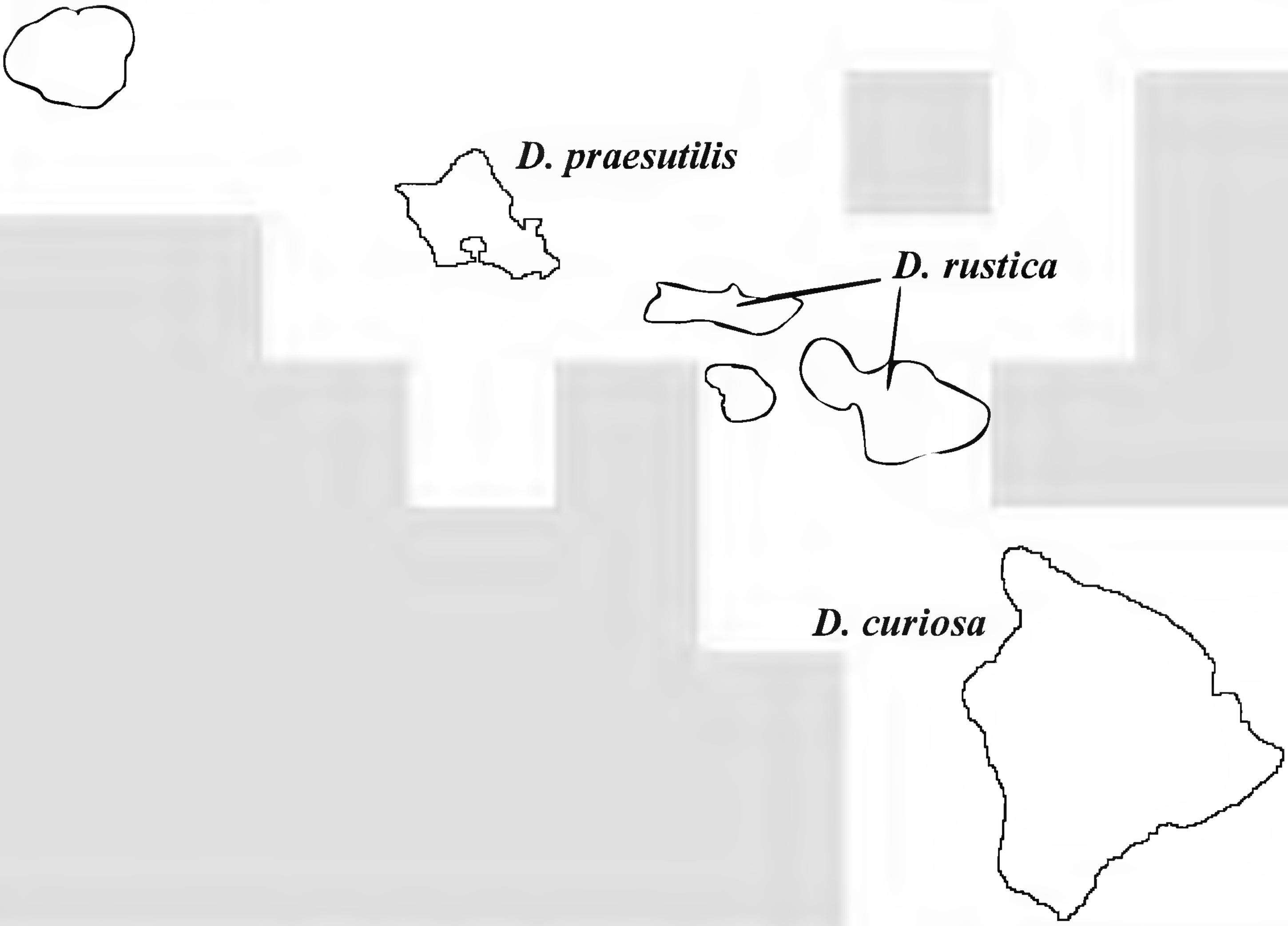

Figure 8. Distribution of *D. curiosa, D. praesutilis*, and *D. rustica*.

DROSOPHILA PRAESUTILIS

(Fig. 8)

Drosophila praesutilis Hardy 1965: 422.

Diagnosis.—*D. praesutilis* differs from members of this group by having three strong pairs of dorsocentral setae, anterior pair situated presutural.

Types.—Holotype, male, deposited BPBM #6422, hindlegs beyond coxae and abdomen missing; apical ½ of right wing torn off, left wing torn in 1/2 on anterior and posterior margins, genitalia in microvial mounted below specimen (Evenhuis, 1982); data: USA, HAWAIIAN ISLANDS. *O'AHU:* Pupukea, Jul 1952, D. E. Hardy.

Description.—Refer to Hardy (1965).

Distribution.—*Drosophila praesutilis* is endemic to O'ahu (Fig. 8) and known only from the type male.

Discussion.—This species is being placed in the *rustica* species group because of it's entirely pale yellow body and labellar characters. Nothing is known of the habits or the biology of these species. The female has not been associated.

DROSOPHILA RUSTICA

(Figs. 3, 6–8)

Drosophila rustica Hardy 1965: 452.

Diagnosis.—*D. rustica* differs from other species treated here by having the front tibia and tarsi ciliated, wings evenly infuscated, costal fringe short, crossvein r-m near basal ⅓ of cell M2, and the upper half of each pleuron distinctly tinged with brown. *D. rustica* is treated here because of the presence of a black sclerotized rim on the labellum of the male. Females can be differentiated from members of the closely related *haleakalae* group by having well sclerotized, mushroom-shaped, spermathecae and by their distinctive ovipositor morphology.

Types.—Holotype, male, deposited BPBM #6438, apices of left and right wings punctured and torn off (Evenhuis 1982); data: USA, HAWAIIAN ISLANDS. *MOLOKA'I:* Pu'u Kolekole, 3600 ft, Jul 1953, D. E. Hardy and M. Tamashiro. TL = 1.1 mm; WL = 2.6 mm; TL/WL = 0.4; HW = 0.9 mm; HW/TL = 0.9; CI = 4.1; 4V = 1.8; 5X = 1.2; 4C = 0.6; M = 0.5. Paratype, 1 male, deposited University of Hawai'i Entomology Collection (UHEC); data: same as holotype, TL = 1.0 mm; WL = 2.3 mm; TL/WL = 0.4; HW = 0.8 mm; HW/TL = 0.8; CI = 5.3; 4V = 1.6; 5X = 1.5; 4C = 0.5; M = 0.3.

Description.—Male. Head. Labellum heavily sclerotized, with two sharply pointed, peg-like setae on dorsolateral margin (Fig. 3). *Thorax.* Area surrounded by inner and outer postalar, supraalar and posterior dorsocentral setae on each side of mesonotum sparsely setose in both sexes (Fig. 6). *Legs.* Cilia present on tibia and tarsi (Hardy 1965: 453; fig. 182b). Refer to Hardy (1965) for a description of additional male characters. *Female.* Fitting description of males, except for sexual characters. *Abdomen.* Ovipositor with distinctive clump of prominent ovisensilla on distal portion (Fig. 7); spermathecae well-sclerotized and mushroom-shaped (not shown).

Distribution.—Endemic to Moloka'i and Maui (Fig. 8).

Material Examined: USA, HAWAIIAN ISLANDS, MAUI: Ridge above Kaulalewelewe, 3000–4000 ft, 4 Aug 1964, D. E. Hardy, 1 male. Waikamoi, 4300 ft, 9 Aug 1964, H. L. Carson, 1 male. Waikamoi, 29 Jun 1965, L. H. Throckmorton, 1 male. *MOLOKA'I:* Pu'u Kolekole, 3600 ft., 20 Jul 1964, H. L. Carson, 2 males, 3 females. South of Hanalilolilo, 3600 ft., 2 Mar 1966, K. Resch, 1 male. Material deposited UHEC.

Discussion.—Five females from the Big Island which resemble *D. rustica* have also been studied. It is not possible at this time to determine whether these are conspecific with *D. rustica* or represent another member of the *rustica* species group.

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LITERATURE CITED

Baker, R. H. & R. DeSalle. 1997. Multiple sources of character information and the phylogeny of Hawaiian drosophilids. Syst. Biol., 46: 654–673.

Bonacum, J. 2001. Molecular systematics of the Hawaiian Drosophilidae. Ph.D. Dissertation, Yale University.

Evenhuis, N. L. 1982. Catalog of entomological types in the Bishop Museum. Diptera: Drosophilidae. Pac. Insects, 24: 318–367.

Grimaldi, D. A. 1987. Phylogenetics and taxonomy of *Zygothrica* (Diptera: Drosophilidae). Bull. Am. Mus. Natl. Hist., 186: 103–268.

Hardy, D. E. 1965. Diptera: Cyclorrhapha II, Series Schizophora, Section Acalypterae I, Family Drosophilidae. Volume 12. pp. 1–814. *In* Zimmerman, E. C. (ed.). Insects of Hawai'i. University of Hawai'i Press.

Hardy, D. E., 1966. Descriptions and notes on Hawaiian Drosophilidae (Diptera). Univ. Texas Publ., 6615: 195–244.

Heed, W. B., 1968. Ecology of the Hawaiian Drosophilidae. Univ. Texas. Publ., 6818: 388–419.

Kambysellis, M. P., K.-F. Ho, E. M. Craddock, F. Piano, M. Parisi & J. Cohen. 1995. Pattern of ecological shifts in the diversification of the Hawaiian *Drosophila* inferred from molecular phylogeny. Current Biology, 5: 1129–1139.

Spieth, H. T., 1966. Courtship behavior of endemic Hawaiian *Drosophila*. Univ. Texas Publ., 6615: 245–313.

Sturtevant, A. H. 1942. The classification of the genus *Drosophila*, with descriptions of nine new species. Univ. Texas Publ., 4213: 5–51.

Throckmorton, L. H., 1966. The relationships of the endemic Hawaiian Drosophilidae. Univ. Tex. Publ., 6615: 335–396.

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ABSENCE OF LATITUDINAL CLINES IN SPERM CHARACTERS IN NORTH AMERICAN POPULATIONS OF *DROSOPHILA SUBOBSCURA* (DIPTERA: DROSOPHILIDAE)

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Abstract.—Within the past twenty years, *Drosophila subobscura* (Collin 1936), endemic to the Old World, has rapidly colonized South America and the west coast of North America. Despite the recent colonization, inversion polymorphism and body size clines in North America have converged on clines found in Europe, indicating rapid evolutionary responses. One rapidly evolving trait in *Drosophila* is sperm length, which varies 180 fold between species. In species of the *obscura* group, to which *D. subobscura* belongs, sperm length also varies within individuals, a phenomenon known as sperm heteromorphism, in which males produce both short and long sperm. I examined sperm length evolution in males from eleven North American populations of *D. subobscura* representing a latitudinal transect of 1750 km. Significant differences between the populations in short and long sperm head lengths, and the total length of long sperm were found. However, these differences were not explained by latitude. A significant effect of males within a population on sperm length parameters was found indicating that sperm length variation within a population was equal to or exceeded variation across populations. Additionally, a potential constraint or stabilizing selection on sperm design was identified in that the ratio of short head to short tail compared to that ratio of long sperm did not differ. Results from this analysis suggest that significant inter-population variance in sperm length is unrelated to predictable environmental variation that mediates other traits, such as body size.

Key Words.—Insecta, Diptera, *Drosophila subobscura*, cline, sperm length, sperm heteromorphism.

Clines in genetic and morphometric traits, such as chromosomal inversions and body size, may result from historical processes and/or adaptive selection (Endler 1986). In a geographically wide-ranging species, such as some *Drosophila* species, the demonstration of parallel clines on different continents is taken as strong support for adaptive evolution (Endler 1986), presumably related to climate. In *Drosophila*, chromosomal polymorphisms (e.g., Anderson 1981, Oakeshott et al. 1982, Prevosti et al. 1985, 1988, Ayala et al. 1989, Berry & Kreitman 1993) and body size clines (e.g., Prevosti 1955, Coyne & Beecham 1987, Capy et al. 1993) have been well-documented and are thought to reflect climatic factors, such as temperature, rainfall and relative humidity (James et al. 1995).

Drosophila subobscura (Collin 1936) has recently expanded its geographic range, from its endemic Palearctic regions, to colonization and establishment of populations in both South (Brncic et al. 1981) and North America (Beckenbach & Prevosti 1986). Colonization in the New World occurred in the late 1970s and early 1980s and, since this accidental introduction, these populations have rapidly expanded along the western coasts of the South and North American continents such that, in certain areas, they can be the most abundant species (Ayala et al. 1989) and have been found as far west as Utah (Noor et al. 2000). Allozyme

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(Prevosti et al. 1983, Balayna et al. 1994), chromosomal (Prevosti et al. 1985, 1988; Ayala et al. 1989, Krimbas & Powell, 1992), and DNA (Latorre et al. 1986, Rozas et al. 1990, Rozas & Aguade 1991) polymorphisms have been studied in these newly founded populations. Significant latitudinal clines of chromosomal polymorphisms in both North and South America populations have been described that converge on clines found in Old World populations (Prevosti et al. 1990). Additionally, strengths for S. American chromosomal polymorphism clines increased between 1981 and 1986 (Prevosti et al. 1990), indicating the clines are rapidly evolving and are potentially adaptive. In addition to chromosomal clines, converging body size clines for both Old and New World *D. subobscura* populations have been documented (Pegueroles et al. 1995, Huey et al. 2000), indicating rapid evolution and possible selection for morphometric traits (Pegueroles et al. 1995).

A morphometric trait that appears to be rapidly evolving in *Drosophila* is sperm length (Joly et al. 1989, 1991; Pitnick et al. 1995). *Drosophila* exhibit the greatest inter-specific variation in sperm length (ranging from ca. 0.090 to 58 mm; Pitnick et al. 1995) of any animal taxa so far examined. The adaptive significance of sperm length is under debate (Birkhead & Møller, 1998), but is likely related to sexual selection (e.g., Pitnick et al. 1995, Pitnick & Miller 2000). Additionally, in a phylogenetically controlled study, Pitnick and colleagues (1995) found that on a macroevolutionary scale, species in which males were bigger produced longer sperm. Given that several *Drosophila* species, including *D. subobscura*, exhibit body size clines, that the body size cline in *D. subobscura* occurred rapidly and that *Drosophila* sperm length is a rapidly evolving trait, the question of whether intra-specific clinal variation in *D. subobscura* sperm length exists is an intriguing one.

Members of the *obscura* group, including *D. subobscura* and *D. pseudoobscura* (Frolowa 1929), are also of particular interest regarding sperm length evolution because males exhibit sperm heteromorphism in which they simultaneously produce two lengths of sperm, short and long (Fig. 1; Beatty & Sidhu 1970, Snook et al. 1994, Bressac & Hauschteck-Jungen 1996, Snook 1997). Sperm heteromorphic species produce and transfer to females both sperm types, and females store both sperm types, at least transiently (Beatty & Sidhu 1970, Snook et al. 1994, Bressac & Hauschteck-Jungen 1996). However, the different sperm lengths are functionally nonequivalent in that only long sperm participate in fertilization (Snook et al. 1994, Snook & Karr 1998). The evolutionary function of short sperm in the *obscura* group remains a conundrum (Snook 1998a).

Here I examine sperm length evolution in eleven populations of North American *D. subobscura*, representing a latitudinal transect across 15° and 1750 km. I determine whether these populations exhibit nonrandom geographic variation (i.e., cline) in sperm length parameters (head, tail and total lengths) of both short and long sperm. I also examine the evolution of these sperm length parameters within a sperm type and identify a potential constraint on sperm design.

METHODS AND MATERIALS

Flies.—Populations of *D. subobscura* from western North America were collected in 1997 by R. Huey and colleagues (Huey et al. 2000). They collected flies on yeasted banana baits at eleven sites at 1.5° intervals between Atascadero, Cal-

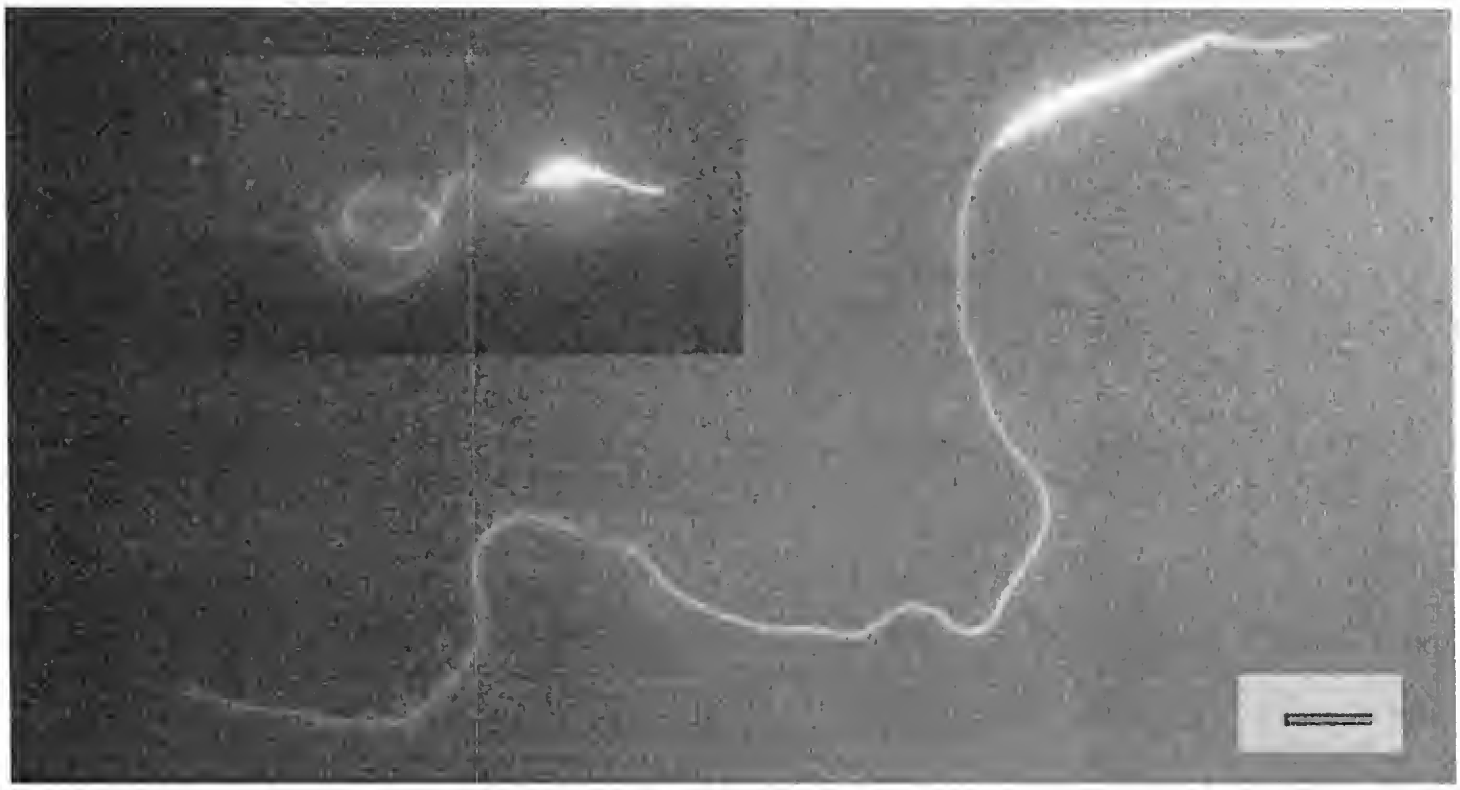

Figure 1. Dimorphic sperm from the seminal vesicles of *D. subobscura*. Sperm were dissected, processed and stained with a DNA-specific fluorescent dye as described previously (Snook et al. 1994). Inset: short sperm type. Scale bar = 25 μm.

ifornia and Port Hardy, Canada (Fig. 2) and subsequently established isofemale lines of *D. subobscura*. To form populations, 10 F1 males and 10 F1 females from 25 isofemale lines per locality were combined. Once I received the flies, they were reared in vials containing yeasted banana food at ca. 22° C. Flies went through less than 20 generations from the time of collection to this study.

Sperm Length Measurements.—To measure sperm, virgin males were collected by aspiration upon eclosion and stored in 25 mm × 95 mm food vials until males were 7 days old. Each male was ether-anaestetized and dissected in phosphate buffer solution to remove the reproductive tract. Sperm were removed from the seminal vesicles and processed for sperm length measurements on gelatin/chrome alum-coated glass microscope slides as previously described (Snook et al. 1994).

Computer images of sperm were taken using a Zeiss AxioPlan epifluorescent microscope and a Princeton Instruments Quantum camera. Sperm heads and tails were measured using the length measurement function in IP Lab Spectrum. The total lengths of sperm were obtained by adding the head and tail length for each sperm measured. From 15 to 10 sperm of each sperm type from 3 or 4 males in each population were measured (Table 1).

Statistics.—To test if populations significantly differed in sperm length parameters, nested ANOVAs were performed with males nested within a population. A potential ecological determinant of sperm length through latitudinal and body size clines for sperm lengths were assessed by linear regression. The relationship of the ratio between short head and tail lengths compared to that ratio in long sperm was tested using a paired t-test. All statistics were performed with JMP (SAS 1995).

RESULTS

Sperm length data for each male were normally distributed. Means and standard error of the mean for each sperm length parameter in all populations are reported

Figure 2. Collection sites of *D. subobscura* along the west coast of North America.

in Table 1. Nested ANOVAs indicated a significant effect of male nested within population for each sperm length parameter (Table 2). Nested ANOVAs also indicated a significant difference between populations in short and long sperm head lengths and the total length of long sperm (Table 2). However, these differences were not correlated with latitude for any sperm length parameter (Table 3; Fig. 3).

In *obscura* group species, the length of sperm heads for both sperm types are notably longer (Fig. 1) than the more commonly studied *D. melanogaster* (Meigen 1830) or *D. hydei* (Sturtevant 1921) (Fuller 1993). In other *Drosophila* species, the primary variation in sperm length between species is the sperm tail. In *obscura* group species, head length comprises a larger ratio of the total length of the sperm (Snook 1997). I used a paired *t*-test to test the relationship between the ratio of sperm head to tail lengths, comparing short and long sperm types. This analysis revealed that short and long sperm have the same ratio of head: tail lengths ($t = 1.184$, $df = 36$, $P = 0.244$; Fig. 4) and that there was a significant positive relationship between the ratios (Fig. 4; $F = 15.6$, $df = 1, 35$, $P < 0.001$).

Table 1. The names of the eleven strains and their latitude, arranged from south to north, from which sperm morphometrics (mean ± SE) were determined. Sample sizes are below the means; the first number is the number of males and the second number is the total number of sperm measured per population.

		Sperm Morphometrics					
		Short Sperm			Long Sperm		
Population	Lat (°N)	Head	Tail	Total	Head	Tail	Total
Atasca	35.5	24.1 ± 0.7 4,60	103.3 ± 2.4 4,58	127.3 ± 2.9 4,58	53.0 ± 1.1 4,60	243.7 ± 4.8 4,60	296.7 ± 5.0 4,60
Gilroy	37.00	26.1 ± 0.6 3,30	105.7 ± 2.5 3,30	131.8 ± 2.7 3,30	54.3 ± 1.2 3,30	239.0 ± 6.2 3,30	293.3 ± 7.2 3,30
Davis	38.60	15.8 ± 0.5 3,30	105.2 ± 3.2 3,30	121.0 ± 3.3 3,30	33.9 ± 1.2 3,30	191.7 ± 4.5 3,30	225.7 ± 5.3 3,30
Redding	40.60	19.3 ± 0.6 3,24	93.6 ± 2.5 3,24	113.0 ± 2.5 3,24	47.1 ± 1.2 3,30	220.0 ± 4.7 3,30	267.2 ± 4.7 3,30
Eureka	40.80	22.7 ± 0.7 3,30	100.1 ± 2.5 3,30	112.8 ± 2.7 3,30	46.8 ± 1.8 3,30	242.1 ± 6.9 3,30	288.9 ± 8.1 3,30
Medford	42.30	19.5 ± 0.7 3,30	99.1 ± 2.7 3,30	118.6 ± 2.7 3,30	39.3 ± 0.6 3,30	228.6 ± 5.9 3,30	267.8 ± 5.9 3,30
Salem	44.90	23.7 ± 1.1 3,30	114.4 ± 2.2 3,30	138.1 ± 2.7 3,30	52.7 ± 1.0 3,30	265.4 ± 5.4 3,30	318.1 ± 5.9 3,30
Centralia	46.70	20.6 ± 0.5 4,60	115.5 ± 1.4 4,57	135.9 ± 1.3 4,57	44.3 ± 1.0 4,60	242.7 ± 2.8 4,59	286.7 ± 3.2 4,59
Bellingham	48.70	21.4 ± 0.7 3,30	105.8 ± 2.1 3,30	127.2 ± 2.2 3,30	46.7 ± 1.2 3,30	215.1 ± 5.0 3,30	261.8 ± 5.6 3,30
Peachland	49.80	24.7 ± 0.5 4,60	113.9 ± 1.4 4,58	138.6 ± 1.3 4,58	49.2 ± 0.9 4,60	241.4 ± 4.7 4,60	290.6 ± 5.1 4,60
Port Hardy	50.70	22.7 ± 0.5 4,60	105.2 ± 2.2 4,60	128.0 ± 2.3 4,60	48.1 ± 0.8 4,60	231.7 ± 4.3 4,60	279.8 ± 4.4 4,60
Overall		21.9 ± 0.9	105.6 ± 2.1	127.5 ± 2.5	46.9 ± 1.8	232.8 ± 5.8	279.7 ± 7.2

Table 2. Results from nested ANOVAs testing for differences between populations in sperm parameters with the effects of individual males from each population nested within population (Male (pop.).

Sperm Parameter	Source	SS	MS	df	F	P
Short Head	Population	2997.8	299.78	10	2.76	0.018
	Male (pop)	2982.08	114.69	26	10.95	0.0001
Short Tail	Population	16933.5	1693.35	10	1.47	0.21
	Male (pop)	31554.9	1213.26	26	8.89	0.0001
Short Total	Population	23236.7	2323.67	10	1.74	0.12
	Male (pop)	36527	1404.89	26	8.71	0.0001
Long Head	Population	12383.4	1238.34	10	3.07	0.01
	Male (pop)	10962.6	421.64	26	15.08	0.0001
Long Tail	Population	116973	11697.3	10	1.65	0.15
	Male (pop)	192665	7410.2	26	12.14	0.0001
Long Total	Population	183514	18351.4	10	2.25	0.0471
	Male (pop)	221629	8524.19	26	11.8	0.0001

DISCUSSION

Several *Drosophila* species exhibit body size clines perhaps associated either with temperature, rainfall or relative humidity (James et al. 1995). The demonstration by Huey and colleagues (2000) that rapid clines in male and female body size were established in these *D. subobscura* populations suggests strong selection by some environmental component. Sperm length is a rapidly diverging trait in *Drosophila*, thus I addressed whether clinal variation in sperm length existed. While significant differences between populations in the lengths of short and long heads and in the total length of long sperm were identified, these differences were unrelated to latitude. Similarly, palearctic *D. subobscura* do not vary clinally in the number of teeth on sex combs and claspers (Perguoles et al. 1995). Inter-specific variation in the meristic characters of sex comb teeth and claspers may play a role in sexual selection and influence isolating mechanisms, whereas intra-specific variation in these traits may not have an adaptive function and are used as taxonomic traits in *obscura* group phylogenies (Buzzati-Traverso & Scossironi 1955, Perguoles et al. 1995). Likewise, inter-specific variation in *Drosophila* sperm length may play a role in isolating processes (Joly et al. 1997, Snook 1997), whereas the adaptive function of intra-specific sperm length variation is debated (e.g., Birkhead & Møller, 1998).

In mice (Beatty 1970) and other insect systems (Gage & Cook 1994, Pitnick et al. 1995), sperm morphometric traits appear to be genetically determined (Beatty 1970), with minimal variability in sperm dimensions due to environmental effects (Beatty 1970, Gage & Cook 1994, Pitnick et al. 1995). In *Drosophila*, little work has been done examining either ecological or genetic factors controlling sperm length (Pitnick et al. 1995, Joly et al. 1997, Snook 1998b). Here I found that predictable changes in the environment associated with latitude do not influence alterations in sperm length, although significant intra-specific differences in sperm length existed. Intra-specific differences in sperm length in the *D. subobscura* populations studied may not be the result of selection but of drift due to the potentially small numbers of flies colonizing a particular area (Noor et al. 2000). The origin and number of emigrants colonizing these populations, in ad-

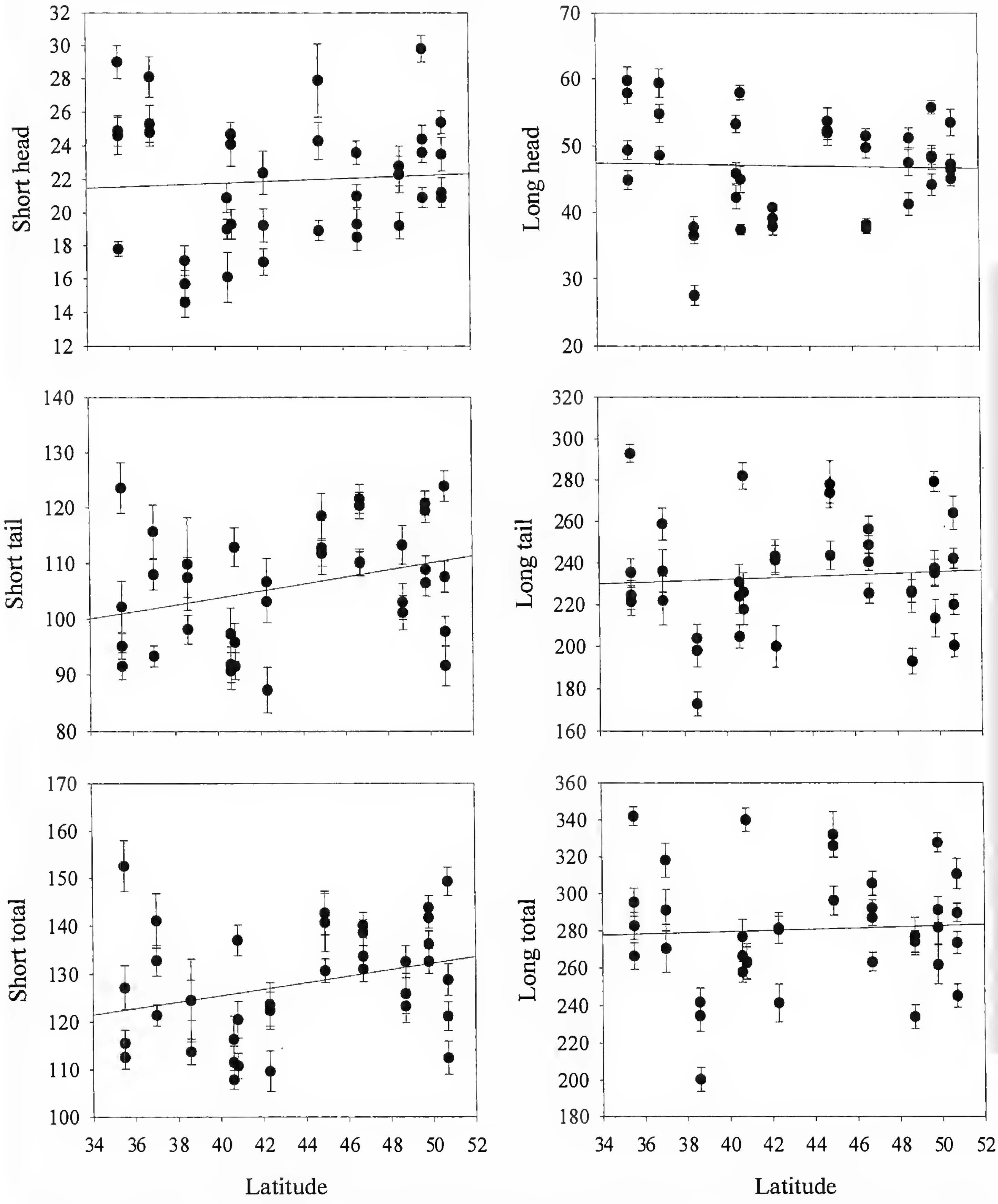

Figure 3. Relationships between sperm length parameters (μm) and latitude. See text for statistics.

dition to migration, are unknown. However, if drift is responsible for the population differences in sperm length, there was no corresponding effect on male and female body size given the rapid establishment of a latitudinal cline in body size in these same populations (Huey et al. 2000).

Nested ANOVA analyses revealed significant intra-population variation in sperm length parameters for all morphometrics, indicating that variance in sperm length parameters between males within a population is equal to or higher than variance between populations. The biological relevance of the high intra-population variance is unknown, but could be related to the outcome of sperm com-

Table 3. Correlations between sperm parameters and latitude for eleven *D. subobscura* populations.

	Latitude		
Sperm Parameter	R^2	F	P
Short Head	0.004	0.1494	0.70
Short Tail	0.09	3.77	0.06
Short Total	0.09	3.43	0.07
Long Head	0.001	0.03	0.86
Long Tail	0.005	0.17	0.68
Long Total	0.002	0.099	0.75

petition. In *Drosophila*, sperm are stored by females in two sperm storage organ types, paired mushroom-shaped spermathecae and a tubular ventral receptacle. Sperm length is highly correlated to ventral receptacle length, suggesting that sperm competitive ability or cryptic female choice may be mediated by the correspondence between sperm length and sperm storage length (Pitnick et al. 1999). If female receptacle length also varied significantly within populations, then selection pressures associated with sperm competition may alter sperm length in a manner consistent with ventral receptacle length. However, a recent analysis by Pitnick and Miller (2000) found that selection for increased sperm length in *D. melanogaster* did not result in a correlated increase in ventral receptacle length. Variation in sperm length may not be directly related to any parameter associated

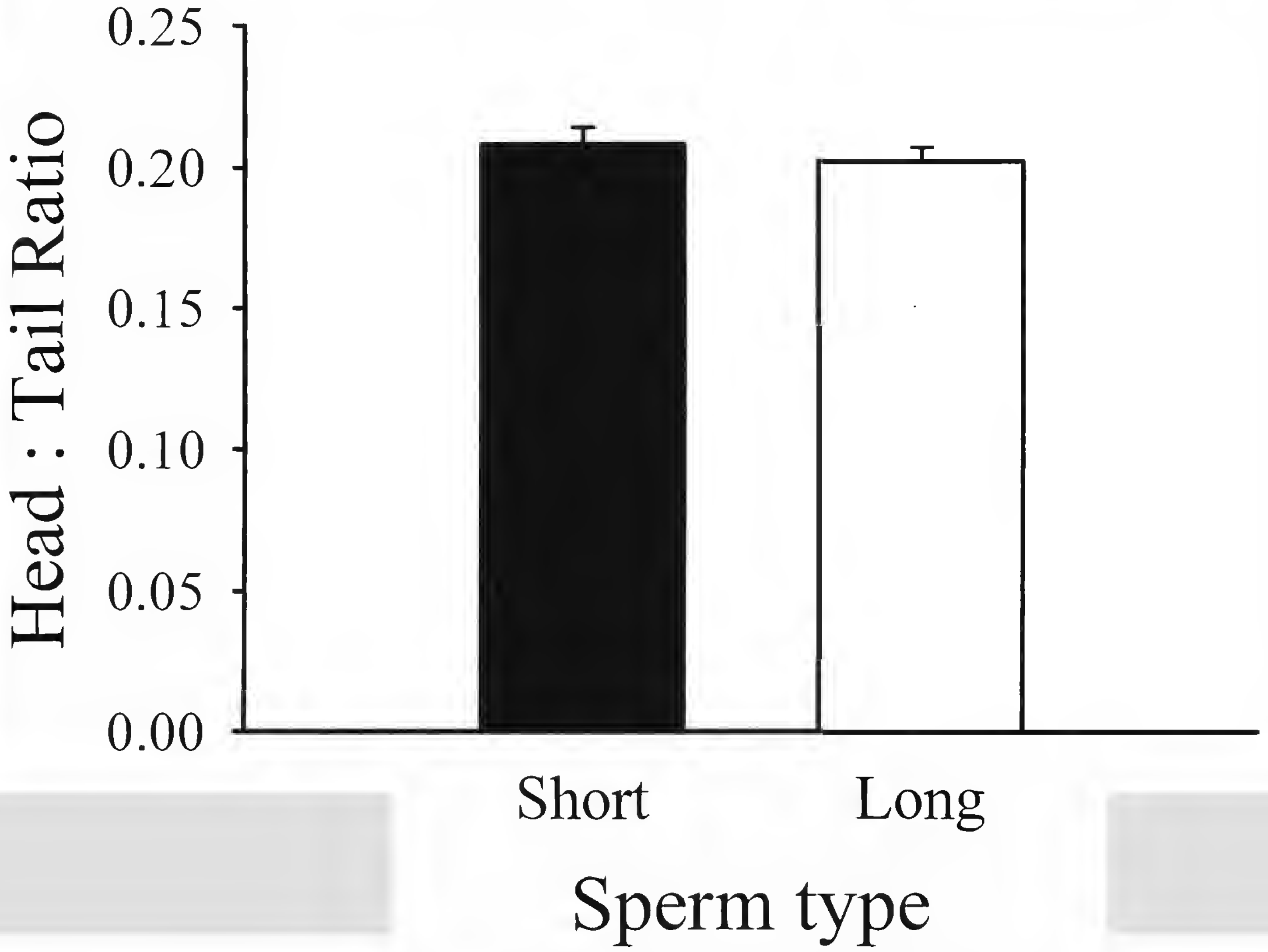

Figure 4. Relationship between the ratio of short head to short tail (μm) vs. the ratio of long head to long tail (μm). See text for statistics.

with latitude (e.g., temperature, rainfall) but with operational sex ratios and the risk of sperm competition. Unfortunately, these associations cannot be tested with the flies examined in this study.

Within a species, sperm length also does not seem to respond to male body size differences. Among the eleven *D. subobscura* populations that exhibit both male and female body size clines (Huey et al. 2000), I found no correspondence between sperm length and previously identified body size clines. Similarly, a recent study across sperm dimorphic diopsid flies found that male body size was unrelated to both short and long sperm lengths (Presgraves et al. 1999) and a lack of intra-specific association between sperm length and male body size was found in a single population of *D. hydei* (Pitnick & Markow 1994). In toto, these results indicate that factors influencing inter-specific sperm length variation, such as body size (Pitnick et al. 1995), are not similar to those influencing intra-specific variation.

Both short and long sperm had similar ratios in head compared to tail lengths regardless of the population from which males derived. This similarity suggests that there is either some isometric growth of sperm or a developmental constraint on sperm design. Alternatively, sperm design may be under stabilizing selection. In a phylogenetic analysis examining the evolution of sperm heteromorphism in the *obscura* group, long fertilizing sperm were found to be constrained by phylogeny, whereas short sperm were uncoupled from phylogeny and fertilization requirements, indicating independent evolutionary change (Snook 1999). Similarly, in sperm heteromorphic diopsid flies, the total length of short and long sperm were unrelated and suggests different selection pressures on sperm length evolution (Presgraves et al. 1999). These phylogenetic analyses examined total sperm length and not the effect of phylogeny on head and tail lengths. Given the consistent results between the sperm heteromorphic systems, however, it seems unlikely that the similar ratios of short and long sperm in *D. subobscura* are a result of stabilizing selection. Each sperm type serves a different function and thus selection should be acting differently on each type. Long sperm function in fertilization (Snook et al. 1994, Snook & Karr 1998) whereas the adaptive significance of short sperm remains a conundrum (Snook & Markow 1996, Snook 1998a). Thus, the similar ratios of head to tail lengths in both short and long sperm support the interpretation of either isometric growth or developmental constraint.

In conclusion, while chromosomal polymorphism and morphometric body size clines have quickly developed in recent New World populations of *D. subobscura* and while sperm length is a rapidly evolving trait in *Drosophila*, a sperm length cline has not developed. Furthermore, similarities in sperm design were identified that may indicate either proximate or ultimate mechanisms controlling sperm morphometrics. The intra-specific variation in sperm characteristics found in this study and others (Ward 1998) suggests extended work on genetic and ecological factors influencing sperm to more fully understand the evolutionary significance of this variation.

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LITERATURE CITED

Anderson, P. R. 1981. Geographic clines and climatic associations of Adh and alpah-Gpdh frequencies in *Drosophila melanogaster*. pp. 237–250. *In* Gibson, J. B. & J. G. Oakeshott (eds.). Genetic studies of *Drosophila* populations. Australian National University, Canberra.

Ayala, F. J., L. Serra & A. Prevosti. 1989. A grand experiment in evolution: the *D. subobscura* colonization of the Americas. Genome, 31: 246–255.

Balanya, J., C. Segarra, A. Prevosti & L. Serra. 1994. Colonization of American by *D. subobscura:* the founder event and a rapid expansion. J. Heredity, 85: 427–432.

Beatty, R. A. 1970. The genetics of the mammalian gamete. Biol. Rev., 45: 73–119.

Beatty, R. A. & N. S. Sidhu. 1970. Polymegaly of spermatozoan length and its genetic control in *Drosophila* species. Proc. R. Soc. Edinburgh Section B, 71: 14–28.

Beckenbach, A. & A. Prevosti. 1986. Colonization of North American by the European species *D. subobscura* and *D. ambigua*. Am. Midl. Nat., 115: 10–18.

Berry, A. & M. Kreitman. 1993. Molecular analysis of an allozyme cline: alcohol dehydrogenase in *Drosophila melanogaster* on the east coast of North America. Genetics, 134: 869–93.

Birkhead T. R. & A. P. Møller. 1998. Sperm Competition and Sexual Selection. Academic Press, London.

Bressac, C. & E. Hauschteck-Jungen. 1996. *Drosophila subobscura* females preferentially select long sperm for storage and use. Jr Insect Physiol., 42: 323–328.

Brncic, D., A. Prevosti, M. Budnik, M. Monclus & J. Ocana. 1981. Colonization of *D. subobscura* in Chile. I. First population and cytogenetic studies. Genetica, 56: 3–9.

Buzzati-Traverso, A. & R. E. Scossiroli. 1955. The ‘Obscura group’ of the genus *Drosophila*. Adv. Genet., 7: 47–92.

Capy, P., E. Pla & J. R. David. 1993. Phenotypic and genetic variability of morphometrical traits in natural populations of *Drosophila melanogaster* and *D. simulans*. I. Geographic variations. Genet. Sel. Evol., 25: 517–536.

Coyne, J. A. & E. Beecham. 1987. Heritability of two morphological characters within and among natural populations of *Drosophila melanogaster*. Genetics, 117: 727–737.

Endler, J. A. 1986. Natural Selection in the Wild. Princeton University Press, Princeton.

Fuller, M. T. 1993. Spermatogenesis. pp. 71–147. *In* Bate, M. & A. M. Arias (eds.). The Development of *Drosophila melanogaster*. Cold Spring Harbor Laboratory Press.

Gage, M. J. G. & P. A. Cook. 1994. Sperm size or number? Effects of nutritional stress upon eupyrene and apyrene sperm production strategies in the moth *Plodia interpunctella* (Lepidoptera: Pyralidae). Funct. Ecol., 8: 594–599.

Huey, R. B., G. W. Gilchrist, M. L. Carlson, D. Berrigan & L. Serra. 2000. Rapid evolution of a geographic cline in size in an introduced fly. Science (in press).

James, A. C., R. B. R. Azevedo & L. Partridge. 1995. Cellular basis and developmental timing in a size cline of *Drosophila melanogaster*. Genetics, 140: 659–666.

Joly, D., C. Baxin, L.-W. Zeng & R. S. Singh. 1997. Genetic basis of sperm and testis length differences and epistatic effect on hybrid inviability and sperm motility between *Drosophila simulans* and *D. sechellia*. Heredity, 78: 354–362.

Joly, D., C. Bressac, J. Devaux & D. Lachaise. 1991. Sperm length diversity in Drosophilidae. Drosophila Information Service, 70: 104–108.

Joly, D., M.-L. Cariou, D. Lachaise & J. R. David. 1989. Variation of sperm length and heteromorphism in Drosophilid species. Genet. Sel. Evol., 21: 283–293.

Krimbas, C. & J. R. Powell. 1992. Drosophila Inversion Polymorphism. CRC Press.

Latorre, A., A. Moya & F. J. Ayala. 1986. Evolution of mitochondrial DNA in *D. subobscura*. Proc. Natl. Acad. Sci. USA, 83: 8649–8653.

Noor, M. A. F., M. Pascual & K. R. Smith. 2000. Genetic variation in the spread of *Drosophila subobscura* from a nonequilibrium population. Evolution, 54: 696–703.

Oakeshott, J. G., J. B. Gibson, P. R. Anderson, W. R. Knibb, D. G. Anderson & G. K. Chambers. 1982. Alcohol dehydrogenase and glycero-3-phosphate dehydrogenase clines in *Drosophila melanogaster* on different continents. Evolution, 36: 86–96.

Pitnick, S. & G. T. Miller. 2000. Correlated response in reproductive and life history traits to selection on testis length in *Drosophila hydei*. Heredity, 84: 416–426.

Pitnick, S. & T. A. Markow. 1994. Large male advantages associated with costs of sperm production in *Drosophila hydei*, a species with giant sperm. Proc. Natl. Acad. Sci. USA, 91: 9277–9281.

Pitnick, S., T. A. Markow & G. S. Spicer. 1995. Delayed male maturity is a cost of producing large sperm in *Drosophila*. Proc. Natl. Acad. Sci. USA, 92: 10614–10618.

Pitnick, S., T. A. Markow & G. S. Spicer. 1999. Evolution of multiple kinds of female sperm-storage organs in *Drosophila*. Evolution, 53: 1804–1822.

Perguoles, G., M. Papaceit, A. Quintana, A. Guillen, A. Prevosti & L. Serra. 1995. An experimental study of evolution in progress: clines for quantitative traits in colonizing and Palearctic populations of *Drosophila*. Evol. Ecol., 9: 453–465.

Presgraves, D. C., R. H. Baker & G. S. Wilkinson. 1999. Coevolution of sperm and female reproductive tract morphology in stalk-eyed flies. Proc. R. Soc. Lond. B, 266: 1041–1047.

Prevosti, A. 1955. Geographical variability in quantitative traits in populations of *D. subobscura*. Cold Spring Harbor Symp. Quant. Biol., 20: 294–298.

Prevosti, A., M. P. Garcia, L. Serra, M. Aguade, G. Ribo & E. Sagarra. 1983. Association between allelic isozyme alleles and chromosomal arrangements in European populations and Chilean colonizers of *D. subobscura*. Isozymes, 10: 171–191.

Prevosti, A., L. Serra, G. Ribo, M. Aguade, E. Sagarra, M. Monclus & M. P. Garcia. 1985. The colonization of *D. subobscura* in Chile. II. Clines in the chromosomal arrangements. Evolution, 39: 838–844.

Prevosti, A., G. Ribo, L. Serra, M. Aguade, J. Balana, M. Monclus & F. Mestres. 1988. Colonization of America by *D. subobscura:* experiment in natural populations that supports the adaptive role of chromosomal inversion polymorphism. Proc. Natl. Acad. Sci. USA, 85: 5597–5600.

Prevosti, A., L. Serra, E. Segarra, M. Aguade, G. Ribo & M. Monclus. 1990. Clines of chromosomal arrangements of *D. subobscura* in South American evolve closer to Old World patterns. Evolution, 44: 218–221.

Rozas, J. & M. Aguade. 1991. Using restriction-map analysis to characterize the colonization process of *D. subobscura* on the American Continent. I. rp49 region. Mol. Biol. Evol., 8: 447–457.

Rozas, J., M. Hernandez, V. M. Cabrera & A. Prevosti. 1990. Colonization of America by *D. subobscura:* effect of the founder event on the mitochondrial DNA polymorphism. Mol. Biol. Evol., 7: 103–109.

Silberglied, R. E., J. G. Shepherd & J. L. Dickinson. 1984. Eunuchs: the role of apyrene sperm in lepidoptera? Am. Nat., 123: 255–265.

Sivinski, J. 1980. Sexual selection and insect sperm. Fl. Entomol., 63: 99–111.

Sivinski, J. 1984. Sperm in competition. pp. 86–115. *In* Smith, R. L. (ed.). Sperm competition and the evolution of animal mating systems. Academic Press, London.

Snook, R. R. 1997. Is the production of multiple sperm types adaptive? Evolution, 51: 797–808.

Snook, R. R. 1998a. The risk of sperm competition and the evolution of sperm heteromorphism. Anim. Behav., 56: 1497–1507.

Snook, R. R. 1998b. Sperm production and sterility in hybrids between two subspecies of *Drosophila pseudoobscura*. Evolution, 52: 266–269.

Snook, R. R. & T. L. Karr. 1998. Only long sperm are fertilization-competent in six sperm-heteromorphic *Drosophila* species. Current Biology, 8: 291–294.

Snook, R. R. & T. A. Markow. 1996. Possible role of nonfertilizing sperm as a nutrient source for female *Drosophila pseudoobscura* (Diptera: Drosophilidae). Pan-Pacific Entomol., 72: 121–129.

Snook, R. R., T. A. Markow & T. L. Karr. 1994. Functional nonequivalence of sperm in *Drosophila pseudoobscura*. Proc. Natl. Acad. Sci., USA, 91: 11225–11229.

Ward, P. I. 1998. Intraspecific variation in sperm size characters. Heredity, 80: 655–659.

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Scientific Note

TEMNOSTETHUS FASTIGIATUS DRAKE AND HARRIS, 1926, A SPECIES OF *ELATOPHILUS* REUTER AND A SYNONYM OF *ELATOPHILUS DIMIDIATUS* (VAN DUZEE), 1921 (HEMIPTERA: HETEROPTERA: ANTHOCORIDAE)

The Anthocoridae *Temnostethus fastigiatus* was described by Drake and Harris from the Santa Cruz Mountains; Morgan Hill; and Cayton, Shasta County, all of California (Drake, C. J. and H. M. Harris. 1926. Proc. Biol. Soc. Wash., 39: 33–46). They stated it was the first American record of the genus *Temnostethus*, known previously only from the Palearctic (Péricart, J. 1972. Faune de l'Europe et du Bassin Mediterraneen No. 7 Mason et Cie Editeurs, Paris. 402 pp.; Péricart, J. 1996. pp. 108–140. *In* Aukema, B. and C. Rieger (eds.). Cat. Heteroptera Palearctic Reg. Vol. 2. Cimicormorpha I. Netherlands Entomol. Soc., Amsterdam, The Netherlands.) There appears to have been no further mention of this species until the catalog of Henry (Henry, T. J. 1988. pp. 12–28. *In* Henry, T. J. & R. C. Froeschner (eds.). Cat. Heteroptera, Brill, Leiden.) where *T. fastigiatus* and *T. gracilis* (Horváth) were listed. We have examined the type specimens of *T. fastigiatus* in the United States National Museum, Washington, D.C., and compared them with specimens of *Elatophilus dimidiatus* (Van Duzee) from California and concluded that *T. fastigiatus* is a synonym of *E. dimidiatus.* Kelton (Kelton, L. A. 1977. Can. Entomol., 109: 243–248) reported on the occurrence of the European *Temnostethus gracillis* (Horváth) in Nova Scotia, Canada. He provided a description and illustrations of the adult, ostiolar canal, and male clasper (Kelton, L. A. 1977, 1978. Can. Dep. Agri. Pub. 1639. 101 pp.). The Canadian specimens were taken from moss-covered deciduous trees including *Acer* sp., *Quercus* sp., and *Tilia* sp., agreeing with the information given by Péricart (1972). Species of *Temnostethus* normally occur on broad-leafed trees, especially those encrusted with lichens, but Péricart (1972) stated that *T. wichmanni* Wagner occurs only on the conifer *Picea* in central Europe. In contrast, species of *Elatophilus* occur only on conifers and seem to be limited to species of the genus *Pinus* (Lattin and Stanton, 1992. J. N.Y. Entomol. Soc., 100: 424–479).

Van Duzee (Van Duzee, E. P. 1921. Proc. Calif. Acad. Sci. (4 ser.), 11: 137–144) described *Anthocoris dimidiatus* based upon the holotype, a macropterous female from Felch Ranch, near Cayton, (Shasta Co.), Calif., July 15, 1918. The two other individuals mentioned in the original description were "immature" females, one teneral with fully developed wings and the other with "elytra short, attaining middle of third tergal segment, black with the scutellar margin of clavus castaneous, base of corium and embolium and narrow membrane white." The holotype and teneral female specimen are in the collections of the California Academy of Sciences, San Francisco, #791. The so-called immature female, actually a brachypterous individual with a narrow membrane, is now in the collection of the U.S. National Museum as part of the series of *Temnostethus fastigiatus* Drake and Harris. Kelton (Kelton, L. A. 1976. Can. Entomol., 108: 631–634) placed *Anthocoris dimidiatus* Van Duzee, 1921, into the genus *Elatophilus* Reuter,

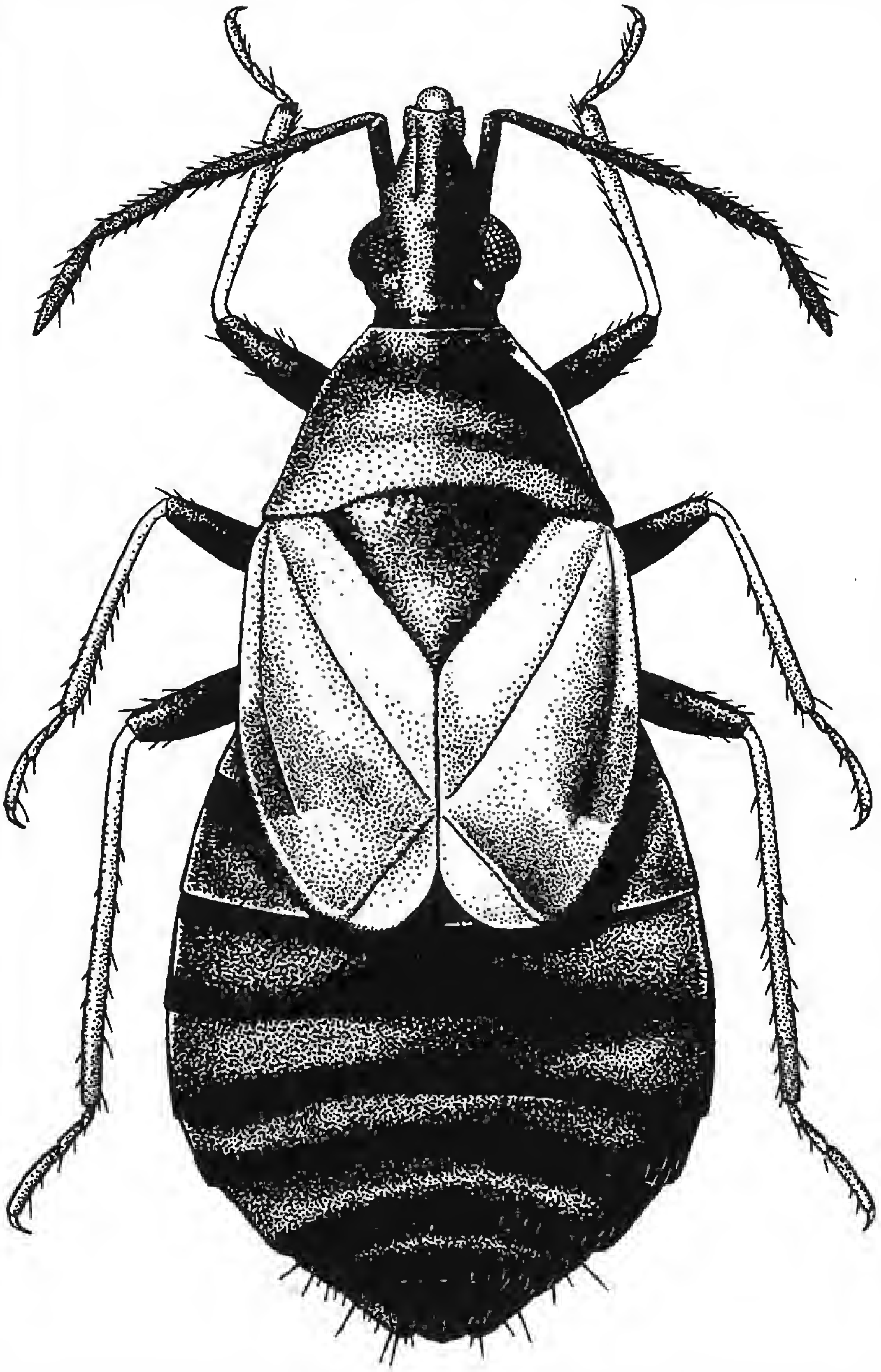

Figure 1. Adult brachypterous female of *Elatophilus dimidiatus* (Van Duzee).

a practice followed by Henry (1988). Kelton (1976) stated "Only the holotype female was available for study; in the California Academy of Sciences, San Francisco." We have examined the type specimens of *Temnostethus fastigiatus* Drake and Harris housed in the U.S. National Museum, Washington, D.C. The series included the following: Holotype (#29151 USNM) from California, Santa Cruz Mountains, brachypterous female; brachypterous female paratype with the same data; brachypterous male paratype from California, Morgan Hill, 23 May 1922, Essig (as allotype); brachypterous female paratype from California, Shasta Co., Cayton, 13 July 1918, E. P. Van Duzee. The brachypterous female from California, Shasta County, Cayton was part of the series of *Anthocoris dimidiatus* Van Duzee 1921 (now *Elatophilus dimidiatus*) who based his species on specimens he collected in California. The specimens of *T. fastigiatus* Drake and Harris agree with specimens of *Elatophilus dimidiatus* (Van Duzee) (NEW SYNONYMY).

Lattin and Stanton (Lattin, J. D. & N. L. Stanton. 1992. J. N.Y. Entomol. Soc., 100: 424–479) gave a review of *E. dimidiatus* that included a habitus drawing of a brachypterous female (Fig. 1) and host and distribution information. Lattin and Stanton (Lattin, J. D. & N. L. Stanton. 1993. J. N.Y. Entomol. Soc., 101: 88–94) briefly described biological information on *Elatophilus* species known to occur in North America, including *E. dimidiatus.* While some species of *Elatophilus* are known predators of the species of the scale genus *Matsucoccus* Cockerell, no specific prey information is yet known for *E. dimidiatus.*

Most of the specimens of *Elatophilus dimidiatus* collected were found on *Pinus contorta murrayana* (Grev. & Balf.) Engelm. The specimens from Morgan Hill and Santa Cruz, California lacked any host plant data, but *Pinus contorta murrayana* does not occur in that region (Forrest, G. I. 1980b. Bioch. Syst. Ecol., 8: 343–359; Forrest, G. I. 1980a. Bioch. Sys. Ecol., 8: 337–341). Digger pine (*Pinus attenuata* Lemm.) would appear to be the likely "host tree" but this remains to be determined. The specimens from Big Bear Lake, California came from the site of the champion lodgepole pine (*Pinus contorta murrayana*). According to Forrest (1980a, b), that locality is well separated from the *Pinus contorta murrayana* of the Sierra Nevada mountains and possesses the rare chemical combination characteristic of type F (αPinene - β pinene > β phellandrene), a type not known to occur in the Sierra Nevada mountains. Further collecting, including information on the prey, may shed more light on this situation.

In summary, *Temnostethus fastigiatus* Drake and Harris, 1926, is considered a synonym of *Anthocoris dimidiatus* Van Duzee, 1921, a species now placed in the genus *Elatophilus* Reuter. The habits of *E. dimidiatus* (i.e., on *Pinus*) are in keeping with the other known species of *Elatophilus* in Europe and North America.

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Scientific Note

FIVE SPECIES OF *EMPICORIS* WOLFF FROM *CORYLUS CORNUTA* AND *CORYLUS AVELLENA* IN OREGON (HEMIPTERA: HETEROPTERA: REDUIVIIDAE)

The genus *Empicoris* Wolff was described from Europe in 1811 based upon *Cimex vagabundus* L. (Fieber, F. X. 1860–1861. Halbflügler (Rhychota Heteroptera). Wien. pp. 1–112, 1860, 113–444, 1861, 2 plates). It occurs in the Old and New World where these tiny predators are found on trees and shrubs. One of us (K.W.) conducted a survey of cultivated (*Corylus avellana* (L.)) and native hazelnuts (*Corylus cornuta* Marsh.) in western Oregon in 1998 via beating. Hemiptera: Heteroptera and Coleoptera were collected on a regular basis through the season at 6 localities where the native species grew in close proximity to the cultivated species. The broader aspects of this study by K.W. are being prepared for publication elsewhere.

Five species of *Empicoris* were collected during this effort: *E. culiciformis* (De Geer), *E. errabundus* (Say), *E. pilosus* (Fieber), *E. rubromaculatus* (Blackburn), and *E. vagabundus* (Linnaeus). Only *E. errabundus* is native to North America; the others are non-indigenous to United States and Canada. *Empicoris errabundus* was found on both *Corylus avellena* and *C. cornuta*, while all other *Empicoris* were taken only on *C. cornuta. Empicoris pilosus, E. rubromaculatus*, and *E. vagabundus* have not been reported from Oregon previously (Wygodzinsky, P. 1966. Bull. Amer. Mus. Nat. Hist., 133: 1–614; Froeschner, R. C. 1988. pp. 616–651. *In* Henry, T. J. & R. C. Froeschner (eds.). Cat. Heteroptera, Brill, Leiden) One additional species, *E. orthoneuron* McAtee and Malloch, was reported from southwest Oregon by Wygodzinsky (1966) but was not recovered in this study on *Corylus*.

Wygodzinsky (1966) revised the Emesinae (Reduviidae) of the Western Hemisphere, and included all species of thread-legged bugs known to occur in the New World. Although the publication contains chiefly taxonomic work, it does include a section on biology. All stages of these insects feed on small, soft bodied arthropods on the substrate where they occur. Because of their small size, slender bodies and slow movement, they are often overlooked in the habitats where they occur. Recently, Southwood (Southwood, T. R. E. 2000. Entomol. Month. Mag., 136: 149–152) reviewed the species of *Empicoris* in Britain.

Of special interest are the specimens taken of *E. pilosus.* Described from Europe, it was first reported from North America by Banks (Banks, N. 1912. Psyche, 19: 97) as *Ploiariodes hirtus* from Vermont, a species later synonomized with *E. pilosus* and considered a variety of *E. vagabundus* by McAtee and Malloch (McAtee, W. L. & J. R. Malloch. 1925. Proc. U.S. Nat. Mus., 67: 1–153). Blatchley (Blatchley, W. S. 1926. Nature Publishing Company, Indianapolis) considered *E. pilosus* to be a distinct species, a decision followed many years later by Wygodzinsky (1966), who recorded it from "B.C., Mass., Mich., Pa., Vt, and Wisc." Larochelle (Larochelle, A. 1984. Punaises terrestres du Quebec. Fabreries, Supl. 3) published on its occurrence in Quebec. Most recently, Putshkov and Putshkov

(Putshkov, P.V. and V.G. Putshkov. 1996. Cat. Heteroptera Palaearctic Reg. Vol. 2. Cimicomorpha, Wageningen, The Netherlands) stated that the "*forma pilosus* (Fieber) is more common than the typical one in regions with milder climates. . ." It is clear that the identity of this species is yet to be resolved completely.

Butler (Butler, E. A. 1923. A biology of the British Hemiptera: Heteroptera. H. F. and G. W. Witherby, London) gave an account of the nymph, life cycle, and habitats [under the name *Ploiariola vagabunda* (L.)]. He stated of the nymphs, ". . . hairs on legs and antenna curved, and much longer than in adults," and added that the pale body of the nymph was covered by black spots—both distinctive characters of this species. Hazel was one of the "host plants" as recorded for *E. pilosus* in the United Kingdom. The occurrence of these distinctive nymphs from the *Corylus* trees first alerted us to the presence of this species here in Oregon. Eventually, several adults were taken—also with very long setae on the legs and antenna and pale in color, agreeing with an adult from British Columbia in the collection of Oregon State University and differing from specimens of *E. vagabundus.* A single distinctive nymph of this species was found in the collections of Oregon State University with the following collection data: Oregon. Benton Co., Corvallis, 28-IX-1976.

While considered by some to be a synonym of *E. vagabundus*, from our observations it appears that *E. pilosus* is a distinct species since *E. vagabundus*, too, was collected at the same time in the sampling on *Corylus* and specimens were distinct from *E. pilosus.* Following Wygodzinsky (1966), we considered it to be a valid species.

The remarkable number of species of *Empicoris* found on *Corylus,* mostly nonindigenous, seems unusual. Many introduced species of insects often become pests, but in this case, it appears that some may be a beneficial addition to the predatory guild of Hemiptera: Heteroptera now found on cultivated hazelnuts and other crops in western Oregon.

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Scientific Note

LABORATORY REARING OF WINGED ADULTS, AND PRE-SOLDIERS OF *HETEROTERMES AUREUS* SNYDER (ISOPTERA: RHINOTERMITIDAE)

Field collection of termites is vital for laboratory bioassays. To collect *Heterotermes aureus* in the field, we modified several techniques previously reported (Jones, S. 1990. Environ. Ent., 19(4): 1042–1054; LaFage et al. 1973. Environ. Ent., 2: 954–956.). We cut 15.3-cm PVC pipe into 10.4-cm collars and placed them in grids on 1.525-meter centers. Corrugated cardboard was cut to approximately 8 cm, rolled around a similar size piece of softwood (i.e., commercial bait monitoring wood) and held together with a rubber band. The PVC collars were buried to a depth of approximately 5 cm. The rolled cardboard was placed inside with a 2.5-cm concrete paver (20.3 by 20.3 cm) placed on top.

In September of 1999, we placed 50 numbered monitors at the Santa Rita Experimental Range, approximately 40 km south of Tucson, Ariz. Approximately every 4 to 8 weeks, monitors were evaluated for the presence of termites by removing the paver and observing soil in the corrugations. Rolls filled with soil and with termites observed in the bottom were collected. Each numbered cardboard roll was placed in a solid white 20.3 by 15.3-cm bucket with a lid. Once in the laboratory, 5 cm of sterilized native soil mixed with 2 ml of sterilized water was placed on the bottom of the bucket. Buckets were placed in a Percival Incubator Model I-36LL set at 29° C and 90% RH, in total darkness. At any given time, buckets contained 150 to 1000 termites and had 3rd instar workers and soldiers present for use in bioassay experiments. Soldiers generally constituted 1 to 2% of individuals in the bucket. On October 21, 1999, we collected termites in the rolls and returned them to the laboratory as previously described. We estimated that each roll contained between 300 and 1000 termites. Every 7 to 10 days all buckets are evaluated for the presence of termite tunneling or other activity. On February 19, 2000, two pre-soldiers were collected from one bucket, and on February 24, six female alates were collected from the same bucket. This is the first record of alates and presoldiers of *Heterotermes aureus* developing in the laboratory from field-collected foraging groups. Alate development in late February is ahead of the normal flight period of *H. aureus*, which is early July through September (Nutting, 1969 Termites of Arizona, Extension publication). As of September 15, 2000, this bucket still had at least 200 third instar workers.

The utility of this method has yet to be determined, but we have been able to maintain termites in similar containers for use in laboratory/field studies for post collection of at least 3 months with no major reduction in survival. These studies include triple mark recapture agnostic behavior and termiticide bioassays.

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Scientific Note

AN UNUSUAL HOST RECORD FOR *IMATIDIUM* AND NEW DISTRIBUTIONAL RECORDS FOR *I. RUFIVENTRE* BOHEMAN AND *I. THORACICUM* FABRICIUS (COLEOPTERA: CHRYSOMELIDAE: HISPINAE: CEPHALOLEIINI)

During August of 1998 two of the authors spent about a week collecting at Yasuni Scientific Research Station in the Orientale (Amazon) region of Ecuador. At the end of the final day of the trip a few specimens of *Imatidium* were collected sweeping *Inga marginata* Willd. (Fabaceae). This beetle was subsequently identified as *Imatidium rufiventre* Boh. by the authors. The trees are growing along the dirt road leading into the research station; they appear to have been planted in the open areas along the road. In an attempt to collect a series of this insect, a visual search of the trees was made. During this visual search one unknown larva and two pupae were collected adhering to the upper surface of the leaves (Fig. 1). These were photographed and placed into a dry container with the hope that one would develop to the adult stage. Also during this visual search it was noted that scattered throughout the trees were pairs of leaves held together with about one-third of the bottom of one leaf over-lapping the top of another leaf. In a significant number of cases (probably 70 percent or more), when the two leaves were separated, an adult specimen of *Imatidium* was found, along with fresh feeding damage (Fig. 1). The feeding damage was an unorganized array of short lines on the top of the bottom leaf, extending to the margins of the leaf over-lap. A total of 21 adult specimens were collected in this manner from *Inga marginata.* Eight adult specimens of the same species were collected individually from *Heliconia* during our stay at Yasuni.

Over the next two weeks the immature specimens were checked periodically. During the latter part of the second week an adult specimen of *Imatidium* was observed crawling around in the container. The adult was removed and preserved along with the old pupal case. The other two immature specimens did not survive. This may be the first collection of the immature stages of this beetle. The larvae are evidently free-living on the upper and lower surfaces of the leaf, unprotected by any exuvial or fecal shield. Pupae live unprotected on the upper surface of the leaf and the adults live protected between the leaves.

Species of the genus *Imatidium* have been reported feeding on *Calathea insignis* Hort. & Ball. (Marantaceae) (Spaeth, F. 1938. Revista de Entomologia, 9: 305–317) and on *Heliconia latispatha* Bentham (Heliconiaceae) in Panama (Windsor, D. M., E. G. Riley & H. P. Stockwell. 1992. pp. 372–391. *In* D. Quintero & A. Aiello (eds.). Insects of Panama and Mesoamerica. Oxford Univ. Press, Oxford.). Fabaceae are not recorded as a host for any other cassidoid Hispinae in Costa Rica (Flowers, R. W. & D. H. Janzen. 1997. Florida Entomologist, 80: 334–366) or in Panama (Windsor, D. M., E. G. Riley & H. P. Stockwell. 1992). Of the Neotropical cassidoid Hispinae, only *Hemisphaerota* Chev. has been recorded from *Inga*, and this was considered accidental (Jolivet, P., & T. J. Haw-

Figure 1. Immature specimens of *Imatidium rufiventre* Boh. and adult feeding damage (center, between the immature specimens).

keswood. 1995. Host-Plants of Chrysomelidae of the World. An Essay about the Relationships between the Leaf beetles and their Food-plants. Backhuys, Leiden, 281 pp.). Only a few specimens of true cassidoids have been collected or reported from Fabaceae genera, and these were all described as probably accidental or erroneous reports. The Fabaceae, and *Inga* specifically, is recorded as host for many Neotropical non-cassidoid hispine genera. The collection of three life stages, observation of feeding damage and the large number of adults collected confirms *Inga marginata* as a host for *I. rufiventre.*

During previous trips to Central America, the authors collected single specimens of *I. rufiventre* in Costa Rica and Panama. The Costa Rica collection from 5 km. N of Pavones (Puntarenas Province) is a new record for Costa Rica and range extension for this species, previously reported from Panama and South America (Windsor, D. M., E. G. Riley & H. P. Stockwell. 1992). *Imatidium thoracicum* Fab. is reported for the first time from Costa Rica (5 km. N of Pavones and La Selva Biological Station). This species has been previously reported from Nicaragua (Staines, C. L. 1996. Revista Nicaraguense de Entomologia, 37/38: 1–65), Panama and South America (Windsor, D. M., E. G. Riley & H. P. Stockwell. 1992).

Acknowledgment.—The identification of *Inga marginata* was provided by Margot Bass, a botanist conducting research at Yasuni during our visit. Ed Riley provided information on *Imatidium* in South America and verified our identification of *I. rufiventre.*

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Scientific Note

CORRECTION TO HOLOTYPE DEPOSITION OF *PURPURICENUS LINSLEYI* CHEMSAK (COLEOPTERA: CERAMBYCIDAE)

Purpuricenus linsleyi Chemsak, 1961 (Coleoptera: Cerambycidae) was described from two female specimens labeled "Tex." (Chemsak, J. A. 1961. Pan-Pac. Entomol., 37: 183–184.). In the original description, the U.S. Museum of Natural History (USNM), Washington, D.C. was cited as the holotype depository, while the Essig Museum of Entomology, Berkeley was cited as the paratype depository. These type depositions were restated in my recent review of North American *Purpuricenus* Dejean (MacRae, T. C. 2000. Pan-Pac. Entomol., 76: 137–169.), in which the paratype of *P. linsleyi* was examined, but not the holotype. Subsequent to that review, Dr. P. D. Perkins, Museum of Comparative Zoology (MCZ), Harvard University, Cambridge, Massachusetts, informed me that the holotype deposition stated in the original description was apparently an error, and that the holotype had instead been deposited in the MCZ.

In my review (MacRae *loc. cit.*), I noted that the basal elytral marking of the *P. linsleyi* paratype was orange, while that of all other specimens examined was dark red. Based on photographs of the holotype in the MCZ's "Primary Type Specimen Database" (Sikes, D. S. & P. Nasrecki. 1999. World Wide Web: http://mcz-28168.oeb.harvard.edu/mcztypedb.htm), the basal elytral marking of the holotype is slightly darker (red-orange) than in the paratype, but still much lighter than the dark red observed in all other *P. linsleyi* specimens. In all other respects (i.e., shape of basal elytral marking, punctation, vestiture, etc.), the holotype is similar to the paratype. Verbatim label data for the holotype (individual labels separated by a forward slash (/), my notations in parantheses, p = printed, h = handwritten) are: "Tex. / HOLOTYPE (p) Purpuricenus linsleyi Chemsak (h) (red label) / M.C.Z. Type (p) 30929 (h) (red label)".

Acknowledgment.—I thank Dr. P. D. Perkins, Museum of Comparative Zoology, for calling my attention to this discrepancy.

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PROCEEDINGS OF THE PACIFIC COAST ENTOMOLOGICAL SOCIETY, 2000

Five Hundred Fifty-Seventh Meeting

The 557th meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 21 January in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with Mr. David T. Wyatt presiding.

President Wyatt announced the entomology course he is teaching is fully enrolled and expressed optimism in the increasing interest in entomology at Sacramento City College.

Introduced as guests of the Society: By Dr. Charles Griswald of the California Academy of Sciences: George Roderick, and Rosemary Gillespie of the University of California at Berkeley; By Dr. Steve Heydon of the University of California at Davis: Terry Sears and Tino Gonzales; and by Mr. Stanley E. Vaughn of San Jose State University: Ms. Cheri Vaughn.

The featured speaker, Dr. Steve Heydon of the University of California at Davis presented a slide lecture entitled "It Takes a Village to Make a Collection: The New Paradigm in Entomological Expeditions". As Senior Museum Specialist of the Bohart Museum, Dr. Heydon is in a unique position to share firsthand the changes in collection protocols that he encountered while preparing for his most recent expedition to New Guinea. New Guinea is following the current trend of requiring visiting researchers to work closely with local scientists and agencies as part of any scientific endeavor. Dr. Heydon detailed some of the logistical and bureaucratic obstacles that he and his team encountered while complying with more tightly controlled export and transportation permits as well as sharing some of his observations of this most interesting expedition.

The meeting was adjourned at 9:43 PM and was followed by a social hour held in the Department of Entomology Conference Room.

The following 33 persons were present: (19 members) P. H. Arnaud Jr., M. M. Arnaud, J. R. Beley, L. G. Bezark, R. M. Brown, H. K. Court, P. R. Craig, M. Delmas, C. E. Griswold, S. E. Jungers, A. Lohmann, T. C. Meikle, N. D. Penny, E. S. Ross, C. N. Suematsu, D. Ubick, S. E. Vaughn, D. T. Wyatt, and R. L. Zuparko; (14 guests) R. L. Aalbu, L. Allen, C. Daughn, B. Delmas, E. Gillespie, T. Gonzales, S. L. Heydon, K. Ono, M. Rink, G. Roderick, R. Saint John, T. Sears, and S. Ubick.

Five Hundred Fifty-Eighth Meeting

The 558th meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 19 February in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with Mr. David T. Wyatt presiding.

Jason Razgon of the University of California, Davis proposed John C. Morse for membership in the Society. The candidate was voted on and approved as a member in the society.

Dr. Edward S. Ross, Curator Emeritus of the California Academy of Sciences, announced San Francisco City Parks and Recreation will be implementing a plan to put out pitfall traps to sample invertebrates as part of a study of the influx of invasive exotics and the extirpation of natives. Dr. Ross also announced Bug Club will be holding meetings at San Francisco State from 5:00 PM to 8:00 PM on the first Tuesday of every month.

Mr. Vincent F. Lee of the California Academy of Sciences announced there will be a forensic entomology workshop held at Pen State University. Mr. Lee, on behalf of Curtis Takahashi, of the California Department of Food and Agriculture, announced the CDFA will be hiring several seasonal trapper and insect survey positions in San Jose, and one trapper position in San Rafel.

The featured speaker, Mr. Thomas L. Chester of the San Francisco Beekeepers Association presented a slide and equipment demonstration lecture entitled "*Apis mellifera* in San Francisco: Culturing Honeybees in an Urban Environment". Mr. Chester briefly outlined the history of beekeeping and detailed the theory and use of the Langstroff Hive for culturing bees in densely populated cities. Fourteen to fifteen thousand years ago people began collecting honey and wax from hives of wild bees. Today, beekeepers culture bees in Moveable Hive Frames that take advantage of honeybee behavior so that honey and wax can be collected while avoiding destruction to the hive as a whole. Among other things, Mr. Chester addressed issues including technical use of essential beekeeping equipment, the $125 to $140 investment required to start a hive, coping with bee stings, controlling swarming, dealing honestly with neighbors, Africanized honeybees, and managing the various diseases currently afflicting honeybees. Mr. Chester brought in reference material for people to borrow and let them also know they can get information by logging onto www.citybees.com or www.sfbees.org.

The meeting was adjourned at 9:18 PM and was followed by a social hour held in the Department of Entomology Conference Room.

The following 57 persons were present: (26 members) P. H. Arnaud Jr., M. M. Arnaud, J. R. Beley, L. G. Bezark, K. W. Brown, R. M. Brown, H. K. Court, P. G. DaSilva, M. Delmas, C. A. D. Edwards, J. J. Fairbanks, M. Gross, V. F. Lee, A. Lohmann, N. D. Penny, W. W. Pitcher, J. L. Rasgon, K. J. Ribardo, C. Saux, W. E. Savary, J. S. Schweikert, C. N. Suematsu, D. Ubick, S. E. Vaughn, S. C. Williams, and D. T. Wyatt; (31 guests) R. L. Aalbu, M. Andres, A. Boler, C. Burford, C. Cartwright, T. L. Chester, M. Delmas, M. Flaughter, L. Franseur, K. Hamann, L. Hines, G. Holland, D. K. James, P. Koski, S. Lau, A. Lohmann, K. Mason, S. Mason, V. S. Mason, D. Nichols, L. Okomoto, M. Rink, T. Robertson, J. Sakamoto, P. Schlerres, M. Scholl, S. Shaffer, J. Stones, S. Torres, S. Ubick, and L. Williams.

FIVE HUNDRED FIFTY-NINTH MEETING

The 559th meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 17 March in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with Mr. David T. Wyatt presiding.

Jason Rasgon of the University of California in Davis proposed the following seven people for membership in the society: (four regular members) Mr. David K James of Fairfax, CA, Ms. Tanya Robertson of Larkspur, CA, Mr. Patrick Schlemmer of San Francisco, CA, and Ms. Sarah E Schaffer of El Cerrito, CA; (three student members) Ms. Adrienne Cadman of San Jose State University, Ms. Joyce Sakamoto of the University of California in Davis, and Ms. Stephanie A. Stephens of Solano Community College. The candidates were voted on and approved as members in the society.

Dr. Norm Penny of the California Academy of Sciences introduced as guest Dr. Sergio DeFreitas from Brazil.

Stanley E. Vaughn of San Jose State University introduced as guests TJ and Jake Stovall.

President Wyatt of Sacramento City College introduced as guests Steve Lipman, Hallie Meyers, Mimi Fogg Fong, Jennifer Griffin, Mike Pitner, Bruce Leavitt, Philip Coleman, and Corinne Shell.

Ms. Josephine Jose of San Jose State University introduced as guests Mr. Zia Nisani and Ms. Jennifer Wilhoit.

Dr. Jerry Powell of the University of California in Berkeley announced the unfortunate passing of Dr. E. Gorton Linsley.

Dr. Norm Penny of the California Academy of Sciences announced the unfortunate passing of Phil Adams and announced the availability of literature on Neuropteran systematics.

Mr. Vince Lee of the California Academy of Sciences announced a series of lectures every 2nd Tuesday from March through June at the Oakland Zoo for $8, with a lecture featuring Baja California and its predators. Mr. Lee also announced a bond on the ballot to retrofit CAS structures was expected to pass, as the "yes" votes were far ahead of the "no" votes.

Dr. Paul Arnaud of the California Academy of Sciences, along with Dr. Robert Lane of the University of California in Berkeley, presented the Tuareg Shield that the late Dr. Cornelius Becker Philip owned and donated to the archives of the Pacific Coast Entomological Society and the California Academy of Sciences. The shield contains the signatures of several prominent medical entomologists from the 1930's through the 1980's. The shield was put out for display during the social hour.

Ms. Sheryl Barr of the University of California in Berkeley announced an open house at the Berkeley campus featuring special events, talks and tours on April 15th from 9 AM to 4 PM.

Ms. Josephine Jose of San Jose State University announced the SJSU Entomology Club's annual camping trip to Arroyo Seco happening April 14 through 16th.

The featured speaker Mr. David Faulkner of the San Diego Natural History Museum presented a fantastic talk entitled "Forensics: A Bug's-Eye View". The Lecture included many detailed and striking photos featuring insect larvae feeding on human remains. He discussed the two aspects of forensic entomology, the civil aspect and criminal aspect most often dealing with unexpected deaths. Mr. Faulkner touched on a few of the 160 abuse and murder cases he has been involved in including one pertaining to the bodies of executed, young, Peruvian males in a Peruvian archeological site, another case where a 22-year-old assault victim had a maggot infested eye, and some other murder cases in

Ventura County, Palm Springs and San Diego. The stages of the decomposition of the body and faunal succession were discussed.

The meeting was adjourned at 9:30 PM and followed by a social hour held in the Department of Entomology Conference Room.

The following 66 persons were present: (29 members) P. H. Arnaud Jr., C. B. Barr, R. M. Brown, P. G. DaSilva, D. K. Faulkner, C. D. Franklin II, A. S. Hunter, J. Jose, V. F. Lee, A. Lohmann, A. M. L. Penny, N. D. Penny, A. Porshnikoff, J. A. Powell, J. L. Rasgon, K. J. Ribardo, J. M. Sakamoto, C. Saux, W. E. Savary, K. N. Schick, P. Schlemmer, J. S. Schweikert, W. D. Shepard, J. C. Spagna, C. N. Suematsu, T. Robertson, S. E. Vaughn, S. C. Williams, and D. T. Wyatt; (37 guests) R. L. Aalbu, A. Bandar, R. Bandar, D. Berndage, A. Cadman, T. Carpenter, P. Coleman, N. Creech, S. DeFreitas, H. Elshennawy, M. Flaughter, M. Fogg Fong, J. Franklin, A. L. Goster, J. Griffin, M. Guyton, G. Holland, T. Isaacson, C. Kent, N. Laurent, T. Lea, B. Leavitt, D. Lefebre, S. Lipman, E. R. Lira, R. Melton, H. Meyers, Z. Nisani, L. Okumoto, H. Perry, M. Pitner, M. Rink, C. Shell, J. Stovall, T. Stovall, J. Wilhoit and L. Williams.

FIVE HUNDRED SIXTIETH MEETING

The 560th meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 21 April in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with Mr. David T. Wyatt presiding.

Mr. Vince Lee of the California Academy of Sciences proposed for membership in the society three regular members: Mr. Hugo E. Fierros-López of El Universidad de Guadalajara, Mr. Robert B. Hole Jr. of Concord, California, Dr. Donald G. Miller III of Trinity University, and 3 student members: Ms. Kara L. Kelley of California State University Sacramento, Mr. José Luis Navarrete-Heredia of El Universidad de Guadalasjara, and Mr. William R. Trione of California State University Sacramento.

Mr. Stan E. Vaughn of San Jose State University introduced as guest Dr. Rod Myatt of San Jose State University.

President David Wyatt announced the untimely deaths of Dr. Gary Polis, Mike Rose and three visiting Japanese Scientists during a March 27 boating accident in the Sea of Cortez. President Wyatt further announced the unfortunate deaths of E. F. Knipling and of Dr. Lindley.

President Wyatt brought in for show and tell a Coleman light that he converted into an easily portable, black light using 8 watt bulbs and D-batteries lasting about 12 hours. *Plusiotis spp.* were one variety mentioned as being effectively drawn to the light.

The featured speaker, Dr. Arthur M. Shapiro of the University of California, Davis, presented an intriguing lecture entitled “Cladistics, DNA and the Death of the Endangered Species Act”. The lecture addressed the continuing development of the species concept and how the Endangered Species Act (ESA) as written fails to recognize the wide range of contradictory views regarding how to define species units. Additional difficulties arise because part of the intention of the ESA is to protect not only species, but unique population segments (sub-species) as well. Currently, most ESA court battles involve debating whether or not there is endangerment to the species. The greater issue that has not played itself out in court is the debate over the species concept. If and when such an issue reaches the courts, the results of these battles may greatly affect which species become and remain protected. Especially vulnerable to delisting, will be the large proportion of the species listed as protected under the ESA that are not yet described as species in the scientific literature.

The meeting was adjourned at 9:39 PM and was followed by a social hour held in the Department of Entomology Conference Room.

The following 42 persons were present: (23 members) F. G. Andrews, C. B. Barr, C. M. Brandau, R. M. Brown, M. Delmas, B. Deutsch, J. G. Edwards, T. D. Eichlin, J. J. Fairbanks, C. E. Griswold, J. Jose, R. L. Langston, V. F. Lee, C. D. MacNeill, T. C. Meikle, N. D. Penny, W. E. Savary, J. S. Schweikert, W. R. Trione, D. Ubick, S. E. Vaughn, S. C. Williams, and D. T. Wyatt; (19 guests) R. L. Aalbu, R. Altomare, T. Carpenter, C. M. Clark, J. Clopton, C. Decker, E. Elsom, J. Griffin, G. Holland, T. Isaacson, S. Lew, L. Lohmiller, R. Myatt, P. Epanchin, H. Perry, M. Pitner, A. M. Shapiro, T. Solari, and S. Ubick.

FIVE HUNDRED SIXTY FIRST MEETING

The 561st meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 19 May in the San Francisco County Building on 9th Street and Lincoln Way in San Francisco with Mr. David T. Wyatt presiding.

There were no motions for any new members.

Introduced as a guest was Dr. Anne Moore of the University of the Pacific.

Introduced as guests by President Wyatt were Tracs Isaacson, David Hanson, Dong Hanson, and Andrew Lohmiller.

Norm Penny of the California Academy of Sciences announced Santa Clara Mosquito Abatement had openings for seasonal positions.

The featured speaker, Dr. Rosemary G. Gillespie of the University of California, Berkeley, presented a slide lecture entitled "Adaptive Radiation in Hawaiian Spiders: Colonization, Speciation and Extinction". Dr. Gillespie briefly outlined the natural history and geography of the Hawaiian Island Chain, then pointed out some of the many species that are not spiders that act as examples of adaptive radiation on the islands. In studying the islands' spiders, Dr. Gillespie found that some of the plain forms that could be found elsewhere displayed a high diversity of forms in Hawaii. She believes that many of the species that are morphologically very different radiated rather recently, as their genitalia is still very similar. General patterns observed seem to be (1) changes in morphology primarily being caused by adaptive shifts and secondarily by founder events; (2) a tendency for the bigger, younger islands to have a lower level of species diversity. In addition to helping to support Dr. Gillespie's findings, the slides gave a striking view of the Hawaiian Islands' highly diversified spider fauna.

The meeting was adjourned at 9:13 PM and was followed by a social hour in the lecture room of the San Francisco County Building.

The following 48 persons were present: (32 members) M. M. Arnaud, P. H. Arnaud Jr., C. B. Barr, R. M. Brown, H. K. Court, P. R. Craig, M. Delmas, J. J. Fairbanks, S. V. Fend, C. E. Griswold, M. E. Hart, D. K. James, R. L. Langston, A. S. Lohman, T. C. Meikle, J. F. Parinas, A. M. L. Penny, N. D. Penny, W. W. Pitcher, J. L. Rasgon, S. Renkes, R. G. Robertson, L. S. Saul, W. E. Savary, K. N. Schick, J. S. Schweikert, W. D. Shepard, W. R. Trione, D. Ubick, S. E. Vaughn, D. T. Wyatt, and R. L. Zuparko; (16 Guests) D. Durante, B. L. Fisher, J. Garb, R. Gillespie, D. Honzay, T. Isaacson, S. Lew, A. Lohmiller, A. Moore, J. H. Mun, K. Norton, J. Robertson, G. Roderick, F. Serna, S. Ubick, and C. H. Zuparko.

Five Hundred Sixty-Second Meeting

The 562nd meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 15 September in the Morrison Auditorium in San Francisco with Mr. David T. Wyatt presiding.

Jason Razgon proposed the following new members: four regular members: Ms. Kathleen R. Donham of Medford, Oregon, Mr. Robert B. Gay of the San Mateo County Mosquito District, Dr. Imelda Martinez M. of el Instituto de Ecología, and J. Tupac Otero of el Universidad de Puerto Rico and four student members: Ms. Inge Armbrecht of the University of Michigan, Ms. Catherine M. Clark of San Jose State University, Ms. Carmen M. Decker of Sacramento City College and Ms. Heather J. Perry of Sacramento City College. The members were voted on and approved by the Society.

Dr. Charles Griswold of the California Academy of Sciences announced that, through the generosity of the Lakeside Foundation for International Students, the Entomology Department has been host, this summer, to six students of Entomology collection, management and taxonomy: Madelyn Peters and Aisha Fredericks from South Africa, and Helian Ratsirorson, Jean Claude Rakotonirina, Daniella Andriamalala and Balsama Rajemison from Madagascar. Ms. Rajemison is curator of the Madagascar Entomology collection in Antananarivo.

Introduced by President Wyatt as guests from Sacramento City College were Jered Wolfe, Ben Blincoe, Mary Jones, Mark Richard, Craig Shell, Kitty Oliver, and Kevin Thomas.

Dr. Brian Fisher of the California Academy of Sciences announced that the National Science Foundation Biotic Surveys and Inventories has awarded a 3 year, $400,000 grant to Brian Fisher and Charles Griswold of CAS for a "Terrestrial Arthropod Inventory of Madagascar." This survey will focus on the little-known western and southern parts of the island.

Dr. Penny of the California Academy of Sciences announced that the Academy had lots of free stuff to give away including plenty of boxes and collecting jars.

The featured speaker, Dr. Charles E. Griswold of the California Academy of Sciences presented a slide lecture entitled "Entomologists in Shangri-La: Investigations in the Gaoligongshan, China." The lecture highlighted joint California Academy of Sciences and Chinese Academy of Sciences biodiversity surveys being carried out in the geologically diverse, biologically rich Gaoligong mountains along the Myanmar border of Yunnan China. The Gaoligongshan is an area of steep topography that contains some of the best preserved forests in China. The area is particularly important to aquatic biologists as five of Asia's greatest rivers come within 100 kilometers of each other here. The survey team comprised Botanists, Vertebrate Zoologists and Entomologists. Important discoveries included many new insects and spiders, including two spider families previously unknown from China, and novel observations on the web building and breeding behavior of these spiders.

The meeting was adjourned at 9:17 PM and was followed by a social hour in the Department of Entomology conference room.

The following 58 persons were present: (34 members) M. M. Arnaud Jr., C. B. Barr, T. S. Briggs, R. M. Brown, H. K. Court, M. Delmas, J. J. Fairbanks, S. V. Fend, B. Fisher, C. E. Griswold, D. H. Kavanaugh, V. F. Lee, A. S. Lohmann, T. C. Meikle, D. R. Parks, N. D. Penny, A. B. Rackett, J. L. Rasgon, S. Renkes, K. J. Ribardo, J. M. Sakamoto, C. Saux, W. E. Savary, P. Schlemmer, J. S. Schweikert, M. Sharp, W. D. Shepard, S. A. Stephens, C. M. Suematsu, D. Ubick, S. C. Williams, D. T. Wyatt, and R. L. Zuparko; (24 guests) D. Andriamalala, P. H. Arnaud, S. Arnaud, R. Bandar, B. Blincoe, C. Decker, M. Delmas, E. Elsom, G. Holland, N. Jablonski, M. Jones, S. Lew, D. Lin, A. Lohmann, R. Maser, B. Rajemison, J. C. Rakotonirinia, H. Ratsirorson, M. Richard, M. Rink, C. Shell, K. Thomas, S. Ubick, and J. Wolfe.

FIVE HUNDRED SIXTY-THIRD MEETING

The 563rd meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 20 October in the Morrison Auditorium in San Francisco with Mr. David T. Wyatt presiding.

Mr. Vincent Lee of the California Academy of Sciences proposed the following four new persons for membership in the society: (3 regular members) Mr. Takashi Kubota of Tokyo, Japan, Dr. Gabriela Parra of the Harvard Museum of Comparative Zoology, and Dr. Richard A. Redak of the University of Riverside Department of Entomology; (1 student member) Ms. Janamjeet Sohal of San Jose State University. The new persons were voted on and approved as members in the Society.

Introduced as a guest was Geno Garcia Rossi.

Larry G. Bezark of the California Department of Food and Agriculture introduced Randy Morrison and Maggie Morrison as guests.

President Wyatt introduced as guests Laney Winter, Karen Hondrick, and Mark Richards from Sacramento City College.

President Wyatt announced that the Society is in the process of selecting a committee to select the new incoming president after Stan E. Vaughn takes over in December.

Dr. Norm Penny and Vincent Lee of the California Academy of Sciences announced Dr. Edward S. Ross' recent publication "Embia: Contributions to the Biosystematics of the Insect Order Embiidina". Signed versions of this paper were offered for sale during the social hour following the meeting. Vincent Lee also announced that the department of entomology is looking for a new secretary. Norm Penny announced boxes and drawers for sale up in the entomology department.

The featured speaker Larry G. Bezark, acting program supervisor of the California Department of Food and Agriculture, presented a comprehensive Powerpoint lecture entitled "Update on the Glassy-Winged Sharpshooter and Pierces Disease Program". Mr. Bezark described the biology of the Glassy-Winged Sharpshooter (GWSS) and its movement into California Wine and Citrus growing regions. GWSS is a strong flyer, carrying Pierces Disease (*Xylella fastidiosa*) to plants further into vinyards than native plant hoppers. Once on the plant, a single GWSS drinks about 13 mL of fluid per day and tends to feed toward the bases of stems, thus vectoring Pierces Disease down where normal pruning does not remove it. Mr. Bezark discussed the powerful political push by grape growers for protection, and the legislation as well as millions of dollars in funding that followed to create protection and generate research. At this point it appears that eradication of GWSS is not feasible. So, the focus should be on control of Pierces Disease. So far the Pierces Disease Control Program has begun to implement a uniform system statewide that responds rapidly and delimits new GWSS outbreaks before new problems occur. The program has put out 350 articles, 100,000 brochures and held 88 outreach meetings. Key research has been in areas of biological control, Integrated Pest Management, breeding Pierces Disease resistant grapes, biology of GWSS, determination of micronutrient effects on Pierces Disease, and in the use of softer chemicals such as cinemaldehydes. As of now there are several parasitoid wasps in the family Mymaridae in experimental phases for biological control potential. Future research will probably concentrate on foreign exploration for other parasitoids and subsequent parasitoid releases.

The meeting was adjourned at 9:39 PM and followed by a social hour held in the Department of Entomology conference room.

The following 46 persons were present: (30 members) R. L. Aalbu, C. B. Barr, J. R. Beley, L. G. Bezark, R. M. Brown, J. R. Clopton, H. K. Court, P. R. Craig, C. M. Decker, M. Delmas, J. J. Fairbanks, C. E. Griswold, L. A. Irons, J. Jose, J. B. Knight, V. F. Lee, T. C. Meikel, N. D. Penny, W. W. Pitcher, A. B. Rackett, K. J. Ribardo, E. S. Ross, K. N. Schick, J. S. Schweikert, J. Sohol, C. M. Suematsu, C. Y. Takahashi, D. Ubick, S. E. Vaughn, and D. T. Wyatt; (16 guests) R. Almeida, M. Delmas, J. Franklin, L. Garner-Winter, D. D. Guiliani, K. Hondrick, D. R. Jimenez, V. Knight, R. Morrison, M. Murphy, K. Okano, A. Purcell, M. Richards, M. Rink, T. Solari, N. Stern, and P. T. Yamamoto.

Five Hundred Sixty-Fourth Meeting

The 564th meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 17 November in the Morrison Auditorium in San Francisco with Mr. David T. Wyatt presiding.

There were no motions for any new members to the Society. Cheryl Barr of UC Berkeley introduced as guests Ellen Claridge and George Roderick. President Wyatt introduced as guests Ben Blincoe, Karen Thomas, Jared Wolf, and David Jernigan of Sacramento City College.

Norm Penny of the California Academy of Sciences announced a full time position available in the State Department of Public Health.

President Wyatt announced an Insect Systematist Position available at U.C. Berkeley.

President Wyatt, Norm Penny, and Warren Savary briefly discussed issues regarding collecting permits in Mexico.

President Wyatt brought in the headline of the *Sacramento Bee*, "Brazilian Flies Enlisted in War on Fire Ants". The subject of the article was a Phorid fly larva that eats the heads and brains of the fire ant, causing general panic in the fire ant colony, which tends to keep the fire ants in check.

The featured speaker, Leslie Saul-Gershenz, cofounder of the San Francisco State University Center for Ecosystem Survival and the current Director of Conservation Education, presented a curious slide lecture entitled, "Mimicry by Mojave Desert Meloid Beetles". Dr. Saul's study in the Kelso Dunes in California followed the mysterious behavior of Meloid beetle (*Meloe triangulins*) larval aggregations on *Astragalus lentigenosus*. Dr. Saul found that adult *Meloe sp.* are actually diurnal and will travel far. She observed one female that walked 0.3 miles. Dr. Saul's experimentation in the field confirmed that the larval aggregations of 120 to 2,300 individuals cooperate to use visual cues and pheromones to mimic female bees. When male bees attempt to mate with the aggregations, some of the *M. triangulins* larvae will attach to the bee. Four to 369 (mean = 51) *M. triangulins* were counted on each bee. Presumably, when the male mates with a female bee, the *M. triangulins* larvae attach to the female and are later taken to her nest. In the bees nests, which are 2 meters or deeper in the ground, the *M. triangulins* parasitize the provisions and possibly prey upon the bee larva in the chamber.

The meeting was adjourned at 9:35 PM and followed by a social hour held in the Department of Entomology conference room.

The following 40 persons were present: (25 members) C. B. Barr, J. R. Beley, K. W. Brown, J. R. Klopton, H. K. Court, C. M. Decker, M. Delmas, J. J. Fairbanks, N. E. Gershenz, C. E. Griswold, D, K. James, R. L. Langstrom, V. F. Lee, A. S. Lohmann, T. C. Meikel, N. D. Penny, W. W. Pitcher, L. S. Saul, K. N. Schick, J. S. Schweikert, S. S. Shanks, D. Ubick, S. E. Vaughn, S. C. Williams and D. T. Wyatt; (15 guests) T. Blackledge, B. Blincoe, E. Claridge, M. Delmas, L. M. Franzen, L. Garb, G. Holland, A. Hom, D. Jernigan, J. Laux, A. Lohmann, D. Taylor Jr., K. Thomas, S. Ubick and J. Wolfe.

Five Hundred Sixty-Fifth Meeting

The 565th meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 8 December in room 2372 of the Academic Surge Building of the University of California, Davis, with Mr. David T. Wyatt standing in as president for Mr. Stan E. Vaughn.

There were no motions for any new members to the Society.

Dave Kistner introduced as guests Erica Jensen and Alzada Kistner.

Vincent Lee of the California Academy of Sciences introduced as guest his wife Linda Lee.

Julio Lopez, of the University of California, Davis, introduced himself as a guest.

Mr. Wyatt of Sacramento City College introduced as guests Ben Blincoe and Jared Wolfe of Sacramento City College.

The Membership Committee announced a gain of 26 new members in the year 2000 (10 student and 16 regular), with membership of the society totaling 325 (271 regular, 32 student and 22 sponsoring) at the end of the year 2000.

The Nominating Committee submitted the following persons to become new officers in the society: Cathy Schick, of the UC Berkeley Dept. of Entomology for President Elect in 2002; Vince F. Lee, of the California Academy of Sciences, for Managing Secretary in 2001; Joshua Fairbanks, of Santa Clara for Recording Secretary in 2001. The new officers were voted and approved by the society.

Steve Heydon, a Hymenopterist in the UC Davis Bohart Entomological Museum, gave a detailed demonstration of new taxonomic software on CD ROM entitled "Beetles of the World" (ISBN 064306557-1). The software is used to key out beetle identifications by entering in the specimen's features until there is only one or few possible correct identifications. It offers the option to skip challenging characteristics and, once an I.D. is reached, is able to give brief and full diagnostic descriptions of the beetle.

The featured speaker, Mr. David T. Wyatt of Sacramento City College, presented a high spirited Powerpoint Slide Lecture entitled "Entomology in Guatemala, the Country Offers Research Opportunities to U.S. Entomologists". The University del Valle (*get spelling*) in Guatemala along with Dr. Jack Shuster the director of its Entomology Museum, openly encourages researchers from the U.S. to come to Guatemala and collect. The University has a very nice systematic entomology lab set up and is especially appreciative plus helpful if you bring along grant money or entomological supplies such as insect pins and nets. Licenses and collecting permits cost the equivalent of six U.S. dollars. Guatemala offers 109,000 km^2 of tropical climate that is mainly mountainous with narrow coastal plains. The highland areas tend to be comfortably cool while the lowlands are fairly hot. There are 32 volcanoes, one of them reaching 4220 m above sea level, a large biosphere reserve, temples, ecolodges in various locations, and a field station located in the rainy Caribbean zone. Rainfall in this zone ranges from 500 to 5,000 mm per year. Nice hotels in Antigua cost about $40 and 4-Wheel Drive rental, which is necessary in some areas, is about $100 per day. The tremendous diversity of insects in Guatemala includes, among other things, many dung beetles, Cerambycids, and the White Witch (having the greatest wingspan of any moth in the world). In order to take dead specimens out make sure you have an export license, a collecting permit form 3-177 from the Fish & Wildlife Service, and a letter from the USDA. Mr. Wyatt encourages all interested in collecting in Guatemala to contact Mr. Shuster.

The meeting was adjourned at 9:29 PM and followed by a social hour held in the downstairs Entomology Museum.

The following persons 35 were present: (18 members) R. L. Aalbu, C. B. Barr, J. A. De Benedictis, B. K. Eya, J. J. Fairbanks, E. M. Fisher, D. H. Kistner, V. F. Lee, A. S. Lohmann, H. J. Perry, D. C. Rogers, K. N. Schick, W. D. Shepard, R. E. Somerby, S. A. Stephens, C. M. Suematsu, R. W. Thorp, and D. T. Wyatt; (17 guests) D. Aalbu, B. Blincoe, S. Heydon, E. A. Jensen, G. Karcopelat, L. Kimsey, A. C. Kistner, A. Lohmann, J. Lopez, A. Ludtke, S. McCauk, B. Patterson, M. Rink, E. Rogers, A. Roln, J. Wolfe and L. Zinn.

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See volume 74: 248–255, October 1997, 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.

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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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